Technical Education and Analysis for Community Hauling and Anaerobic Digesters

(TEACH AD)

TEACH AD Webinar Series - October 18, 2022

Biogas Upgrading: Technology and Case Studies

UIC ENERGY RESOURCES CENTER

Technical Education and Analysis for Community Hauling and Anaerobic Digesters – TEACH AD

The goal of this program is to help communities and water resource recovery facilities in the Midwest region divert food waste from landfills by providing education and no-cost technical assistance to explore the increased adoption of anaerobic digestion and renewable energy biogas technologies.

- Educational Assistance
- Technical Assistance

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PROGRAM OFFERINGS

- Technical Assessments
- In-person Workshops
- On-line Webinars
- Project profiles

ELIGIBLE FACILITIES AND PROJECTS

- Water Resource Recovery Facilities
- Municipal Food Waste Digesters
- Community - Based Digesters
- Food Processing, On-Farm Digesters

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Webinar Speakers

Marcello Pibiri

Senior Research Engineer

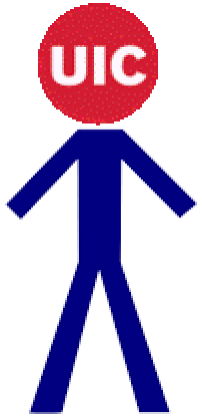
UIC Energy Resources Center

Eric Wilgenbusch

Sales & Application Engineer

Unison Solutions

Thanks to our sponsor!



EPA
United States
Environmental Protection
Agency

Q&A

Submit your questions to the host using the Q&A box in the upper right-hand corner

Presentations

A recording of today's webinar will be posted on the TEACH AD webpage and you will be emailed a link by early next week

Survey

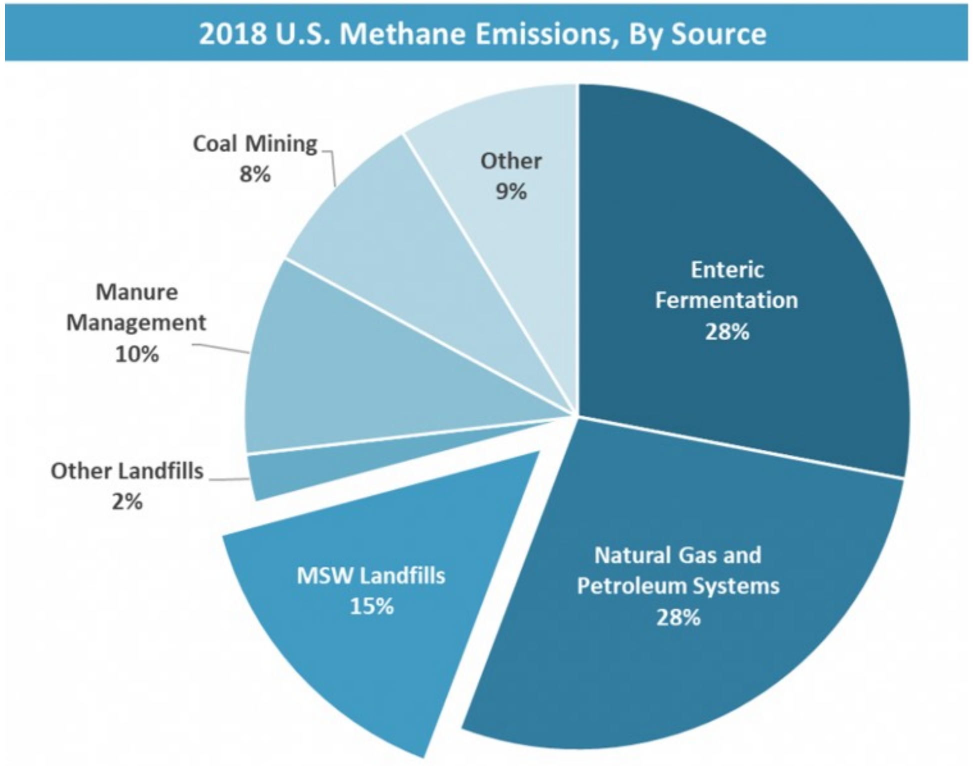
After the presentation you will receive a brief survey. We appreciate your feedback

