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

LFG Wellfield Operational Considerations for Pipeline Quality Gas or Vehicle Fuel Projects

Frank Terry, Smith Gardner, Inc., contractor to U.S. EPA LMOP

Technologies for Processing LFG into Pipeline Quality Gas or Vehicle Fuel

Mark Hill, DTE Biomass Energy

Questions and Answers

Wrap-up & Participant Survey

Mention of any company, association, or product in this presentation is for information purposes only and does not constitute a recommendation of any such company, association, or product, either express or implied, by the EPA.

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

	Low- and Medium-Btu	High-Btu
Heat Content (British thermal unit per standard cubic foot, Btu/scf)	350-550	950-1,000
Uses	Boilers, engines, microturbines, turbines, kilns, combined heat and power, greenhouses, and other manufacturing processes that require fuel	Pipeline injection, vehicle fuel (Compressed Natural Gas ([CNG], Liquefied Natural Gas [LNG])
Number of Operational Projects*	483 – electricity 121 – non-Electricity	38 – pipeline injection 5 onsite CNG 1 onsite LNG
First Project Installation*	1974 (Sheldon Arleta, CA) [Demonstration Project]	1975 (Palos Verdes, CA)
Gas Treatment	Moisture and contaminant removal (as needed)	Moisture, contaminant and CO_2 removal

*** 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

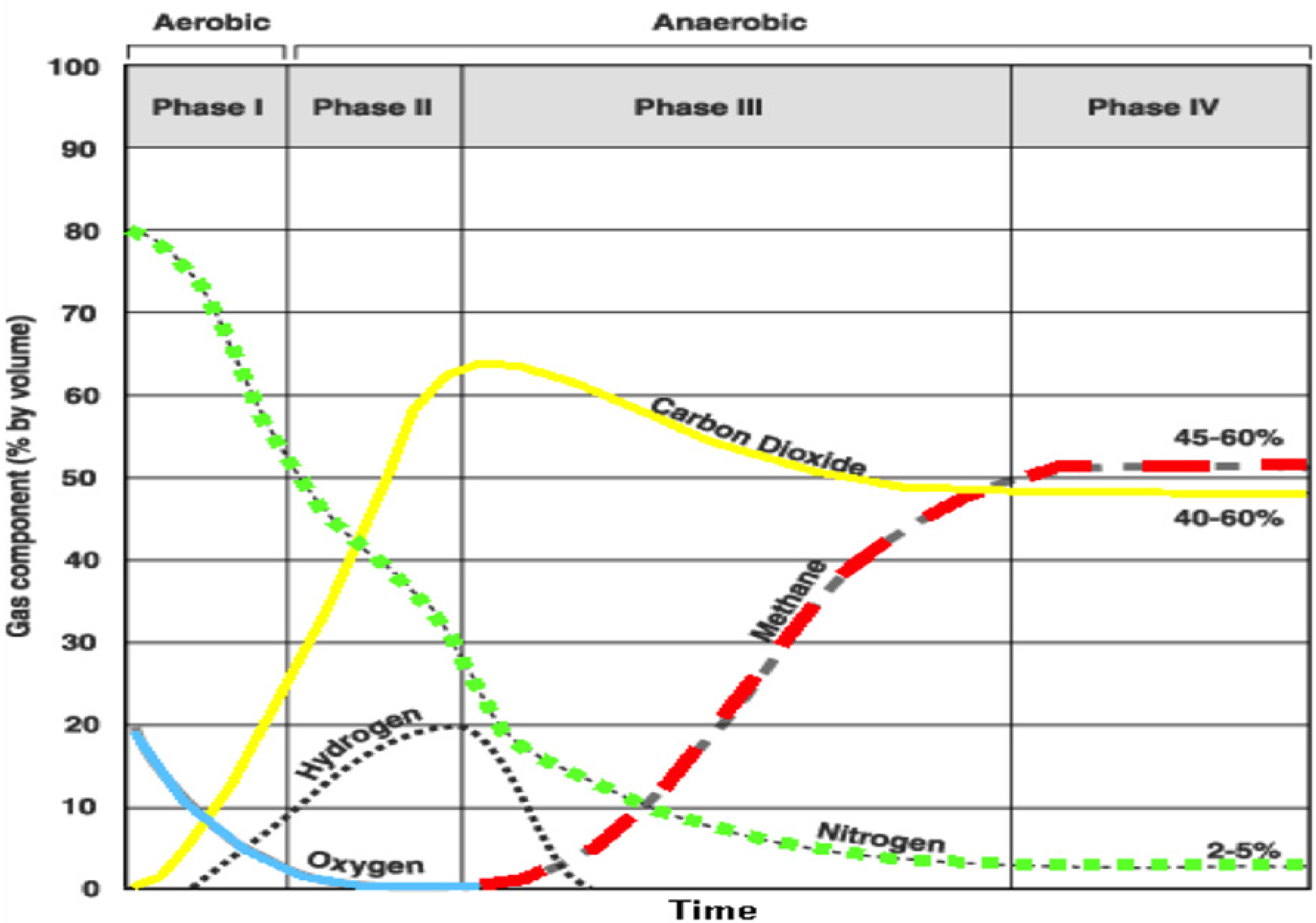
High-Btu Wellfield Monitoring and Tuning

