Webinar:
Wellfield Operations and Technologies for Upgrading Landfill Gas

November 16, 2017

Presenters:
Frank Terry (Smith Gardner, Inc.)
Mark Hill (DTE Biomass Energy)
Welcome

### Webinar Agenda

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<td><strong>Technologies for Processing LFG into Pipeline Quality Gas or Vehicle Fuel</strong></td>
<td>Mark Hill, DTE Biomass Energy</td>
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Webinar:
Landfill Wellfield Design, Construction and Operational Considerations for Upgraded LFG Projects

November 16, 2017

Presenter:
Frank Terry, Project Manager, Smith Gardner, Inc., (contractor to U.S. EPA LMOP)
Topics

- Background
- Collection System Design and Construction for High-Btu Wellfields
- High-Btu Wellfield Monitoring and Tuning
Background
## Background: Low- vs. High-Btu projects

<table>
<thead>
<tr>
<th></th>
<th>Low- and Medium-Btu</th>
<th>High-Btu</th>
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</thead>
<tbody>
<tr>
<td><strong>Heat Content</strong></td>
<td>350-550</td>
<td>950-1,000</td>
</tr>
<tr>
<td>(British thermal unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>per standard cubic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>foot, Btu/scf)</td>
<td></td>
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<tr>
<td><strong>Uses</strong></td>
<td>Boilers, engines,</td>
<td>Pipeline injection, vehicle</td>
</tr>
<tr>
<td></td>
<td>microturbines,</td>
<td>fuel (Compressed Natural Gas</td>
</tr>
<tr>
<td></td>
<td>turbines, kilns,</td>
<td>([CNG], Liquefied Natural Gas</td>
</tr>
<tr>
<td></td>
<td>combined heat and</td>
<td>[LNG])</td>
</tr>
<tr>
<td></td>
<td>power, greenhouses,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and other</td>
<td></td>
</tr>
<tr>
<td></td>
<td>manufacturing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>processes that</td>
<td></td>
</tr>
<tr>
<td></td>
<td>require fuel</td>
<td></td>
</tr>
<tr>
<td><strong>Number of Operational</strong></td>
<td>483 – electricity</td>
<td>38 – pipeline injection</td>
</tr>
<tr>
<td>Projects*</td>
<td>121 – non-Electricity</td>
<td>5 onsite CNG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 onsite LNG</td>
</tr>
<tr>
<td><strong>First Project</strong></td>
<td>1974 (Sheldon Arleta, CA)</td>
<td>1975 (Palos Verdes, CA)</td>
</tr>
<tr>
<td>Installation*</td>
<td>[Demonstration Project]</td>
<td></td>
</tr>
<tr>
<td><strong>Gas Treatment</strong></td>
<td>Moisture and</td>
<td>Moisture, contaminant and CO₂</td>
</tr>
<tr>
<td></td>
<td>contaminant removal</td>
<td>removal</td>
</tr>
<tr>
<td>(as needed)</td>
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</tr>
</tbody>
</table>

* These data are from LMOP’s Landfill and Landfill Gas Energy Database as of November 2017
Collection System Design and Construction for High-Btu Wellfields
Typical Gas Collection System Components

- Vertical Wells
- Horizontal Collectors
- Leachate Riser Tie-ins
- Header and Lateral Piping
- Piping Components
Vertical Wells

• Low impact on landfill operations during construction

• Proven performance and lifespan

• Can be tailored to optimize high-Btu production via:
  ▪ Increased well density
  ▪ Bore depth
  ▪ Solid casing depth
  ▪ Location
  ▪ Bore seal integrity and placement
  ▪ Well boots
Horizontal Collectors

• Inexpensive construction: no specialized equipment

• Effective in supplementing production but also subject to poor reliability, shorter lifespan and intermittent performance due to:
  ▪ Liquid blockage
  ▪ Differential settlement
  ▪ Pipe collapse or pinching
  ▪ Premature use
Leachate Riser Tie-ins