Technical Issues

Contact Sam Rinaldi at: samr@uic.edu or 312-996-2554 for assistance

Importance of diverting food waste from landfills

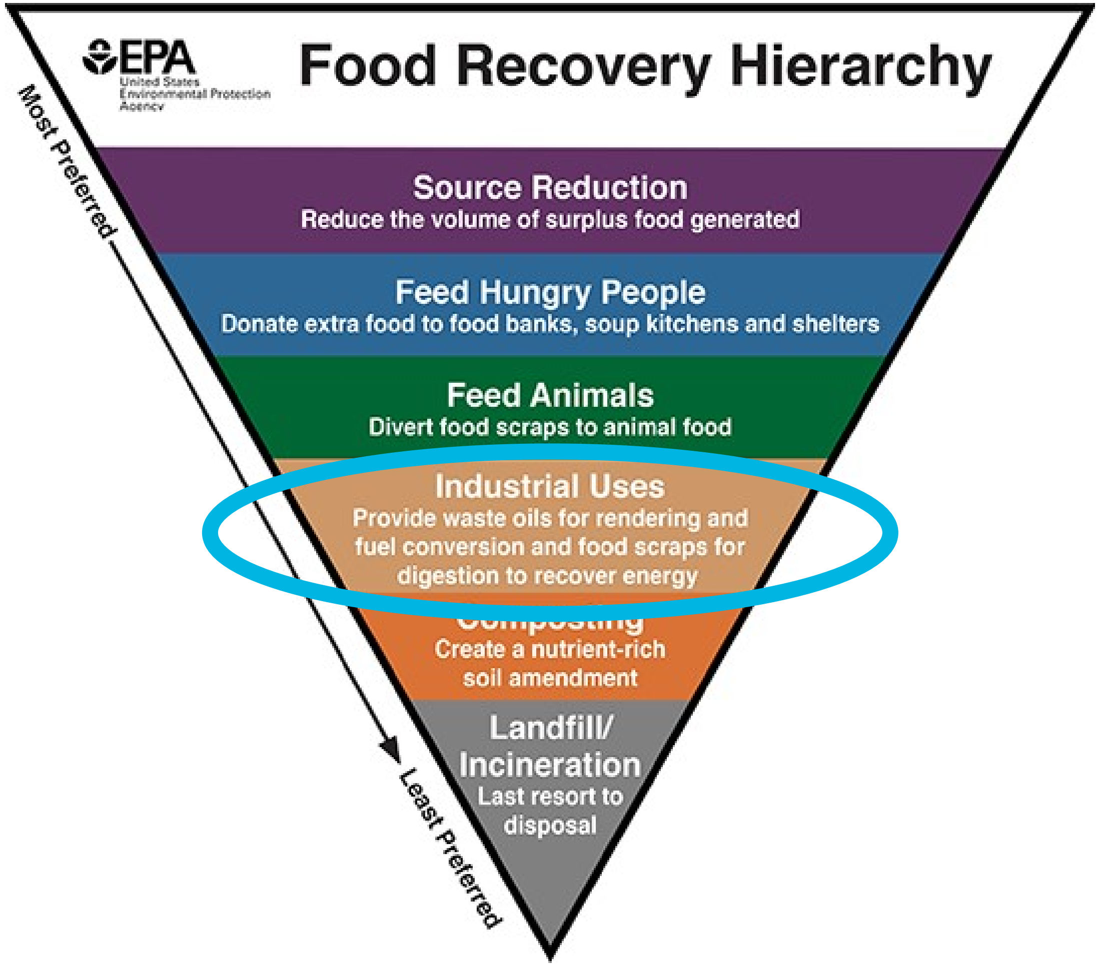
- Municipal solid waste (MSW) landfills are the third-largest source of human-related methane emissions in the United States
- By reducing the amount of food waste landfilled, we reduce methane emissions



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018.* U.S. EPA. 2020.