High-Btu Wellfield Tuning Considerations

- LFG Generation
- Monitoring Objectives
- Analyzers

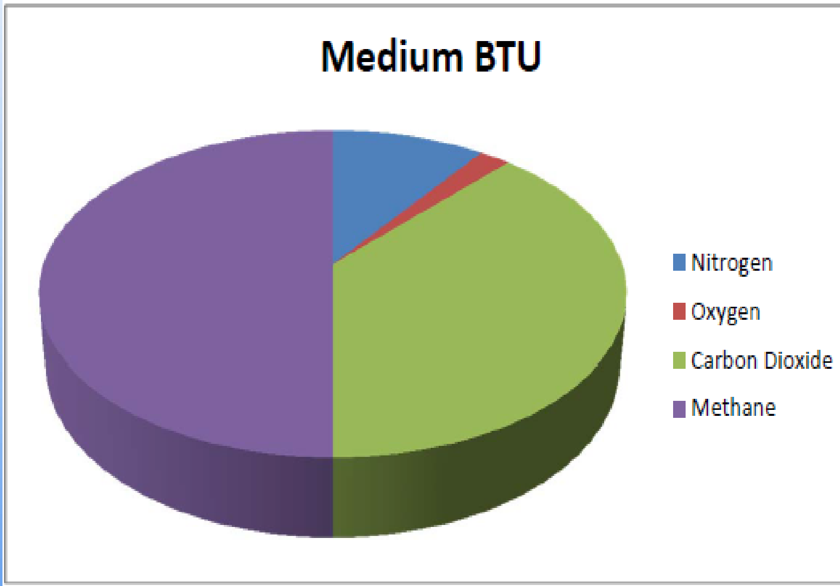
LFG Generation

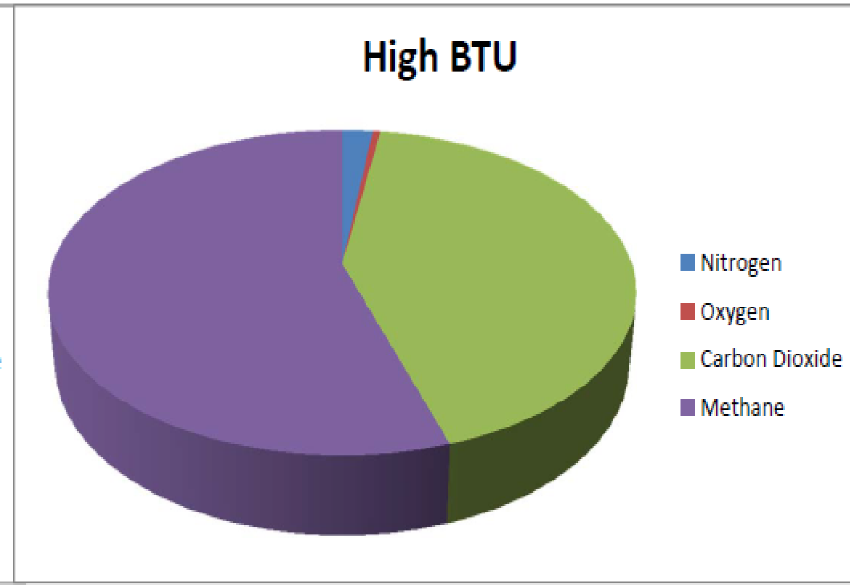
- **Four Phases of LFG Generation**



Source: EPA 1997

Inlet Gas Quality: Medium-Btu vs. High-Btu





Nitrogen	10.0%
Oxygen	2.0%
Carbon Dioxide	38.0%
Methane	50.0%
	100%

Nitrogen	2.0%
Oxygen	0.5%
Carbon Dioxide	42.5%
Methane	55.0%
	100%

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

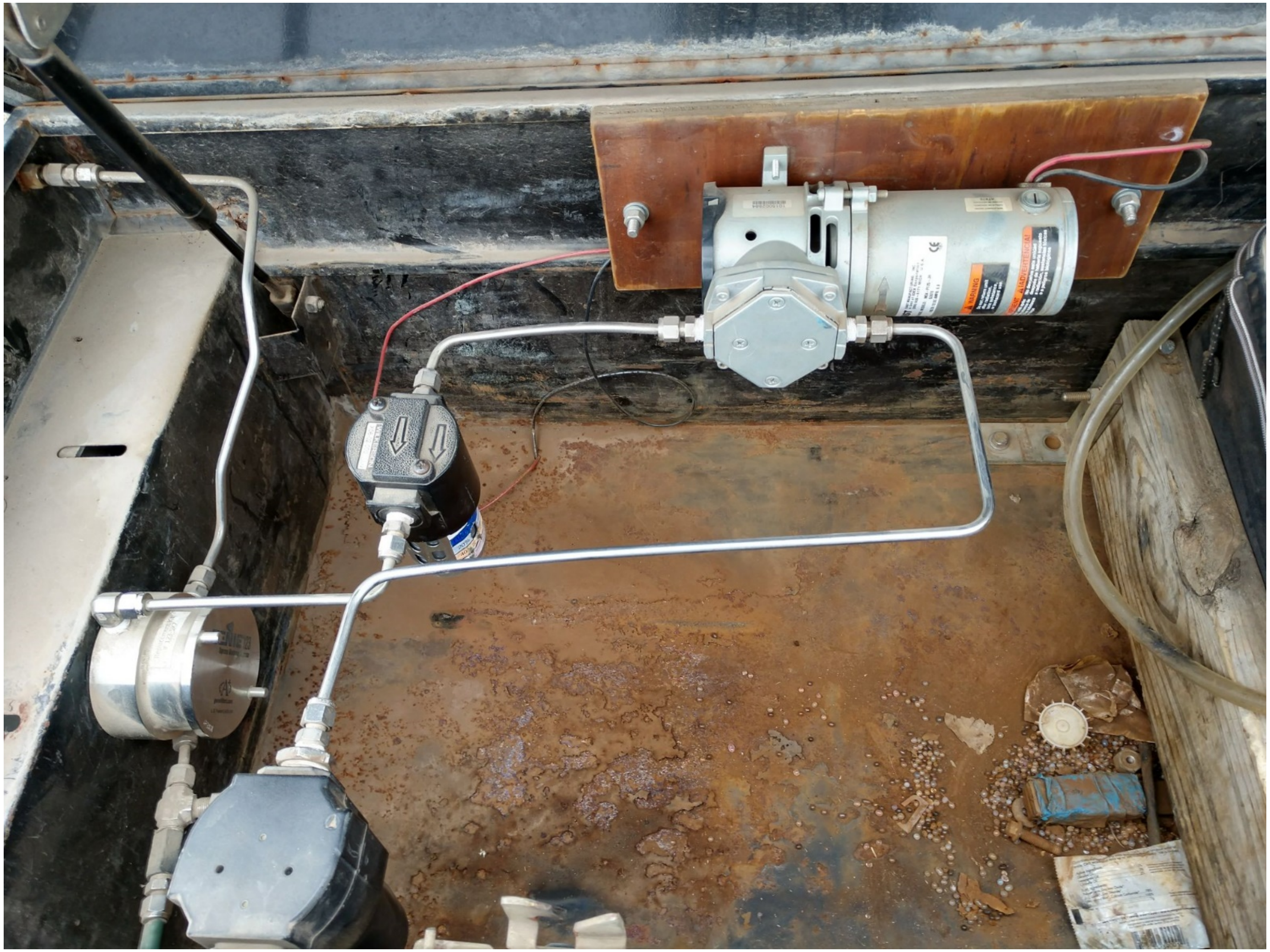
