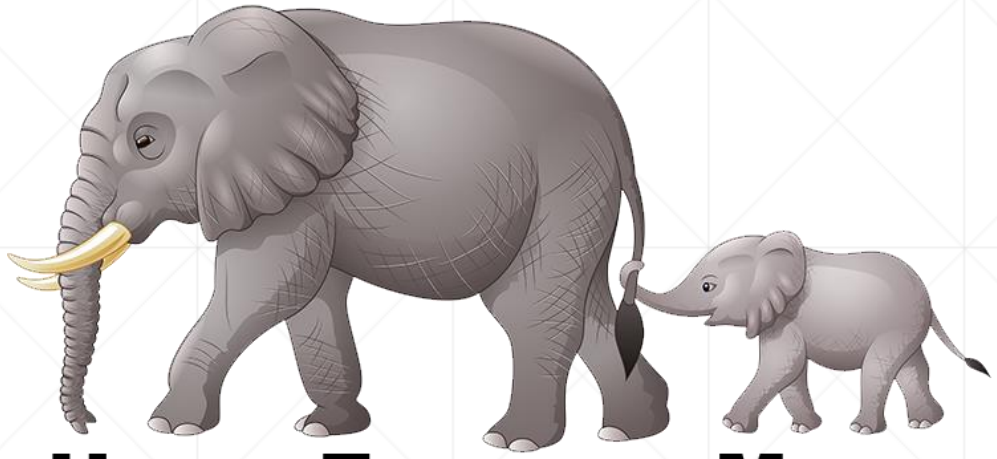
Thursday, September 15, 2022

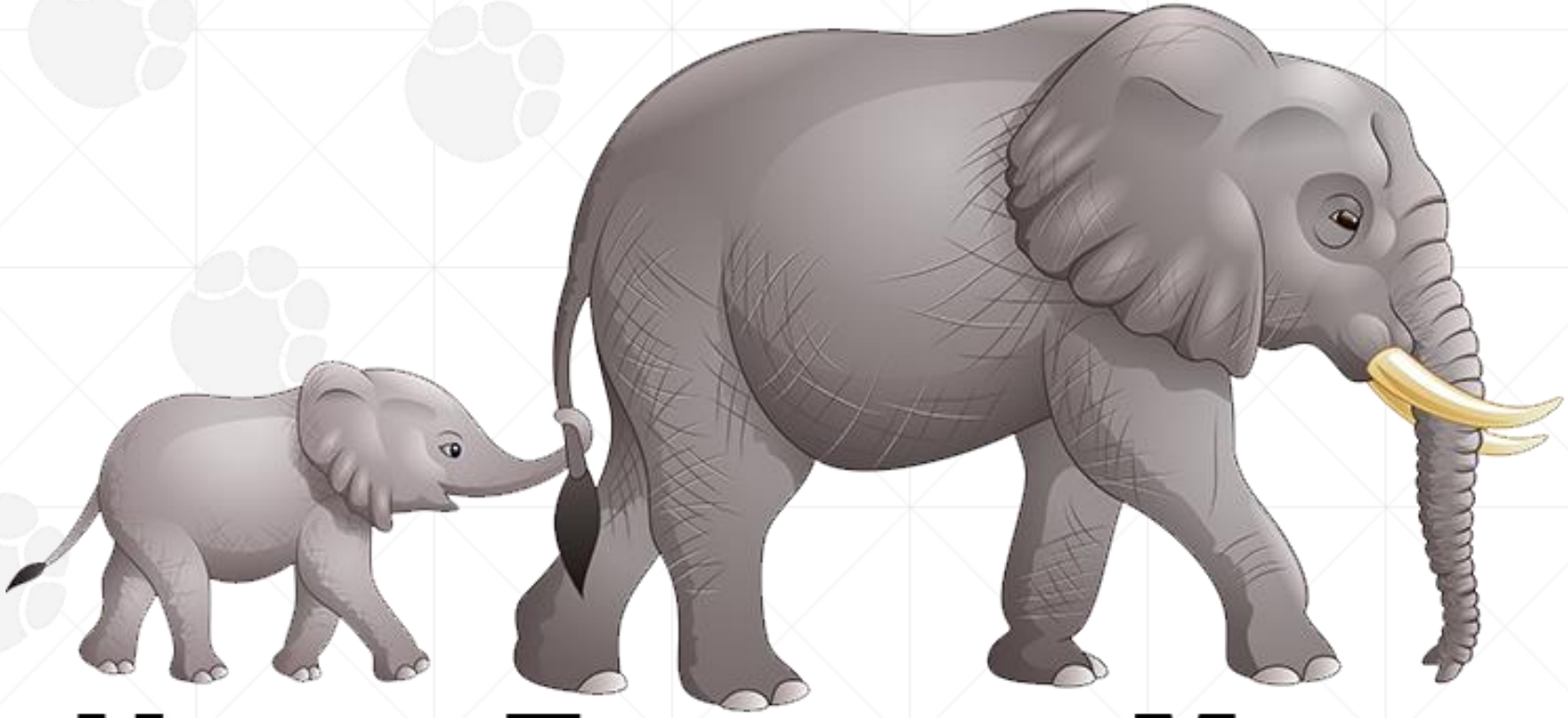


~ PRESENTS ~

Biogas Upgrading, Proven Technologies

Presented by Unison Solutions, Wartsila and Macrotek

Sponsored by Unison Solutions



URBANELEPHANTMEDIA

PEER-TO-PEER LEARNING MADE EASY

Sustainability Training for Urban Designers and Policymakers

Randy Rodgers, Director of Big Ideas
Randy@UrbanElephantMedia.com
563-562-2925

UrbanElephantMedia.com

Our Sponsor

UNISON

Our Presenters

Jan Scott
President
Unison Solutions

Biogas Upgrading, Proven Technologies

UNISON SOLUTIONS
Employee Owned

Overview

- Company founded on January 1, 2000
- Employee Owned: November 2020
- 55 Employees (9 Engineers)
- 65,000 ft^2 manufacturing facility
- Over 360 systems sold worldwide

Sales team

Unison's founders
Jan Scott & Dave Broihahn

Adam Klaas

Eric
Wilgenbusch

Curt Schiesl

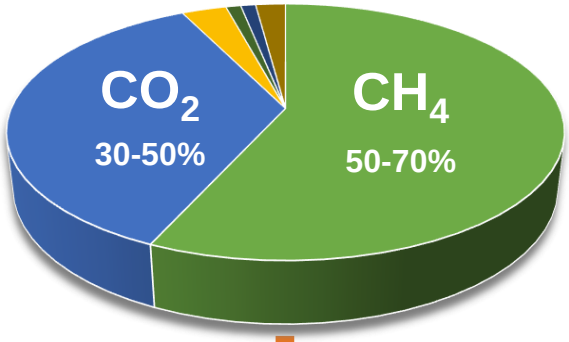
Kim Murdock-
Timmerman

Jared Roling

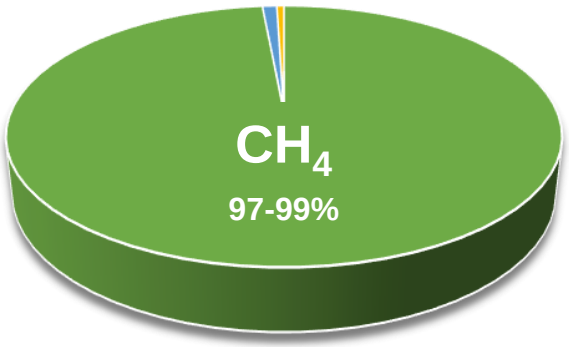
Over 100 years of combined experience in biogas applications

Biogas to RNG

Raw Biogas



Renewable Natural Gas (RNG)



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Know your pipeline requirements

- **Gas quality requirements***
  - Wobbe Index/BTU Content
    - Methane
  - Carbon dioxide
  - Oxygen
  - Nitrogen
  - Hydrogen sulfide
  - Siloxanes and VOCs
  - Bacteria
  - Moisture content