- Usually can be easily connected to the GCCS
- Typically high flow rates, but notorious for oxygen leaks
- Effective in supplementing production, but also subject to poor reliability and intermittent performance due to:
  - High leachate levels
  - Pump failure
  - Transducer malfunction
Lateral and Header Piping

• Construction quality matters
  ▪ Leaks may not be noticeable immediately after installation
  ▪ Poor construction technique will eventually be revealed under high-Btu extraction conditions

• High Density Polyethylene (HDPE) piping is preferred over polyvinyl chloride (PVC)
  ▪ Joining and fittings preferences, where possible:
    ▪ Butt fusion joining is preferred over electrofusion
    ▪ Molded fittings preferred over fabricated fittings
Other Piping Components

- Control Valves: More is better
- Sample Port Risers: Placement for easy access
- Condensate traps, sumps, and pump stations
  - Minimize penetrations
  - Utilize flanged or threaded connections wherever possible in place of rubber slip couplings
Typical Problematic Areas for Potential Air Leaks

- **Sumps**
- **Wellheads**
Pipe Fitting Selection for High-Btu Wellfield Applications

Molded Fitting

Fabricated Fitting
Minimize Potential Air Leaks During Construction

Fabricated fittings will be under stress from differential settlement
High-Btu Wellfield Monitoring and Tuning
High-Btu Wellfield Tuning Considerations

• LFG Generation
• Monitoring Objectives
• Analyzers
LFG Generation

• Four Phases of LFG Generation

Source: EPA 1997
Inlet Gas Quality: Medium-Btu vs. High-Btu

**Medium BTU**
- Nitrogen: 10.0%
- Oxygen: 2.0%
- Carbon Dioxide: 38.0%
- Methane: 50.0%

**High BTU**
- Nitrogen: 2.0%
- Oxygen: 0.5%
- Carbon Dioxide: 42.5%
- Methane: 55.0%
Monitoring Objectives for High-Btu*

- Define and understand production goals and compliance requirements
  - Monthly NSPS minimum for compliance
  - Bi-monthly recommended for production

- Define and categorize collection zones
  - Identify problematic or sensitive areas

- Determine baseline tuning frequency to maintain consistency
  - Increase monitoring focus where necessary

- Establish call out schedules and troubleshooting procedures to minimize downtime

* Monitoring requirements for a high-Btu project often differ from regulatory monitoring requirements. You are responsible for compliance with applicable regulations.
Options: LFG Analyzers

Landtec GEM 5000

Elkins Envision
Options: Analyzers

Gas Chromatograph (e.g., Agilent Micro GC 3000)
## Summary: LFG Analyzers

<table>
<thead>
<tr>
<th></th>
<th>Handheld LFG Monitor: GEM 5000</th>
<th>Handheld LFG Monitor: Envision</th>
<th>Gas Chromatograph: Agilent Micro</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gases Measured</strong></td>
<td>CH&lt;sub&gt;4&lt;/sub&gt;, CO&lt;sub&gt;2&lt;/sub&gt;, O&lt;sub&gt;2&lt;/sub&gt;, CO, H&lt;sub&gt;2&lt;/sub&gt;S</td>
<td>CH&lt;sub&gt;4&lt;/sub&gt;, CO&lt;sub&gt;2&lt;/sub&gt;, O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>CH&lt;sub&gt;4&lt;/sub&gt;, CO&lt;sub&gt;2&lt;/sub&gt;, O&lt;sub&gt;2&lt;/sub&gt;, H&lt;sub&gt;2&lt;/sub&gt;, N&lt;sub&gt;2&lt;/sub&gt;, H&lt;sub&gt;2&lt;/sub&gt;S</td>
</tr>
<tr>
<td><strong>CH&lt;sub&gt;4&lt;/sub&gt; Accuracy</strong></td>
<td>+/-&lt; 0.5%</td>
<td>+/-&lt; 2%</td>
<td>10ppm</td>
</tr>
<tr>
<td><strong>O&lt;sub&gt;2&lt;/sub&gt; Accuracy</strong></td>
<td>+/-&lt; 1%</td>
<td>+/-&lt; 2%</td>
<td>10ppm</td>
</tr>
<tr>
<td><strong>Onboard Vacuum Pump</strong></td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td><strong>Internal Data Storage</strong></td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td><strong>Pressure Readings</strong></td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>
Truck-Mounted Gas Chromatograph
Truck-Mounted Gas Chromatograph: Sample Train
Conclusion