Gas Chromatograph (e.g., Agilent Micro GC 3000)

Summary: LFG Analyzers

	Handheld LFG Monitor: GEM 5000	Handheld LFG Monitor: Envision	Gas Chromatograph: Agilent Micro
Gases Measured	CH_4, CO_2, O_2, CO, H_2S	CH_4, CO_2, O_2	CH_4, CO_2, O_2, H_2, N_2, H_2S
CH_4 Accuracy	+/-< 0.5%	+/-< 2%	10ppm
O_2 Accuracy	+/-< 1%	+/-< 2%	10ppm
Onboard Vacuum Pump	Y	Y	N
Internal Data Storage	Y	Y	N
Pressure Readings	Y	Y	N

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

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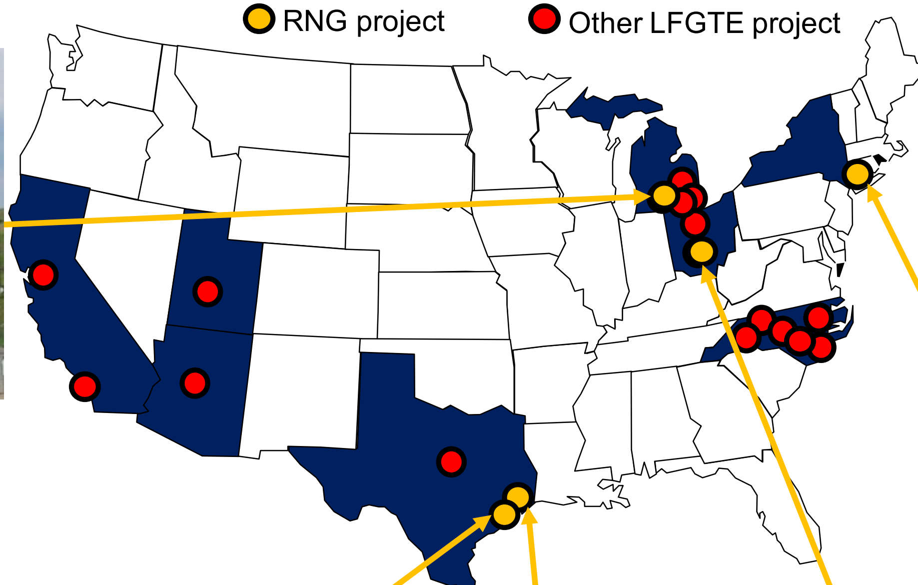
Westside (2001)