*Requirements vary depending on pipeline tariff

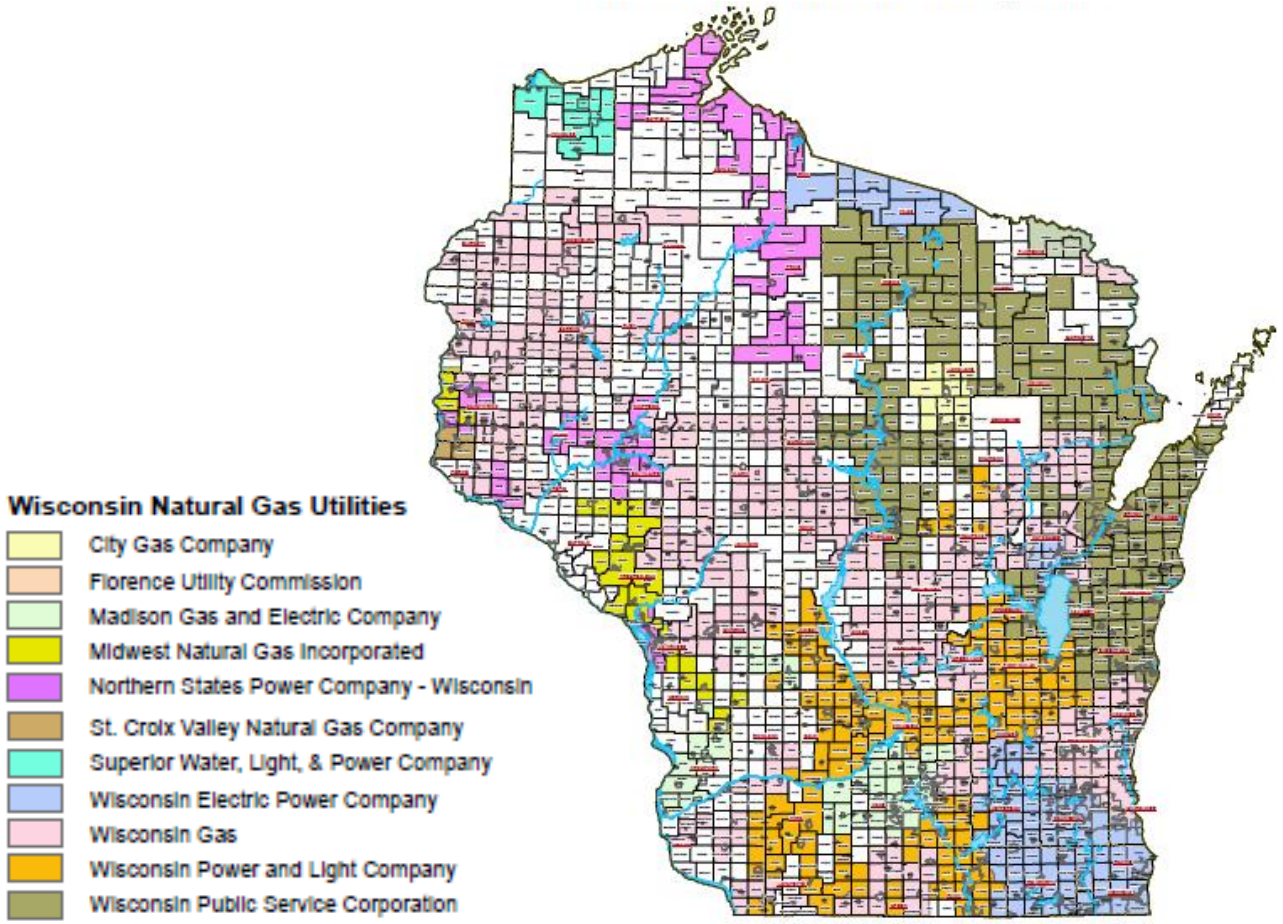
- **Tie-in location and requirements**
  - Interconnect fees
  - Pressure
  - Flow
  - Transport to offloading station-virtual pipeline
    - Compression
    - Tube trailers
- **What RNG monitoring is required?**
  - Online
  - Monthly
  - Yearly
  - Single validation test

Fuel quality specification

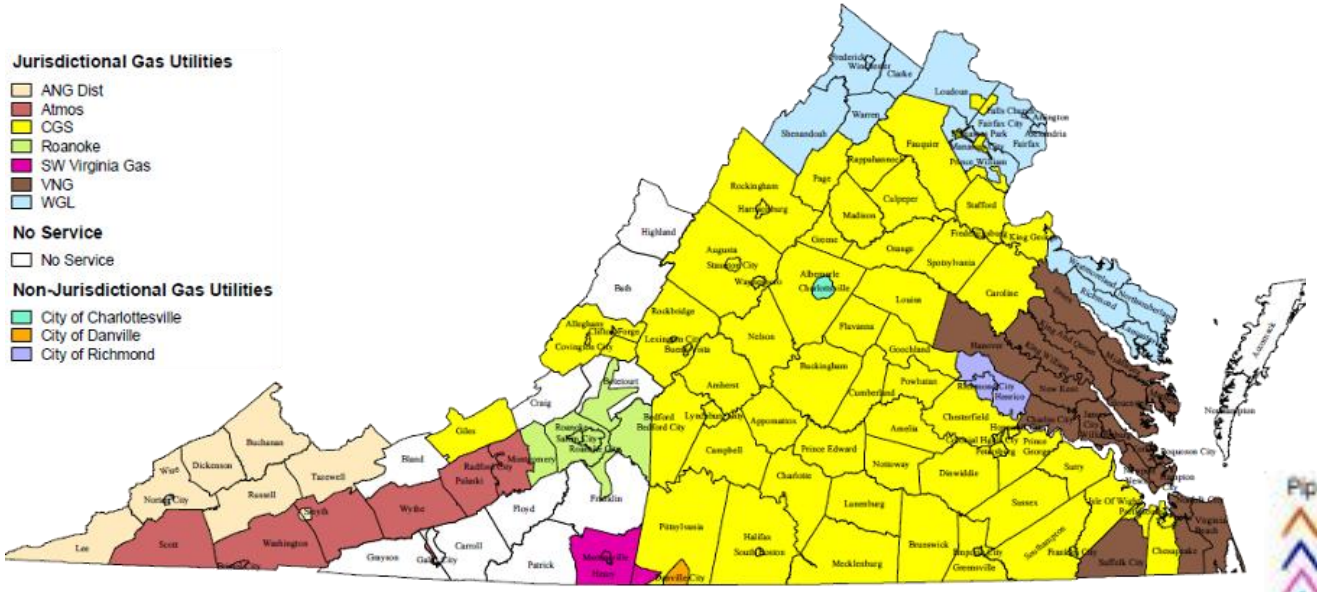
Constituents	Raw Biogas	Midwest Pipeline	Westcoast Pipeline
Wobbe Index			1,185-1,285 BTU/ft^3 max
Higher Heating Value (HHV)		940-950 BTU/scf	Min. 985 BTU/ft^3
Carbon Dioxide (CO_2) and Nitrogen (N_2)	20-50%	2-2.5%	<2%
Oxygen (O_2)	0-1%	0.2-0.3%	0.2%
Hydrogen Sulfide (H_2S)	≤10,000 ppm	≤4 ppm	0.25 grains of H2S/100 scf
Moisture Content	100%	128-170 ppmv	Dewpoint of 9°F measured at or above 200 psig
Siloxanes and Volatile Organic Compounds	<2,000 ppm	4 mg Si/m3	ND to 1 ppm
Biologicals		$4x10^4$/SCF	4×10^4/scf (qPCR per APB, SRB, IOB)
Additional specs		Specific organic compounds, hydrocarbon dewpoint	Mercury, Ammonia