• Understand the various phases of LFG generation
• Define and balance compliance and production goals
• Develop and apply definitive monitoring objectives based on process plant parameters
• Adjust wellfield design, construction and O&M standards to minimize air intrusion
• Engage and educate equipment operators on their role in high-Btu LFG wellfield management
• Invest in your wellfield technical staff
Thank you for participating

If you have any questions, please contact LMOP at

lmop@epa.gov or through our website at

https://www.epa.gov/lmop/forms/contact-us-about-landfill-methane-outreach-program
Upgrading Landfill Gas to Pipeline Quality Renewable Natural Gas
EPA – LMOP Webinar

Mark R. Hill – Vice President of Operations
November 16, 2017
DTE Biomass Energy is a full scope developer that owns or operates 19 landfill gas to energy projects, including five pipeline-quality (renewable natural gas) facilities.

- Westside (2001)
- Fresh Kills (early 1980's) (Owned by Dept. of Sanitation NYC)
- Fort Bend (2014)
- Seabreeze (Q1 ‘18)
- Pinnacle (2002)
Agenda

Value drivers in the market today

Choosing the right technology

Getting the gas into a vehicle

Problems to avoid
With lower natural gas prices and higher priced environmental attributes, getting RNG into a highway vehicle is critical.

<table>
<thead>
<tr>
<th>Date</th>
<th>Henry Hub Natural Gas (D3 RIN)</th>
<th>D3 RIN Pricing (generated when RNG is used in highway vehicle)</th>
<th>LCFS Pricing (RNG used in CA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/6/2014</td>
<td>$5.00</td>
<td>$5.00</td>
<td>$5.00</td>
</tr>
<tr>
<td>5/6/2014</td>
<td>$10.00</td>
<td>$10.00</td>
<td>$10.00</td>
</tr>
<tr>
<td>7/6/2014</td>
<td>$15.00</td>
<td>$15.00</td>
<td>$15.00</td>
</tr>
<tr>
<td>9/6/2014</td>
<td>$20.00</td>
<td>$20.00</td>
<td>$20.00</td>
</tr>
<tr>
<td>11/6/2014</td>
<td>$25.00</td>
<td>$25.00</td>
<td>$25.00</td>
</tr>
<tr>
<td>1/6/2015</td>
<td>$30.00</td>
<td>$30.00</td>
<td>$30.00</td>
</tr>
<tr>
<td>3/6/2015</td>
<td>$35.00</td>
<td>$35.00</td>
<td>$35.00</td>
</tr>
<tr>
<td>5/6/2015</td>
<td>$40.00</td>
<td>$40.00</td>
<td>$40.00</td>
</tr>
</tbody>
</table>

Total value stream can be over $40/MMBtu but is variable.
Producing renewable natural gas (RNG) from landfill gas is capital intensive and has significant operating expenses ...securing the right revenue stream is key.