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

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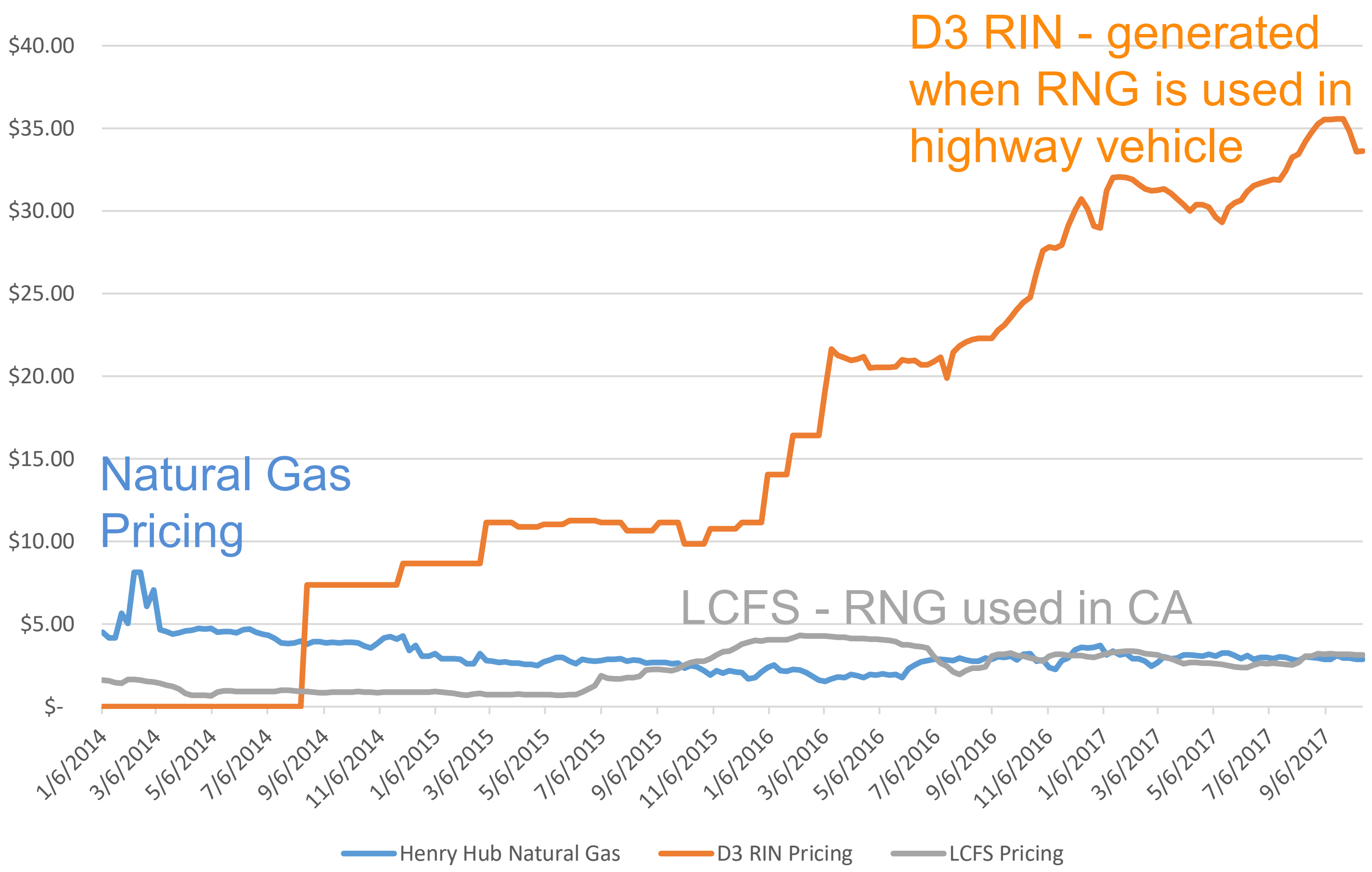

Total value stream can be over $40/MMBtu but is variable

Producing renewable natural gas (RNG) from landfill gas is capital intensive and has significant operating expenses …securing the right revenue stream is key.

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	Historic Approach	Long Term Off-Take	Do-it-yourself RINs	Deliver to a CNG Vehicle via Pipeline
Description	Purify gas to pipeline spec, sell into pipeline, receive NG index pricing	Purify gas to pipeline spec, sell at fixed price to customer	Purify gas, compress to 3500 PSI, and put into CNG highway vehicle	Purify gas to pipeline quality, put in pipeline, deliver to CNG fueling station, fuel highway vehicle
Value Streams	Index pricing based on market natural gas rates	Set price per MMBtu for several years	If you have a CNG vehicle fleet, RNG would offset natural gas costs and RINs would be generated	Natural gas value, RIN value, and LCFS (if vehicles fueled are in California)
Pros	No RIN verification needed	Steady prices typically at a premium to long term natural gas prices	RINs generated with no “middleman” costs No pipeline needed, “easier” spec	Multiple value streams Not captive to local CNG highway vehicle demand
Cons	Natural gas prices are currently very low Requires pipeline	May be at a discount to spot market RIN pricing Requires pipeline	Requires gas storage and large on-highway vehicle fleet to fully utilize RNG Variable pricing	Variable pricing Requires pipeline Possible broker fees