Example: Natural gas utilities

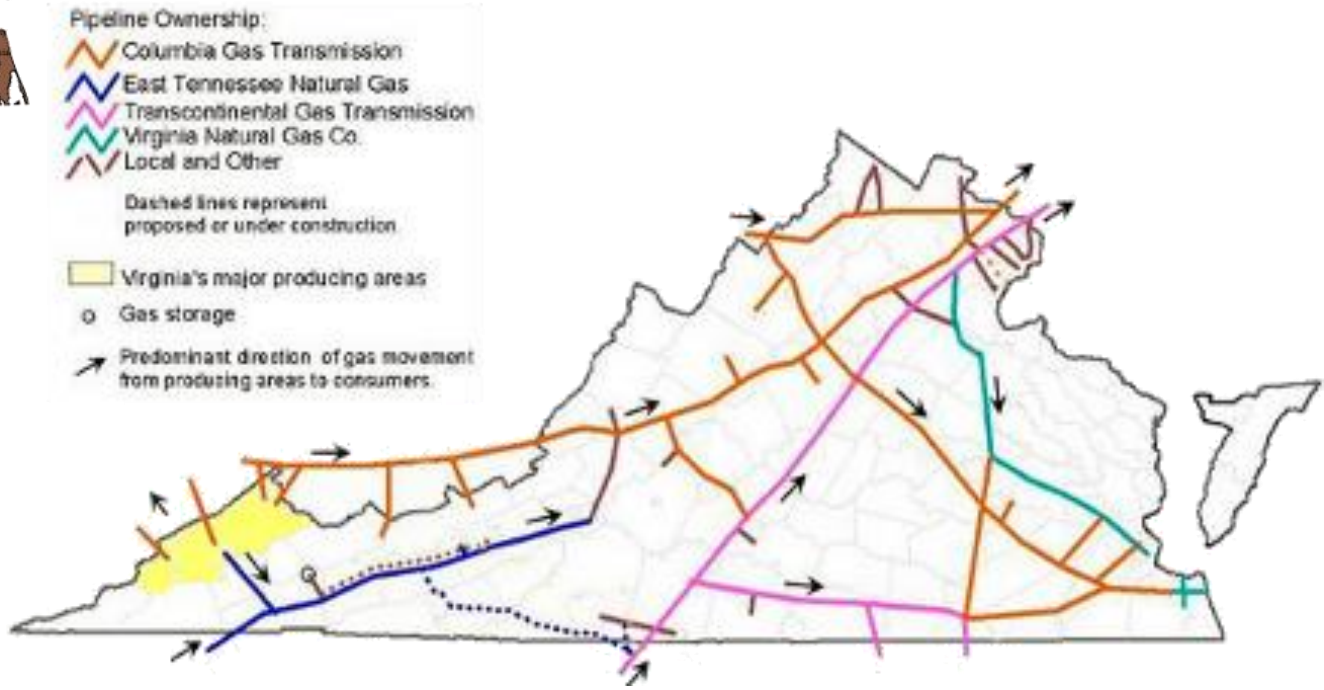
Wisconsin Natural Gas System



Example: Natural gas utilities



Virginia Natural Gas System



Biogas upgrading system: Process flow diagram

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Digester or Landfill

H_2S Removal

Gas Compression/ Moisture Removal

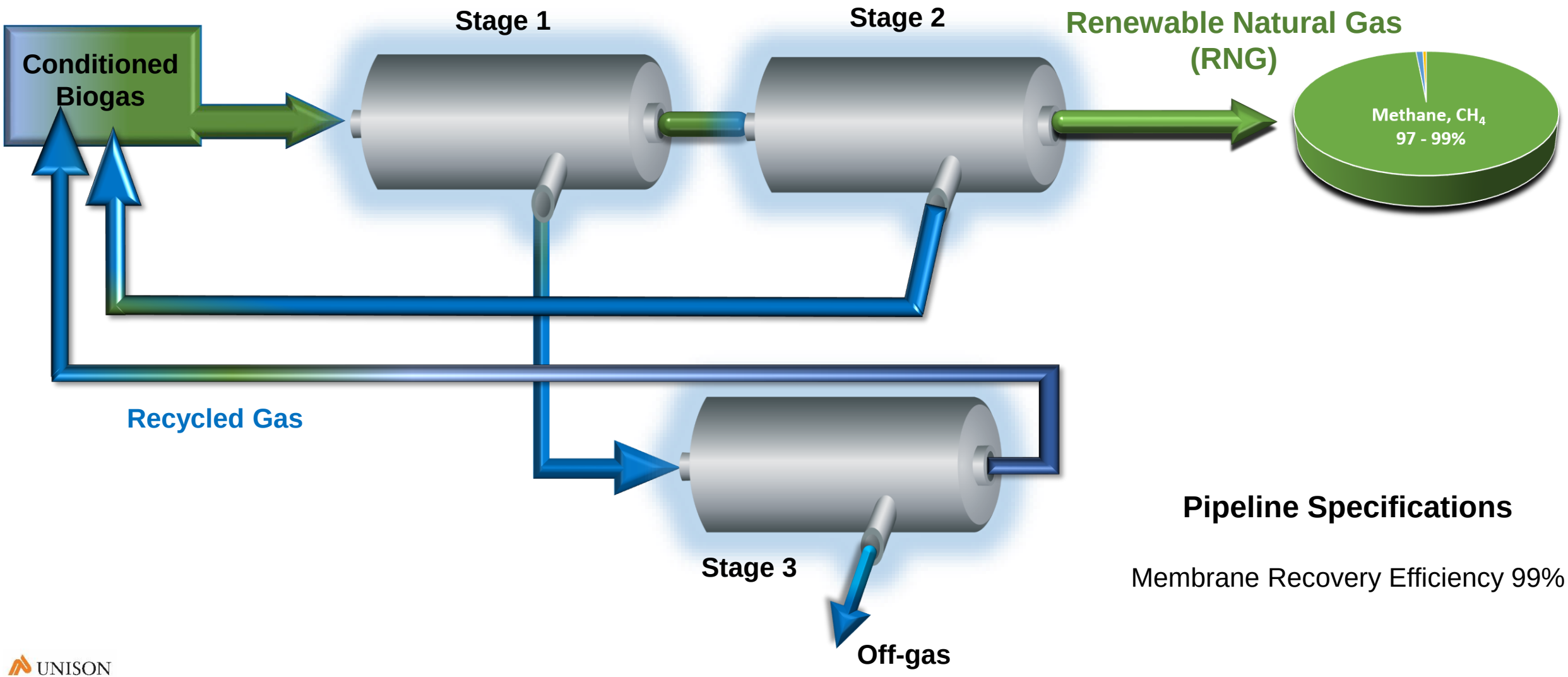
Siloxane/VOC Removal

CO_2 Removal

CNG Vehicle Fueling Station

Vehicle Fuel/Pipelines

CO_2 Removal - Three-stage membrane process



Pipeline Specifications

Membrane Recovery Efficiency 99%

Grand Rapids WRRC, Michigan

- 40 MGD Plant
- Municipal waste
- 2 – 400 scfm systems
- Oxygen removal system
- Start up: December 2021

Gas Compression, Moisture, Bacteria, CO_2 and Siloxane Removal

H_2S Removal

PSB Industries Deox System

Pipeline Injection – DTE Energy Pipeline

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Roanoke Regional WPCP, Virginia

- 37 MGD Plant
- Municipal waste
- 400 scfm system
- Start up: 2023

Gas Compression, Moisture, Bacteria, CO_2 and Siloxane Removal

H_2S Removal

Siloxane/VOC Removal

Pipeline Injection – Roanoke Gas Company Pipeline

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South Platte Renew, Colorado

- Littleton-Englewood, CO
- 20 MGD plant
- 400 scfm
- Start up: October 2019

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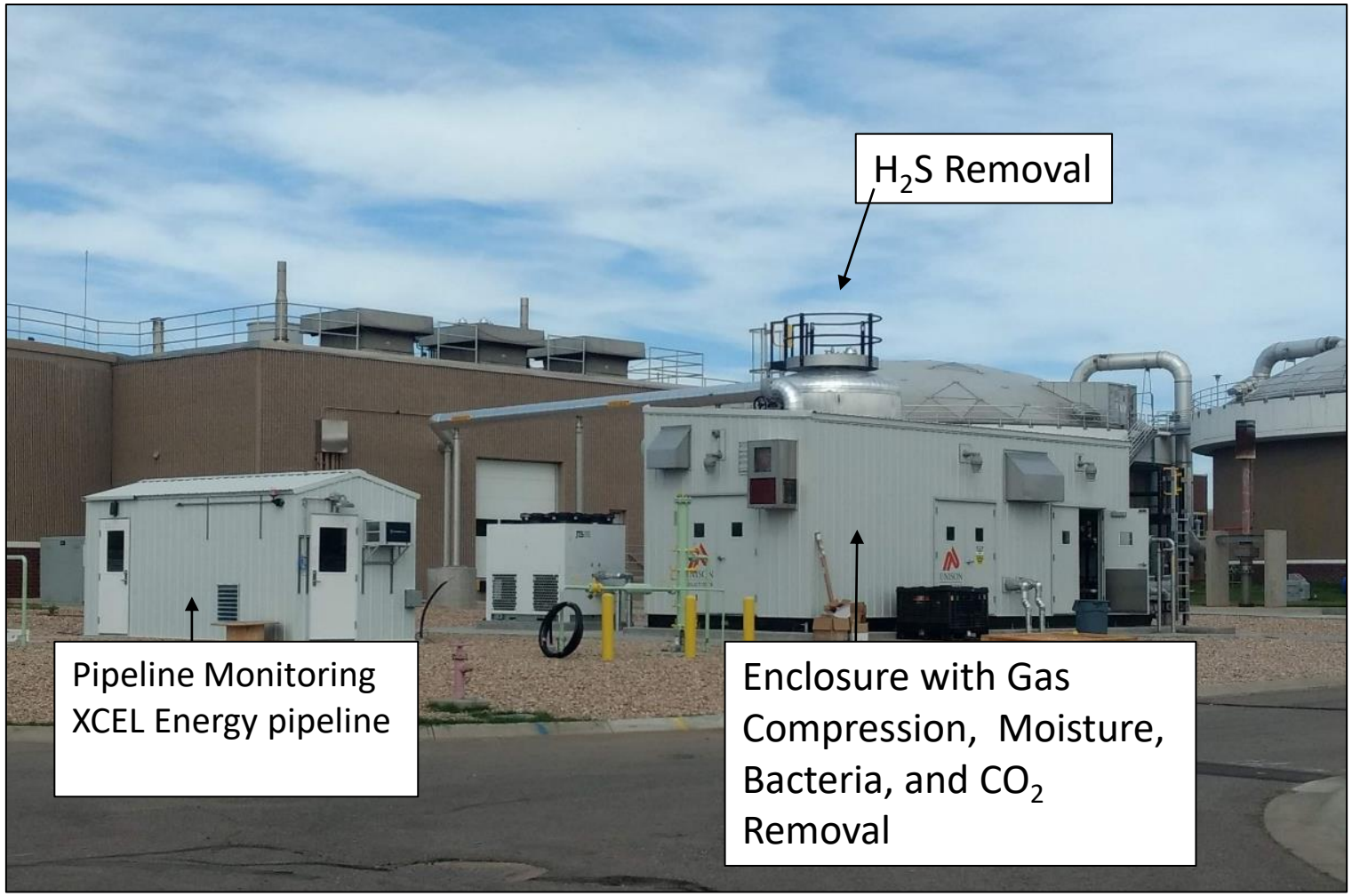
South Platte Renew, Colorado