<table>
<thead>
<tr>
<th>Description</th>
<th>Historic Approach</th>
<th>Long Term Off-Take</th>
<th>Do-it-yourself RINs</th>
<th>Deliver to a CNG Vehicle via Pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Value Streams</strong></td>
<td>Purify gas to pipeline spec, sell into pipeline, receive NG index pricing</td>
<td>Purify gas to pipeline spec, sell at fixed price to customer</td>
<td>Purify gas, compress to 3500 PSI, and put into CNG highway vehicle</td>
<td>Purify gas to pipeline quality, put in pipeline, deliver to CNG fueling station, fuel highway vehicle</td>
</tr>
<tr>
<td><strong>Pros</strong></td>
<td>No RIN verification needed</td>
<td>Steady prices typically at a premium to long term natural gas prices</td>
<td>RINs generated with no “middleman” costs</td>
<td>Multiple value streams</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>Natural gas prices are currently very low Requires pipeline</td>
<td>May be at a discount to spot market RIN pricing Requires pipeline</td>
<td>Requires gas storage and large on-highway vehicle fleet to fully utilize RNG Variable pricing</td>
<td>Variable pricing Requires pipeline Possible broker fees</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td>Index pricing based on market natural gas rates</td>
<td>Set price per MMBtu for several years</td>
<td>If you have a CNG vehicle fleet, RNG would offset natural gas costs and RINs would be generated</td>
<td>Natural gas value, RIN value, and LCFS (if vehicles fueled are in California)</td>
</tr>
</tbody>
</table>
Agenda

Value drivers in the market today

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Getting the gas into a vehicle

Problems to avoid
Ahem….The Disclaimer

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

• Data presented are 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 your own 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>Pipeline Specification Range (Varies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Btu/CF</td>
<td>450 to 600</td>
<td>900 to 1000</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.05% to 2%</td>
<td>Zero to 0.3%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>40% to 55%</td>
<td>Total inert gas no more than 3% to 7%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.5% to 14%</td>
<td>3% to 7%</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>5 PPM to 5000 PPM</td>
<td>Less than 4 PPM</td>
</tr>
<tr>
<td>Water</td>
<td>Fully Saturated</td>
<td>5 to 7 lbs/MMCF</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>5-125 PPM</td>
<td>Non-detect to 4 PPM</td>
</tr>
</tbody>
</table>

Other Considerations: Pipeline pressure, VOCs, dust, bacteria, gas temperature, hydrogen, Wobbe Index

The largest risk any project has is not being able to make pipeline specification RNG
The technology necessary to get into the pipeline can be bewildering if you are new to the process.
Let’s start with the largest component removed – carbon dioxide. There are four “mainstream” competing technologies used to remove CO₂:

<table>
<thead>
<tr>
<th>Technology</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 Pipeline-Quality Membrane System

LFG → Compressor → Dryer → Sulfur Removal → Thermal Oxidizer

CO₂ Some O₂ → Absorbs impurities → Activated Carbon → Regenerative Siloxane Removal

1ˢᵗ Stage Membrane

CO₂ Some O₂ → 2ⁿᵈ Stage Membrane → CH₄ Some O₂ → De-Oxidation Catalyst → Dehydration Skid → Pipeline

TOX
Example of a membrane plant
Non-pipeline quality vehicle fueling station using membrane technology

- Uses membrane technology
- Activated carbon used for siloxane removal instead of regenerative system
- Typically a one pass membrane system – more methane slippage
- Looser spec needed than for pipeline quality gas
- Requires a dedicated fleet of vehicles (which is hard to do)
Typical Solvent System Flow Diagram

LFG → Compressor → Sulfur Removal → Compressor

O₂

CH₄

CH₄

De-Oxidation Catalyst

H₂O Generated

CH₄

Dehydration Skid

H₂O

CH₄

Final Compression → Pipeline

Solvent Treatment

VOC’s H₂O

CO₂

Thermal Oxidizer
Example of a Solvent Plant
Pressure Swing Absorption uses media to absorb and release gases. This process is more energy intensive than others.