Agenda

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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

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Criteria	Typical Raw LFG	Pipeline Specification Range (Varies)
Btu/CF	450 to 600	900 to 1000
Oxygen	0.05% to 2%	Zero to 0.3%
Carbon Dioxide	40% to 55%	Total inert gas no more than 3% to 7%
Nitrogen	0.5% to 14%	
Hydrogen Sulfide	5 PPM to 5000 PPM	Less than 4 PPM
Water	Fully Saturated	5 to 7 lbs/MMCF
Siloxanes	5-125 PPM	Non-detect to 4 PPM

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

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Nitrogen Rejection Unit (NRU)

Siloxane Removal

De-Oxidation Catalyst

Dehydration Skid

Solvent Based Removal

Sulfur Removal

Carbon Polisher

Gas Chromatograph

Membrane System

Water Absorption

Let's start with the largest component removed – carbon dioxide. There are four "mainstream" competing technologies used to remove CO_2

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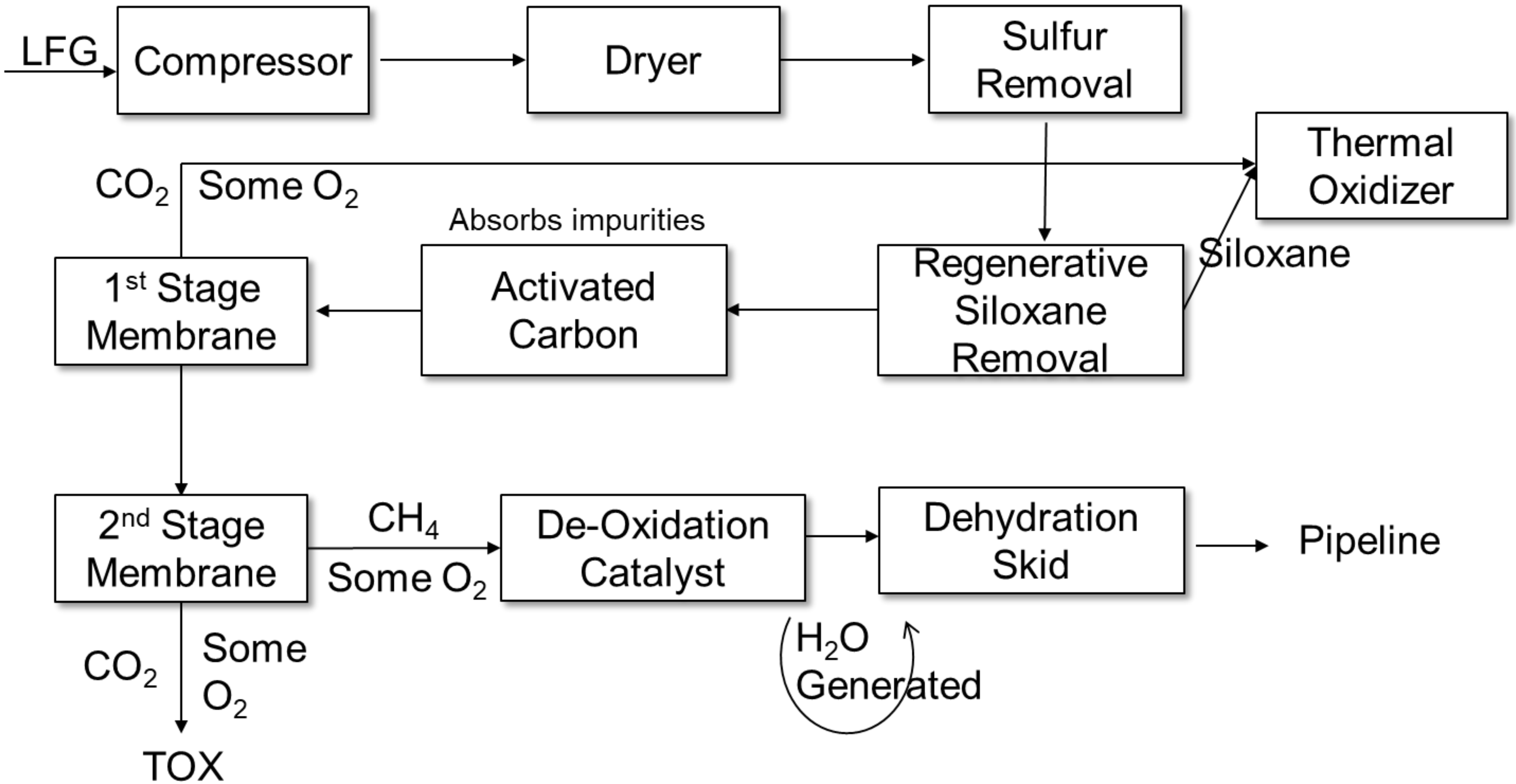
Membrane System	Polymer membranes with tiny "tunnels" that separate carbon dioxide from methane	
Solvent System	Vessels filled with liquid that absorbs carbon dioxide and lets methane pass through; the solvent is regenerated by releasing the carbon dioxide	
Pressure Swing Absorption (PSA)	Uses an absorbent material (molecular sieve) that separates the carbon dioxide from the methane then releases it when the pressure in the vessel changes	
Water Absorption	Uses large amounts of water to absorb the carbon dioxide, letting the methane pass through	