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Theresa Street WRRF, Nebraska

CITY OF LINCOLN NEBRASKA

- 27 MGD Plant
- 400 scfm
- Municipal and industrial waste
- Start up: November 2020

H_2S Removal

Gas Compression, Moisture, Bacteria, and CO_2 Removal

Siloxane Removal

Pipeline Injection
Black Hills Energy Pipeline

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Theresa Street WRRF, Nebraska

CITY OF LINCOLN NEBRASKA

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Pacific NW facility

- 130 MGD Plant
- Municipal waste
- 300 scfm system
- Start up: Fall 2021

Gas Compression, Moisture, Bacteria, & CO_2 Removal

Pipeline Injection – PSE

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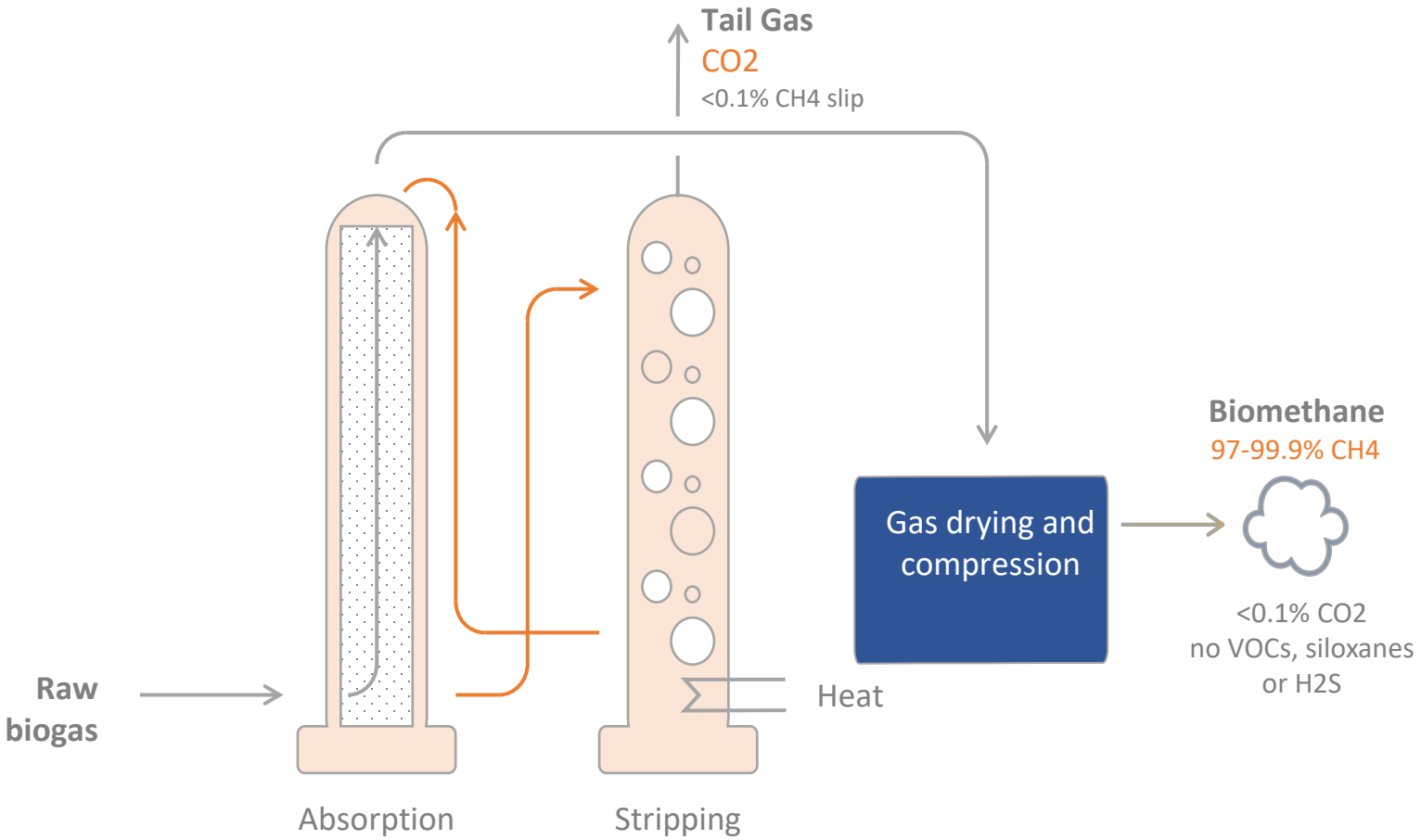
Tamara Siskind

Tamara Siskind, B.S. ChE,

Puregas Sales Engineer

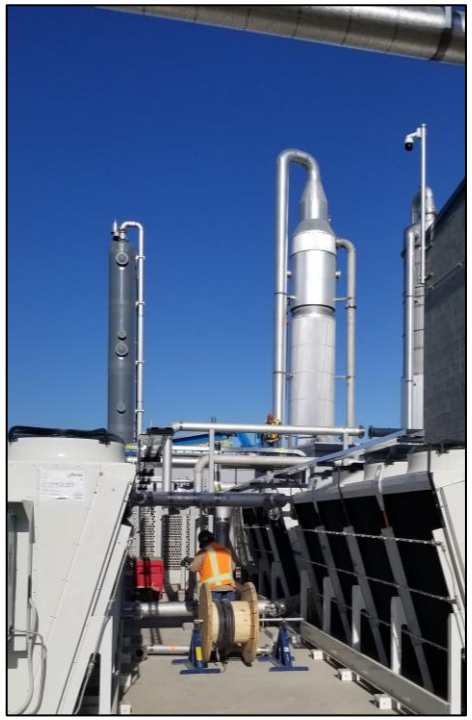
CApure process overview



- CO_2 separation via chemical absorption and stripping of amine
- Low pressure (~12 psig) operation reduces electrical demand, increases plant availability
- Lowest methane slip to tail gas stream (< 0.1%) of biogas upgrading technology options
- Flexibility to treat H2S in raw biogas or in tail gas

Threemile Canyon Farms

- Location: Boardman, Oregon
- Start-up Date: 2019
- Biogas feedstock: dairy manure
- Farm recognized in 2020 for Outstanding Dairy Sustainability by Innovation Center for U.S. Dairy



- Plant capacity: 3500 SCFM
- Puregas CApure upgrading technology with 99.934% biomethane recovery
- Heat integration between CApure plant and substrate pre-heat train upstream of covered lagoon digesters

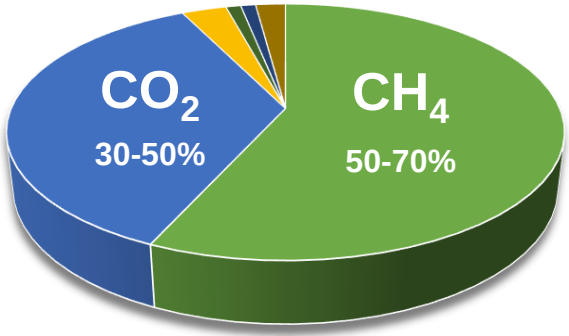
Shell New Energies, Junction City OR

- Location: Junction City, Oregon
- Start-up Date: 2021
- Biogas feedstock: dairy manure and straw/grass residues