1. **Step 1: Absorption**
2. **Step 2: Depressurization**
3. **Step 3: Desorption**
4. **Step 4: Pressurization**

LFG → Compressor → Dryer → H₂S Removal → VOC removal

CO₂, O₂, N₂

Pipeline → Compressor

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&lt;sub&gt;2&lt;/sub&gt; – may help meet looser O&lt;sub&gt;2&lt;/sub&gt; specs</td>
<td>• 94% methane recovery</td>
</tr>
<tr>
<td></td>
<td>• Historically good on-stream rates</td>
<td>• Activated carbon and H&lt;sub&gt;2&lt;/sub&gt;S 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 O&lt;sub&gt;2&lt;/sub&gt; or N&lt;sub&gt;2&lt;/sub&gt;</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 VOCs without needing disposable media</td>
<td>• Does not remove any O&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>• May remove other components of the gas stream, including some N&lt;sub&gt;2&lt;/sub&gt; and O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>• Because of low CH&lt;sub&gt;4&lt;/sub&gt; loss, additional fuel needed for TOX</td>
</tr>
<tr>
<td></td>
<td>• Few moving parts other than valves and compressors</td>
<td>• More things to break (pumps, vacuum blowers, etc.)</td>
</tr>
<tr>
<td>PSA</td>
<td>• Simple process that just uses water</td>
<td>• ~95% methane recovery</td>
</tr>
<tr>
<td></td>
<td>• ~96% methane recovery</td>
<td>• Pressurization/depressurization/re-pressurization process is energy intensive</td>
</tr>
<tr>
<td></td>
<td>• Removes some N&lt;sub&gt;2&lt;/sub&gt; and O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>• Leaky valves can create serious issues</td>
</tr>
<tr>
<td>Water</td>
<td>• Uses a lot of water – treatment of water may be costly and complicated</td>
<td>• Large footprint with large vessels</td>
</tr>
<tr>
<td>Absorption</td>
<td>• Can only handle a certain level of N&lt;sub&gt;2&lt;/sub&gt; and O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>• More moving parts (pumps, valves, etc.)</td>
</tr>
</tbody>
</table>
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

- 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 (H₂S) Removal

Non-NRU plants (no O₂ in inlet gas)

Typically use Sulfatrap, Sulfatreat, activated carbon or similar disposable media

Can be very expensive if inlet H₂S levels are high—factor this into economics of a project

Ensure you have a back-up vessel so that you are able to meet pipeline quality if media becomes exhausted

NRU Plants (O₂ 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
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 – if that amount is exceeded the plant capacity rapidly drops

Methane percent yield drops to upper 80s 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! 90% of 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) Blend natural gas at the interconnect (for a fee, and if allowed). Separate metering required to keep renewable and non-renewable accounted for – check with RIN verifier. Alternatively, blend propane (again, separate metering required – check with RIN verifier).

3) Expensive equipment (e.g., amine unit or NRU) to remove remaining carbon dioxide or nitrogen.
Agenda

Value drivers in the market today

Choosing the right technology

Getting the gas into a vehicle

Problems to avoid
The majority of RNG is shipped via pipeline to vehicle fueling stations.
Not all landfills are near a pipeline. There are virtual pipeline alternatives, but they require more operating expenses and logistics.
Agenda

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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)

Most projects that fail, fail due to poor quality of gas from the wellfield
- NRUs 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 (Continued)

**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 RINs 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
Be ready for a very expensive capital investment

Like a new car, the base model looks like a bargain, but by the time you get all the options you need, costs can increase by 50%

**Plants**
Base plant: Ten(s) of millions in capital – very dependent on size of plant
NRU: Millions of dollars
De-Oxidation Unit: Hundreds of Thousands to $1.5 Million

**Wellfield**
Depends on the site, but could cost $1 million or more to convert a medium-Btu wellfield to a high-Btu wellfield

**Pipeline**
Interconnects in the hundreds of thousands of dollars (or even millions). Installed pipeline can be near $1 million per mile. Right of ways can delay projects by over a year.
Feel free to contact our team with further questions

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