Typical Pipeline-Quality Membrane System



Example of a membrane plant

Non-pipeline quality vehicle fueling station using membrane technology

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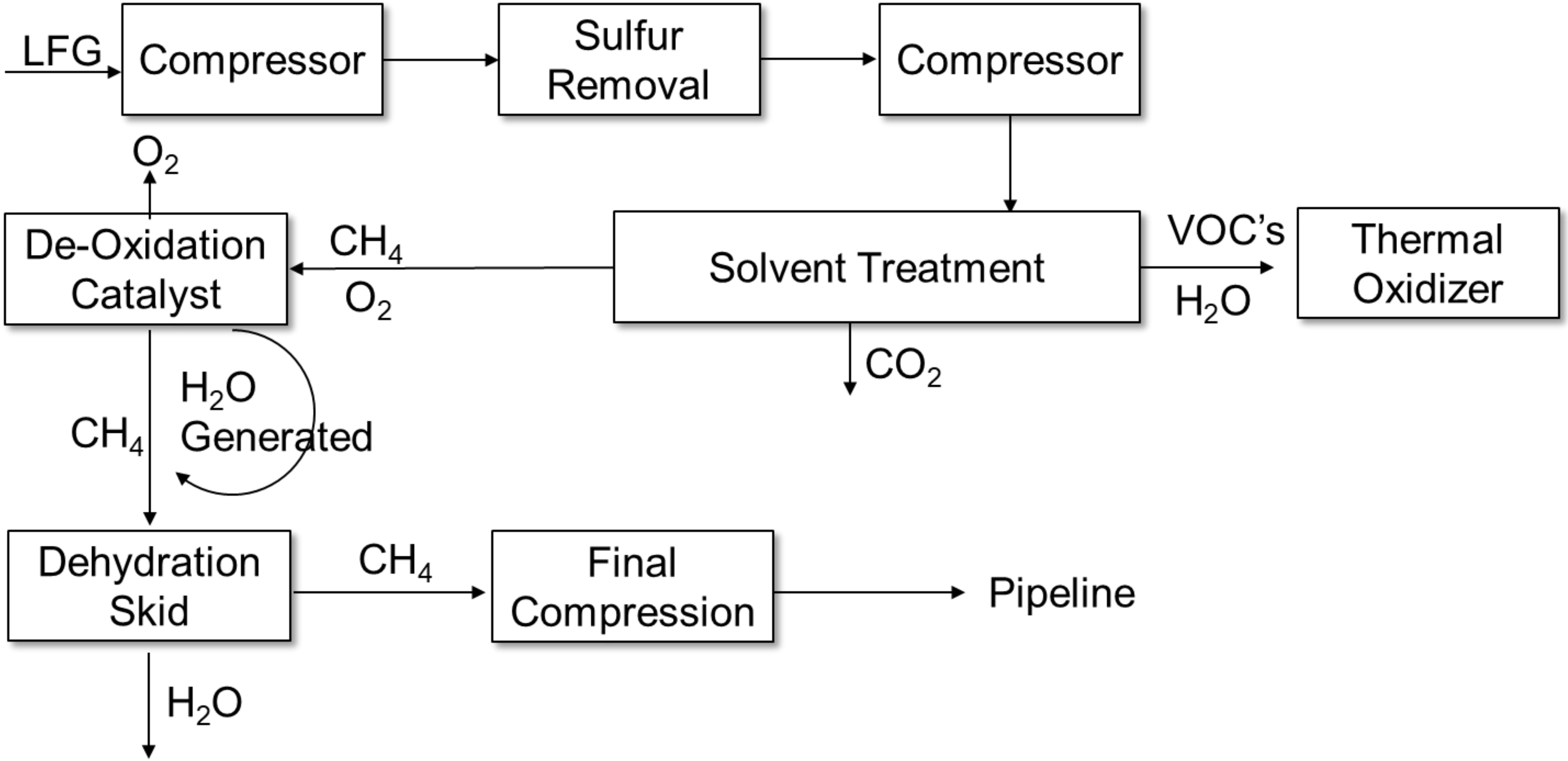
- Uses membrane technology
- Activated carbon used for siloxane removal instead of regenerative system
- Typically a one pass membrane system – more methane slippage
- Looser spec needed than for pipeline quality gas
- Requires a dedicated fleet of vehicles (which is hard to do)