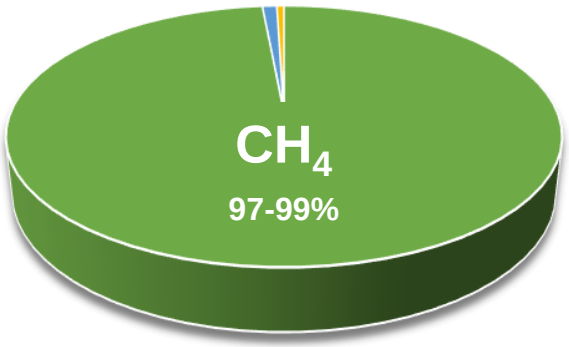
- Plant capacity: 3500 SCFM
- Puregas CApure upgrading technology
- Prefabricated equipment modules fully factory-tested prior to delivery on-site, reducing site installation scope and schedule

Biogas to RNG for direct vehicle fueling

Raw Biogas



Renewable Natural Gas (RNG)



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Fuel quality specification - Onsite vehicle fueling

Constituents	Raw Biogas	SAE J1616
Methane content		88% or greater
Wobbe Index		1,250-1,420 BTU/ft^3
Higher Heating Value (HHV)		
Carbon Dioxide (CO_2) and Nitrogen (N_2)	20-50%	
Oxygen (O_2)	0-1%	
Hydrogen Sulfide (H_2S)	≤10,000 ppm	≤4 ppm
Moisture Content	100%	PWDP 10°F below lowest recorded temp
Siloxanes and Volatile Organic Compounds	<2,000 ppm	ND as Si

Manteca, California – Fast Fill

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Janesville WWTP, Wisconsin - Fast Fill

- Gas flow: 140 scfm
  - BioCNG 50 Startup: April 2012
- Fast-fill: Vehicle fueling
- Four 65 kW Capstone turbines
- One 200 kW Capstone turbine

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Blue Line Transfer, California - Time-Fill

- Startup: February 2015
- 8 dry anaerobic digesters
  - 11,200 tons of food and green waste diverted per year
- Gas flow: 100 scfm
- Time-fill: CNG-fueled waste haulers
- Fast-fill: Small amount of high-pressure storage on-site for emergency filling

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Longmont, Colorado - Time-Fill

- Startup: February 2020
- Gas flow: 100 scfm
- Indoor Time-fill: CNG-fueled waste haulers
- Fast-fill: Small amount of high-pressure storage on-site for emergency filling

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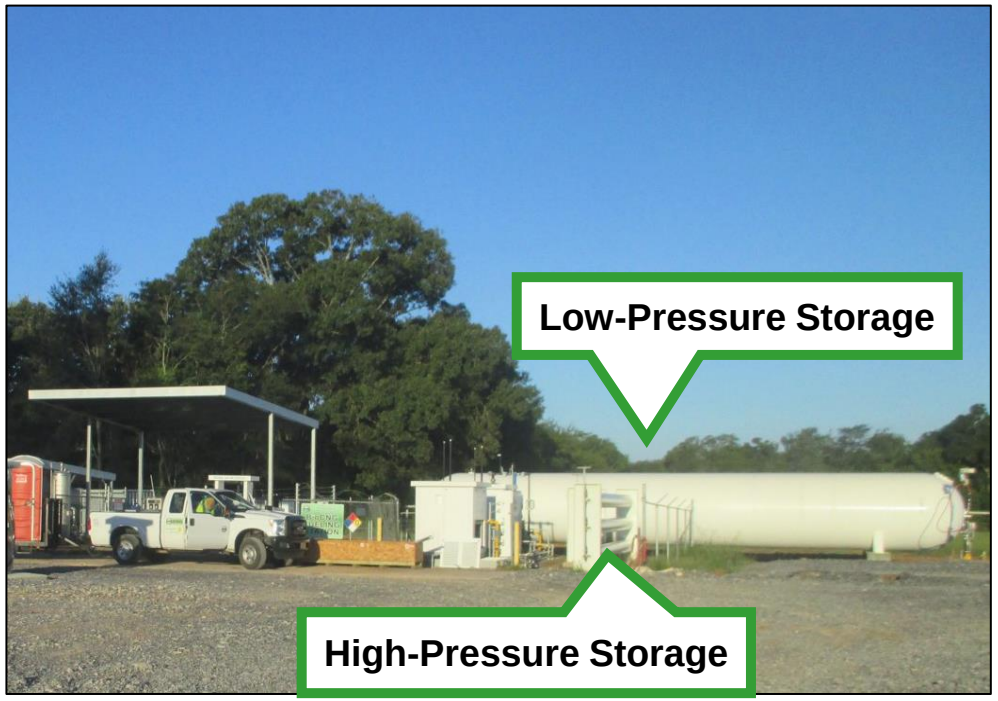
St. Landry Parish Landfill, Louisiana - Virtual Pipeline

- Startup: March 2012
- Gas flow: 150 scfm
- BioCNG 50 & 100
- Low-pressure fuel storage vessel (120 psi)
- Fast-fill: Vehicle fueling



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Biogas cogeneration system: Process flow diagram

Digester or Landfill

Biogas Conditioning System

H_2S Removal

Gas Compression/ Moisture Removal

Siloxane/VOC Removal

IC Engines

MicroTurbines

Boilers

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Redlands WWTF, CA

- 9.5 MGD Plant
- Municipal waste
- 170 scfm system feeding a boiler/sludge heater system
- Start up: February 2022

H_2S, Siloxane/VOC Removal with Custom Platform

Gas Compression and Moisture Removal

Oneida WPCP, NY

- 48 MGD Plant
- Municipal waste
- 250 scfm system feeding Capstone turbines
- Start up: 2019

H_2S Removal

Gas Compression, Moisture, Siloxane/VOC Removal

Capstone turbines

Fort Collins WWTP, CO

- 29 MGD Plant
- Municipal waste
- 170 scfm system feeding (2) Weichai IC Engines
- Start up: March 2021

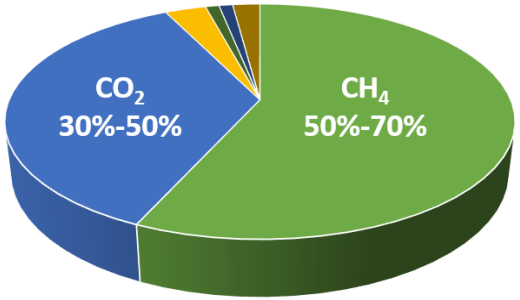
H_2S Removal

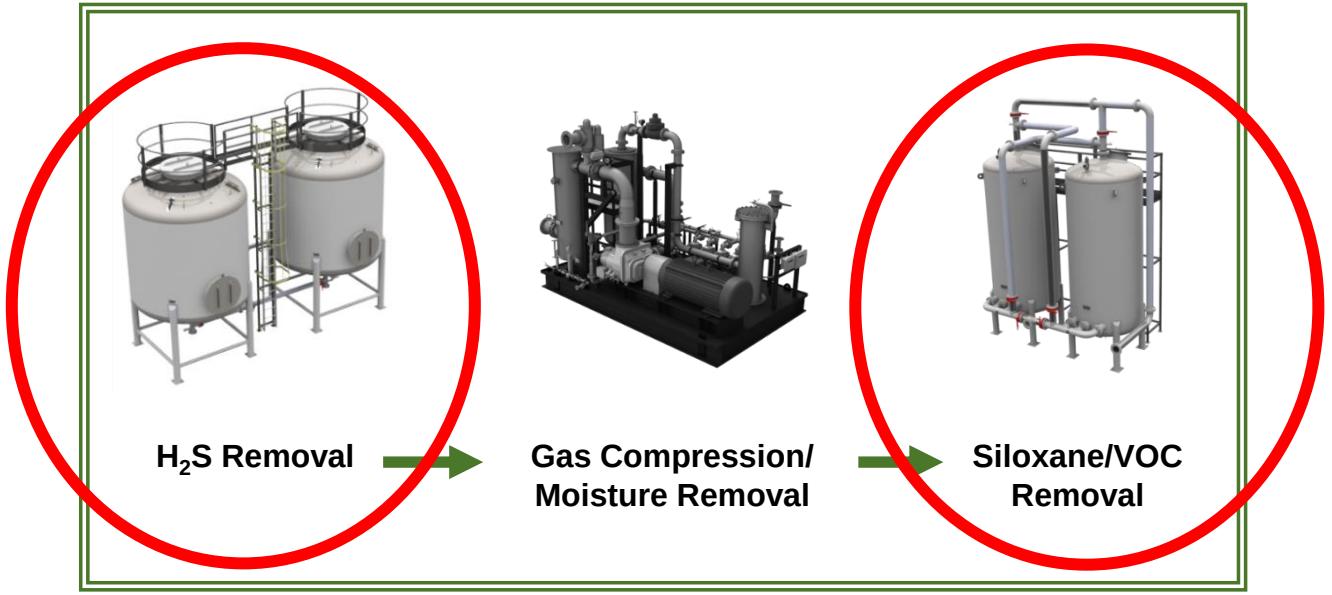
Gas Compression and Moisture Removal

Siloxane/VOC Removal

Biogas treatment systems

Digester or Landfill

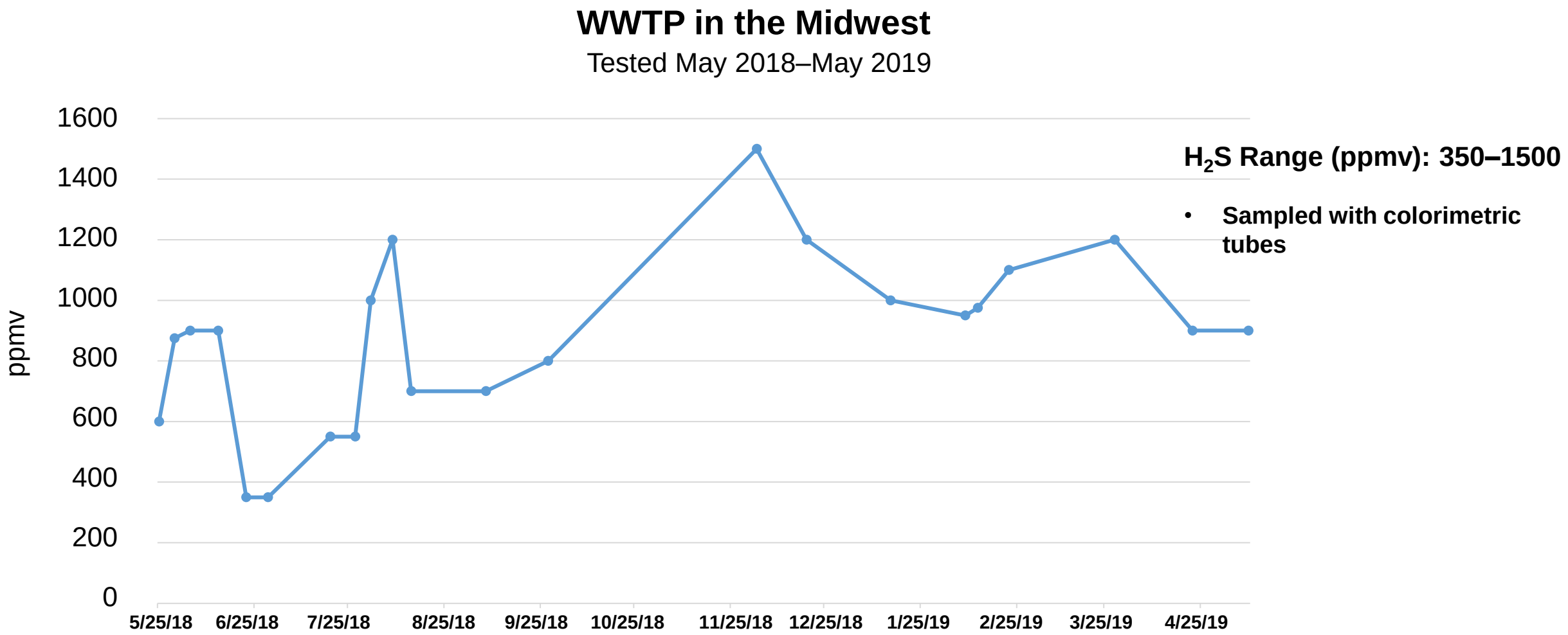




Hydrogen Sulfide (H_2S)

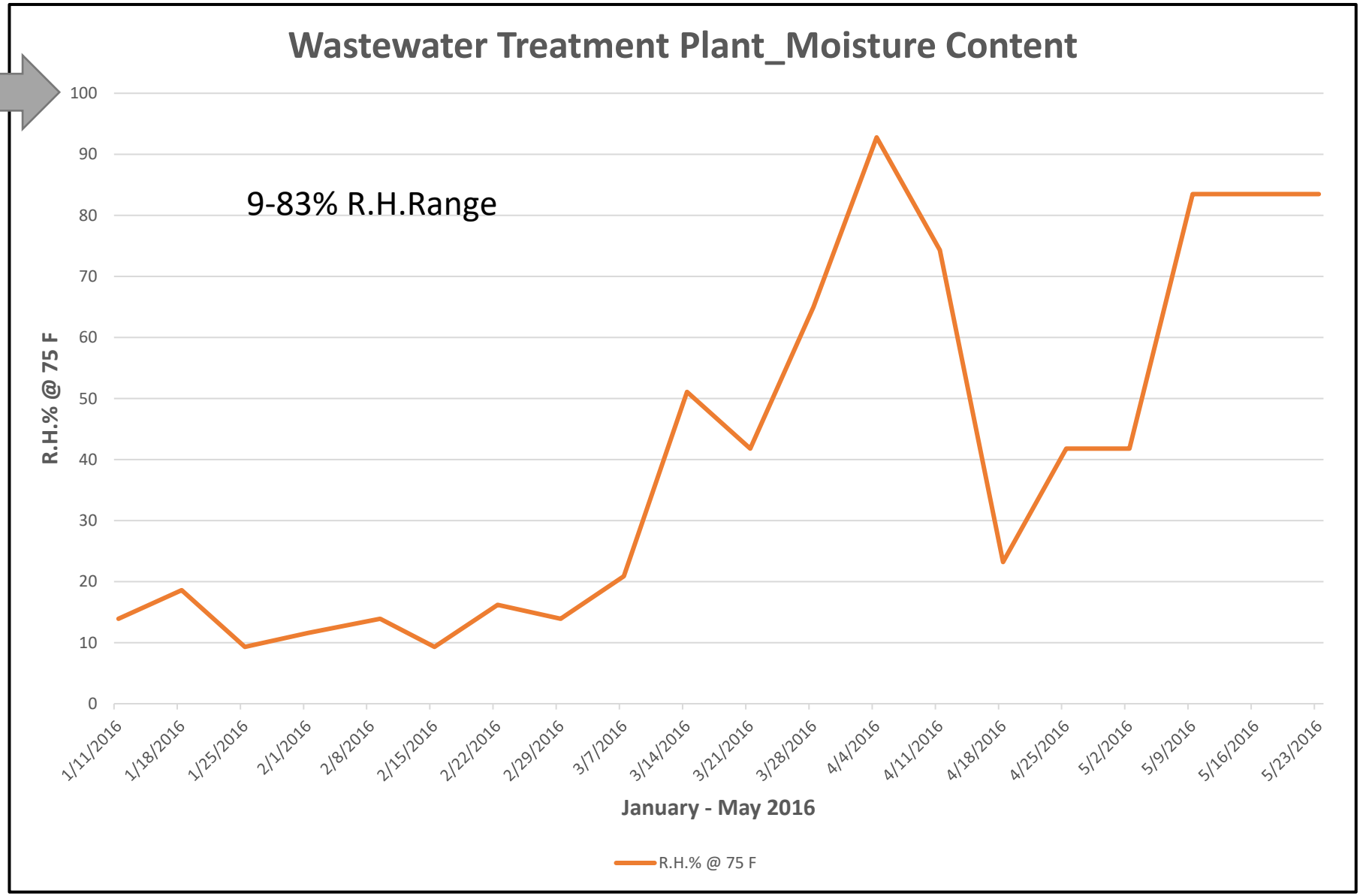
- Where does H_2S come from?
  - Landfills: the breakdown of calcium sulfate used in building materials
  - Digesters: sulfate-reducing bacteria (SRBs) convert the sulfate ion to sulfide
- Equipment damage from corrosion (hydrosulfuric acid)
- SO_x emissions
- Health and safety issues
- Odor control
- **Causes fouling of siloxane/VOC removal media**
- Measure levels with either lab testing, colorimetric tubes, or on-site meter

H_2S levels: Raw gas testing



Moisture levels: Raw gas testing

Optimum



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H_2S removal media costs: Media, removal, disposal