Typical Solvent System Flow Diagram



Example of a Solvent Plant

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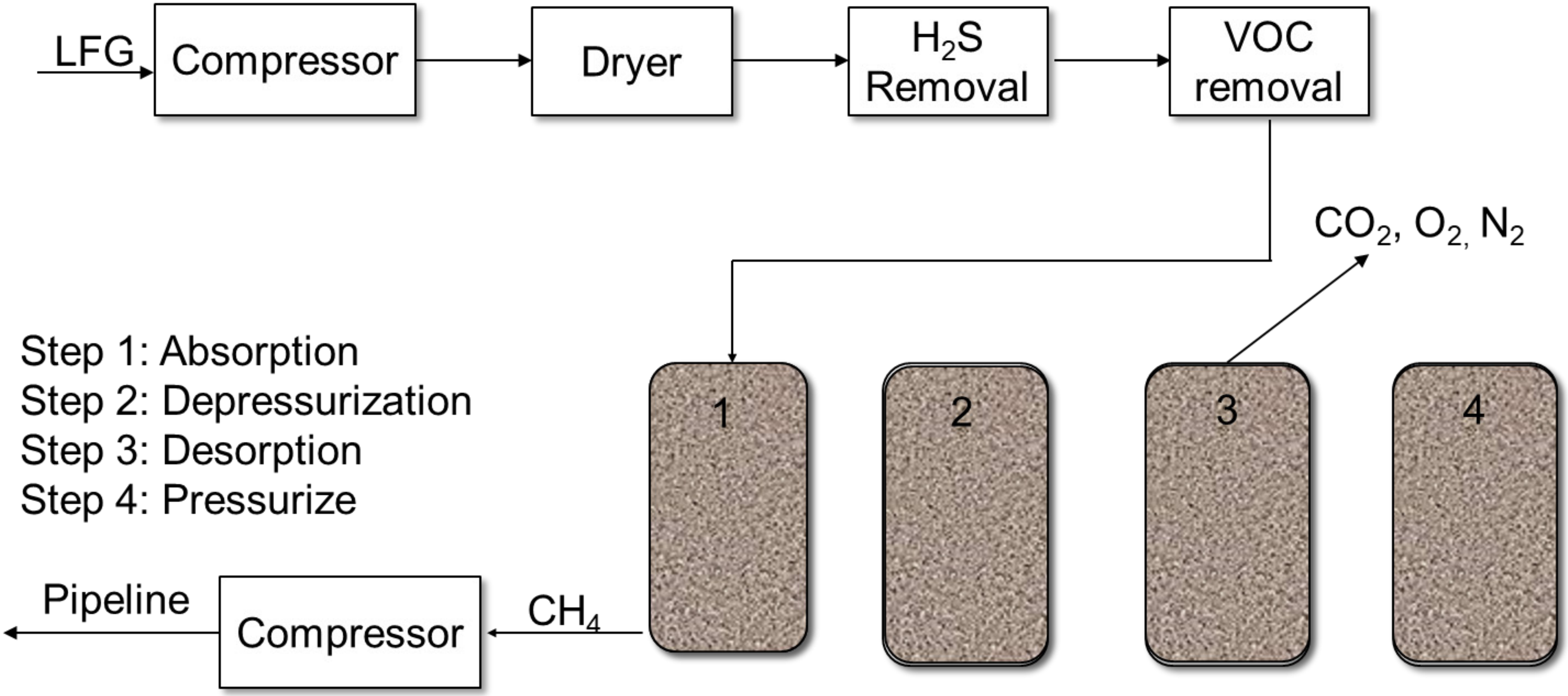
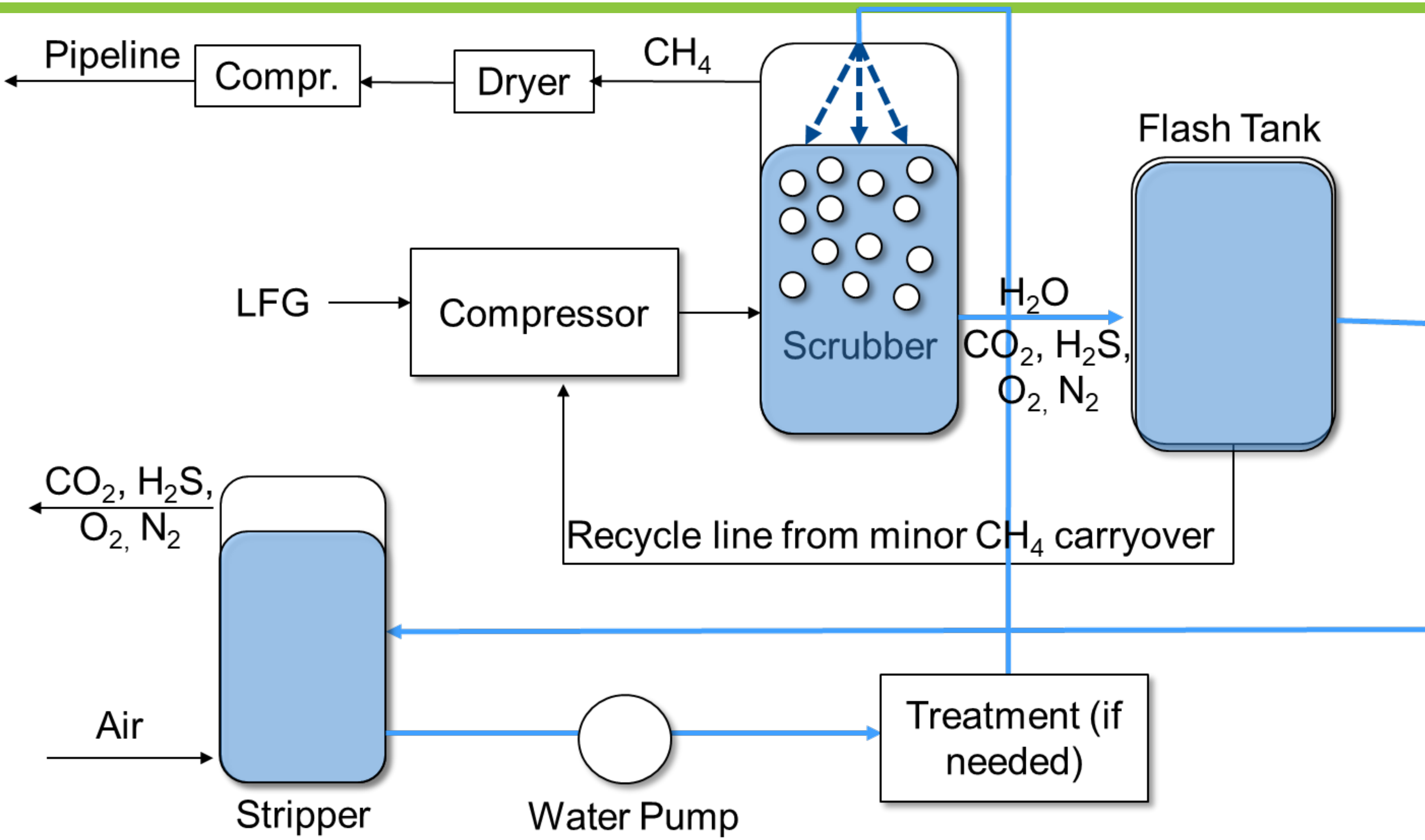
Pressure Swing Absorption uses media to absorb and release gases. This process is more energy intensive than others