Hydrogen Sulfide (H_2S) - Media for all vessel designs

Chris Ristevski

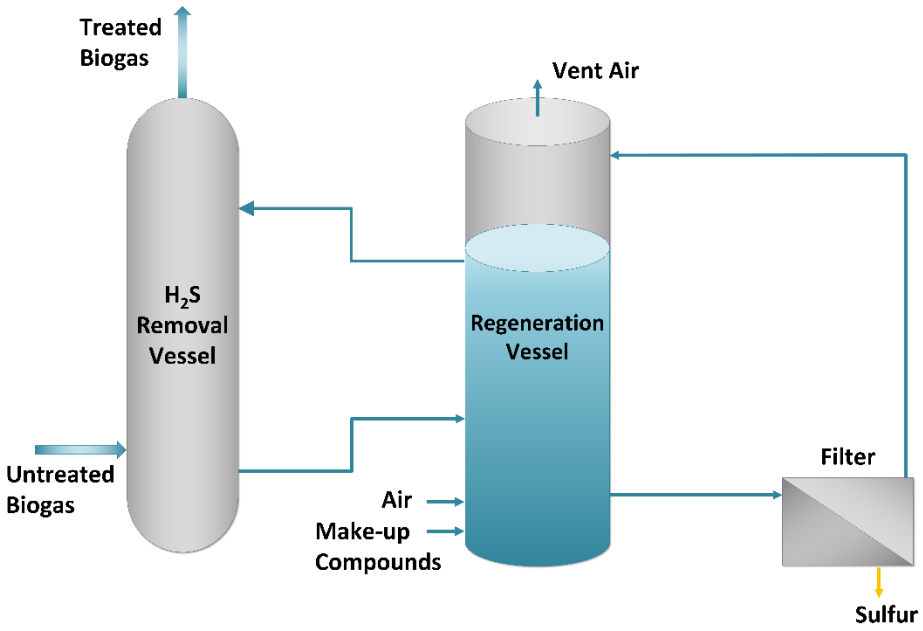
Christopher Ristevski, B.S. ChE

Macrotek's Process Engineering team leader

High H_2S applications

Regenerable H_2S removal

1) H_2S Removal Stage 2) Regeneration Stage 3) Sulfur Separation Stage

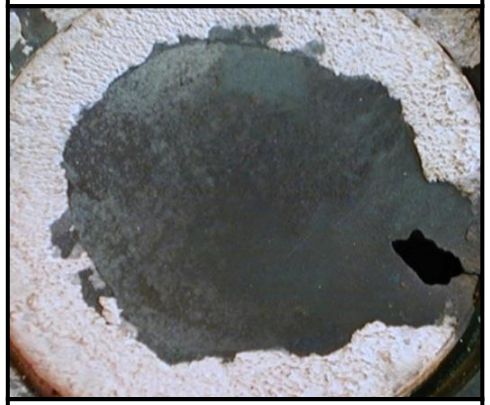


- SULFCAT® Technology
- **Robust chemistry**: Tolerates a wide range of temperatures, flowrates, moisture content and fluctuating H_2S levels
- **H_2S removal compound**: Non-toxic liquid is continually regenerated
- **Alkaline**: Maintains pH above 8
- **Regenerates:** Using ambient air, and minimal waste generation
- **Economical:** Low chemical and maintenance costs
- **Efficient:** Up to 99.9% reduction of H_2S

High H_2S applications

How siloxanes impact equipment

Turbines



Engines

- When methane gas is used as a fuel, the siloxanes form silicon dioxide (SiO_2) and form a hard deposit on surfaces
- Significant impact on electrical generation systems
  - Increased down time for maintaining equipment
  - Increased costs for components, i.e. spark plugs, valve seats
  - Engine rebuild time is more frequent

Boilers

Flares

Siloxane/VOC removal media costs: Media, monitoring, removal, disposal

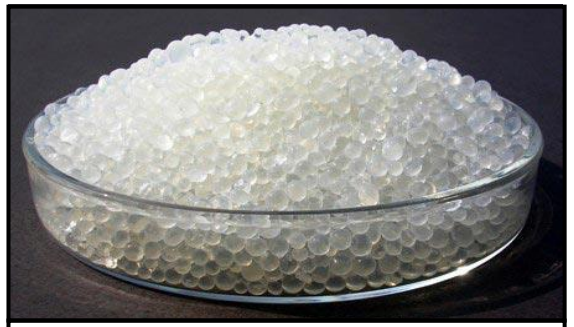
Coconut Shell

Wood

Coal

Extruded Pellets

4 x 8 Mesh Chips



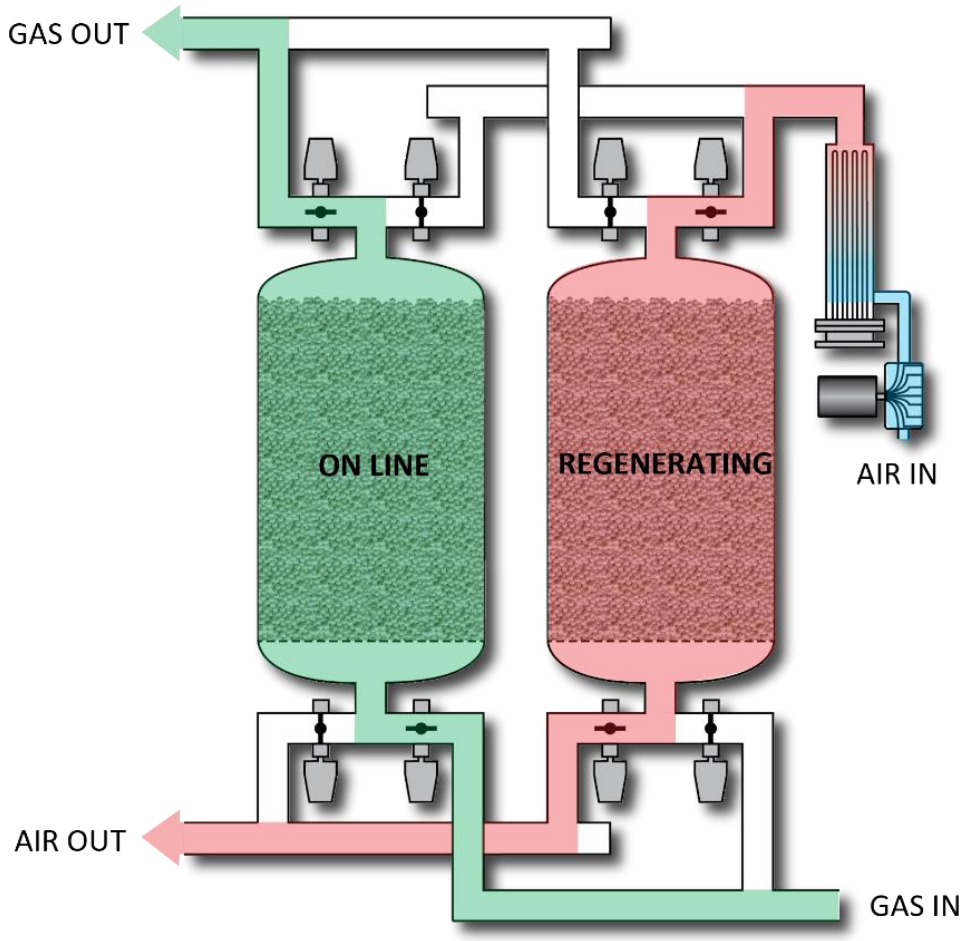
Silica Gel – Spheres

Silica Gel – Irregular Shapes

Siloxane/VOC removal media for all vessel designs

High siloxane/VOC applications

Regenerable Siloxane/VOC Reduction

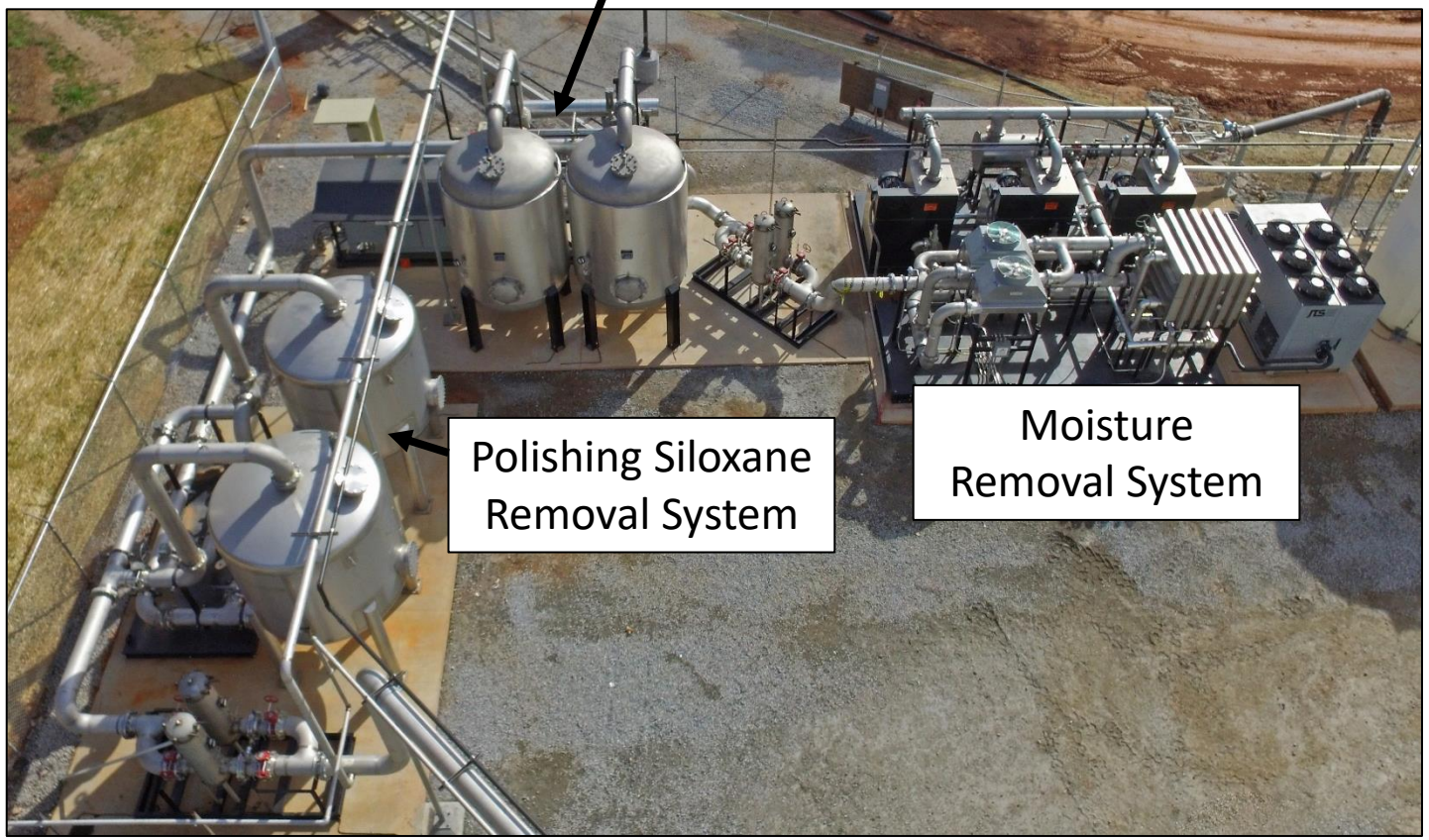


- Willexa® Technology
- A multi tower regenerative temperature swing adsorption system
- Media is regenerated automatically on site providing continuous siloxane reduction.
- No operator input required
- ~Siloxanes – 95% or better reduction rate
- VOC’s – 85% or better reduction rate
- Moisture – 40°F dew point reduction

High siloxane/VOC applications

Regenerable Siloxane/VOC Reduction

- Flow rate: 2800 SCFM
- Installation date: In operation since August 2016
- Inlet siloxanes: 20 ppmv as Si
- Inlet organics: 500 mg/m3 NMOC
- Outlet siloxanes: < 0.5 mg/m3
- CO and SCR catalyst.



Media change out services

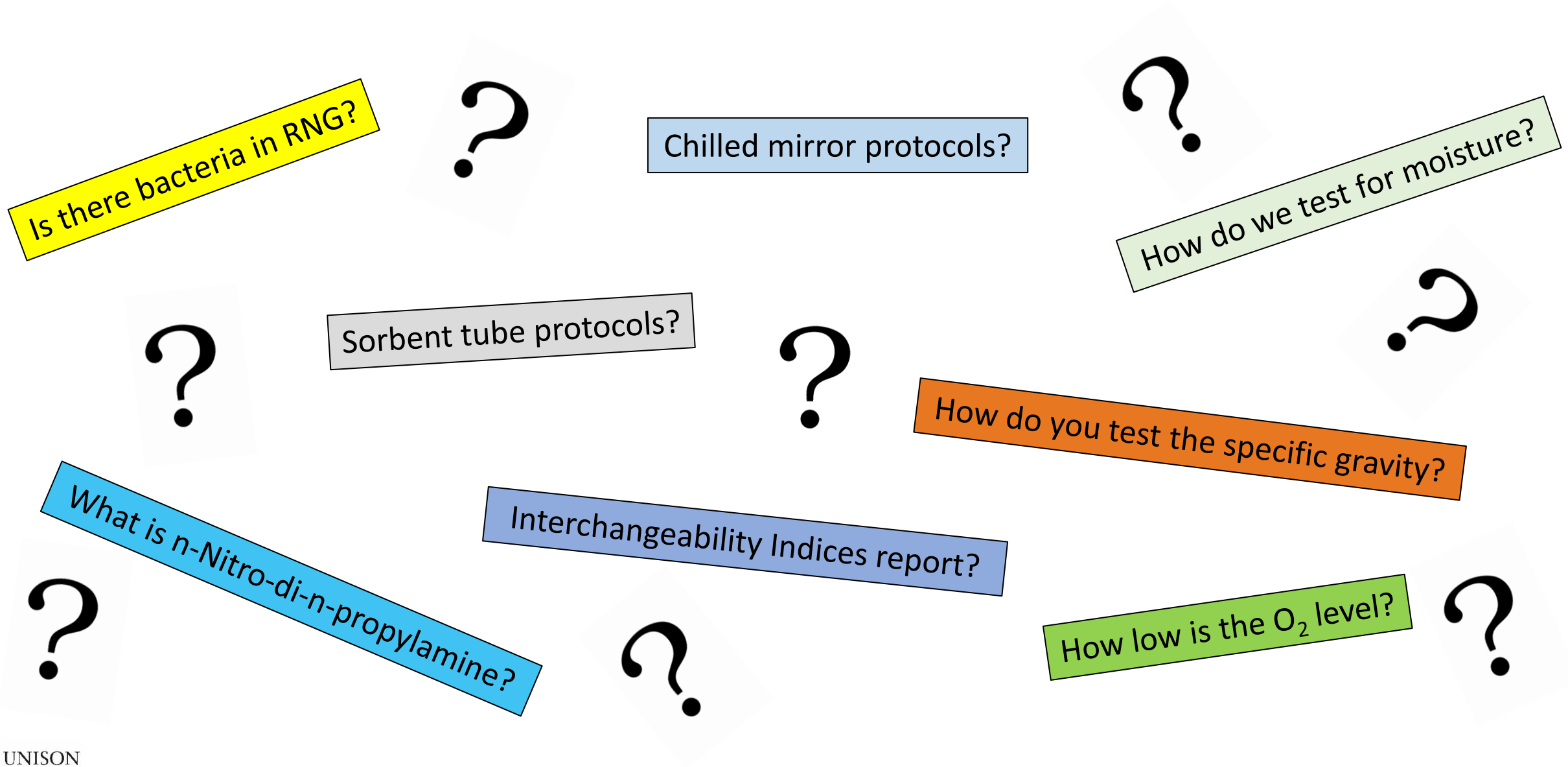
Biogas testing

Before starting a project, we recommend the following biogas tests be performed:

- **Major Components**
  - Methane
  - Nitrogen
  - Oxygen
  - Carbon dioxide
  - BTU calculation
- **Siloxanes**, by speciation
  - Up to 8 compounds common to biogas
- **Sulfur Compounds**, by speciation
  - Hydrogen sulfide
  - Mercaptans
  - Other sulfide compounds
- **Volatile Organic Compounds (VOCs)**, by speciation
  - Follows EPA TO-15 protocol

These compounds will also need to be tested on a regular basis to determine media change out intervals

EPA pathway and tariff testing



EPA pathway and tariff testing

EPA pathway testing will include testing the raw gas and product gas for all constituents listed on the tariff, using the specified protocols.

- Major gases
- Moisture
- Hydrocarbon dewpoint
- Specific gravity
- Wobbe Index
- Ammonia
- Mercury
- Bacteria
- Specific volatile organics
- GPA 2286

Biogas upgrading summary

BIOGAS

PIPELINE INJECTION

- Equipment to meet pipeline spec/tariff
- Interconnect fees for utility
- Fuel testing to pipeline requirements

VEHICLE FUELING

- Less stringent fuel specification
- Fueling infrastructure on site
- Vehicles committed to using fuel

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Thank You!

Visit with us in person!

RNG Works in Nashville, September 20-22, Booth 420

WEFTEC in New Orleans, October 10-12, Booth 2210

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