4 Tanks each going through a stage in cycle

The water absorption process uses only water to remove the H_2S 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

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Tech	Advantages	Disadvantages
Membrane	• Simple "black box" technology with few moving parts other than compressors • Removes some O_2 – may help meet looser O_2 specs • Historically good on-stream rates • Easily expandable • Smaller plant footprint	• Beholden to membrane manufacturer • 94% methane recovery • Activated carbon and H_2S removal are expensive • Membranes do not "like" contaminants • Separate siloxane removal system needed
Solvent	• Plant components are widely used in the oil/gas industry – spares are readily available • 98 to 99% methane recovery • Historically good on-stream rates • Typical solvent removes siloxanes and VOCs without needing disposable media	• Expansion may require new towers and compressors • Typical solvent does not remove any O_2 or N_2 • Larger/taller plant footprint • Does not remove any O_2 • Because of low CH_4 loss, additional fuel needed for TOX • More things to break (pumps, vacuum blowers, etc.)
PSA	• May remove other components of the gas stream, including some N_2 and O_2 • Few moving parts other than valves and compressors	• ~95% methane recovery • Pressurization/depressurization/re-pressurization process is energy intensive • Leaky valves can create serious issues
Water Absorption	• Simple process that just uses water • ~96% methane recovery • Removes some N_2 and O_2	• Uses a lot of water – treatment of water may be costly and complicated • Large foot print with large vessels • Can only handle a certain level of N_2 and O_2 • More moving parts (pumps, valves, etc.)

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

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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 H_2S, can reduce effective life of activated carbon that is targeting siloxane
- Free liquids can reduce effectiveness of media

Hydrogen Sulfide (H_2S) Removal

Non-NRU plants (no O_2 in inlet gas)

Sulfur removal vessels at a solvent plant

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

Can be very expensive if inlet H_2S 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 (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

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)

Storage bladder for methane coming off of NRU

Typically uses pressure swing absorption technology to absorb CH_4 and let N_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

Hitting a "tight" Btu/CF pipeline specification

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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

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Getting the gas into a vehicle

Problems to avoid

The majority of RNG is shipped via pipeline to vehicle fueling stations

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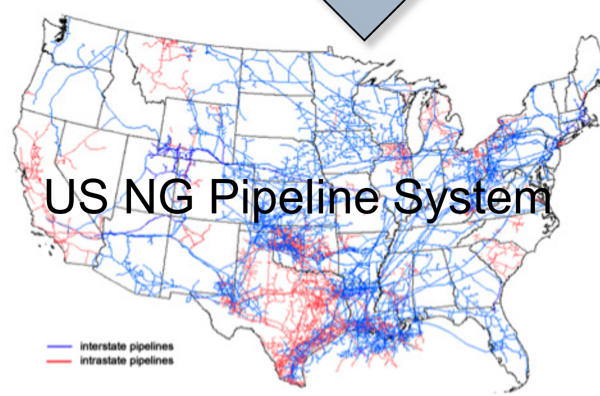
LFG to RNG Plant

Dedicated Pipeline

Interconnect with local NG pipeline



US NG Pipeline System

CNG Filling Station

Not all landfills are near a pipeline. There are virtual pipeline alternatives, but they require more operating expenses and logistics

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LFG to RNG Plant

CNG Tanker

Drive CNG tanker to local interconnect

Drive CNG tanker directly to CNG fueling station

Agenda

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Problems to avoid

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

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"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

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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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Visit us at www.dtebe.com

Our newest team at Seabreeze

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