Importance of diverting food waste from landfills

- One-third of all food produced for human consumption worldwide is lost or wasted
- Source Reduction
- Feed People, Not Landfills
- Industrial Uses
  - **Anaerobic digestion**



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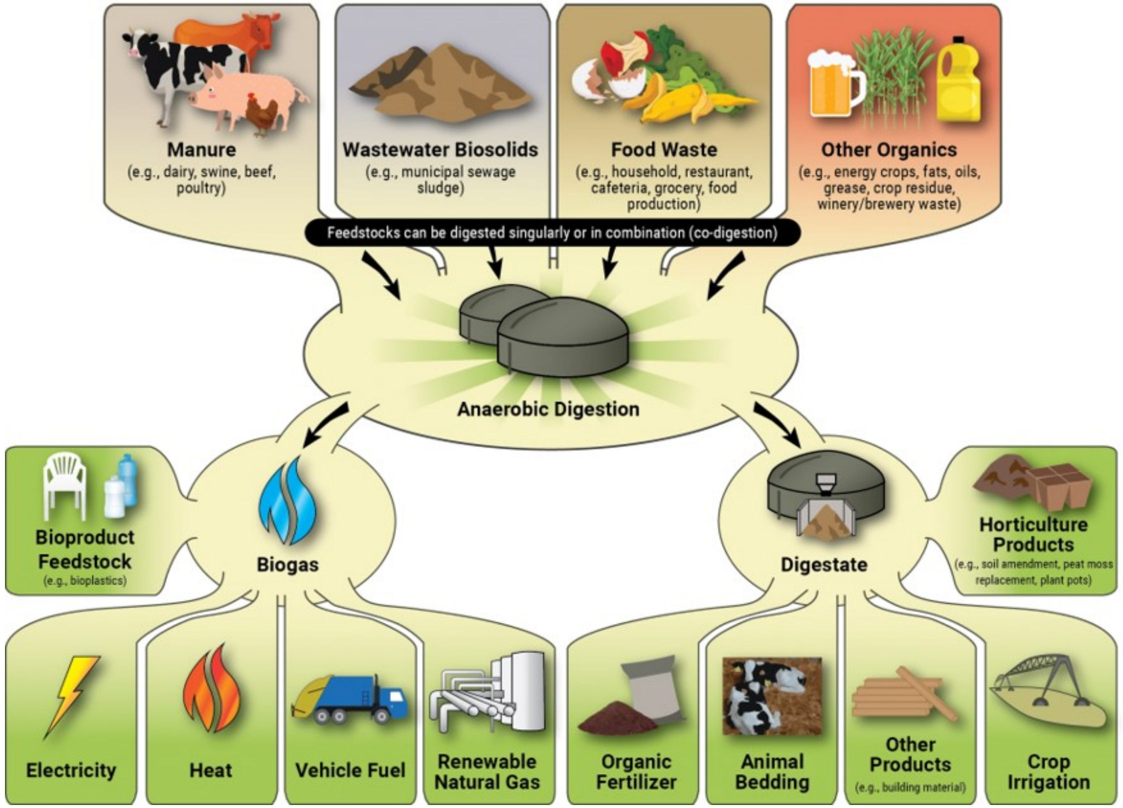
Overview of anaerobic digesters

- Anaerobic digestion is the natural process in which microorganisms break down organic materials in the absence of oxygen.
- Two valuable outputs
  - Biogas
  - Digestate

Sources: U.S. Environmental Protection Agency



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Biogas to Renewable Natural Gas

October 2022

Overview

- Company founded on January 1, 2000
- Employee owned: November 2020
- 50 Employees (9 Engineers)
- 65,000 ft^2 Manufacturing facility
- Over 330 systems sold worldwide

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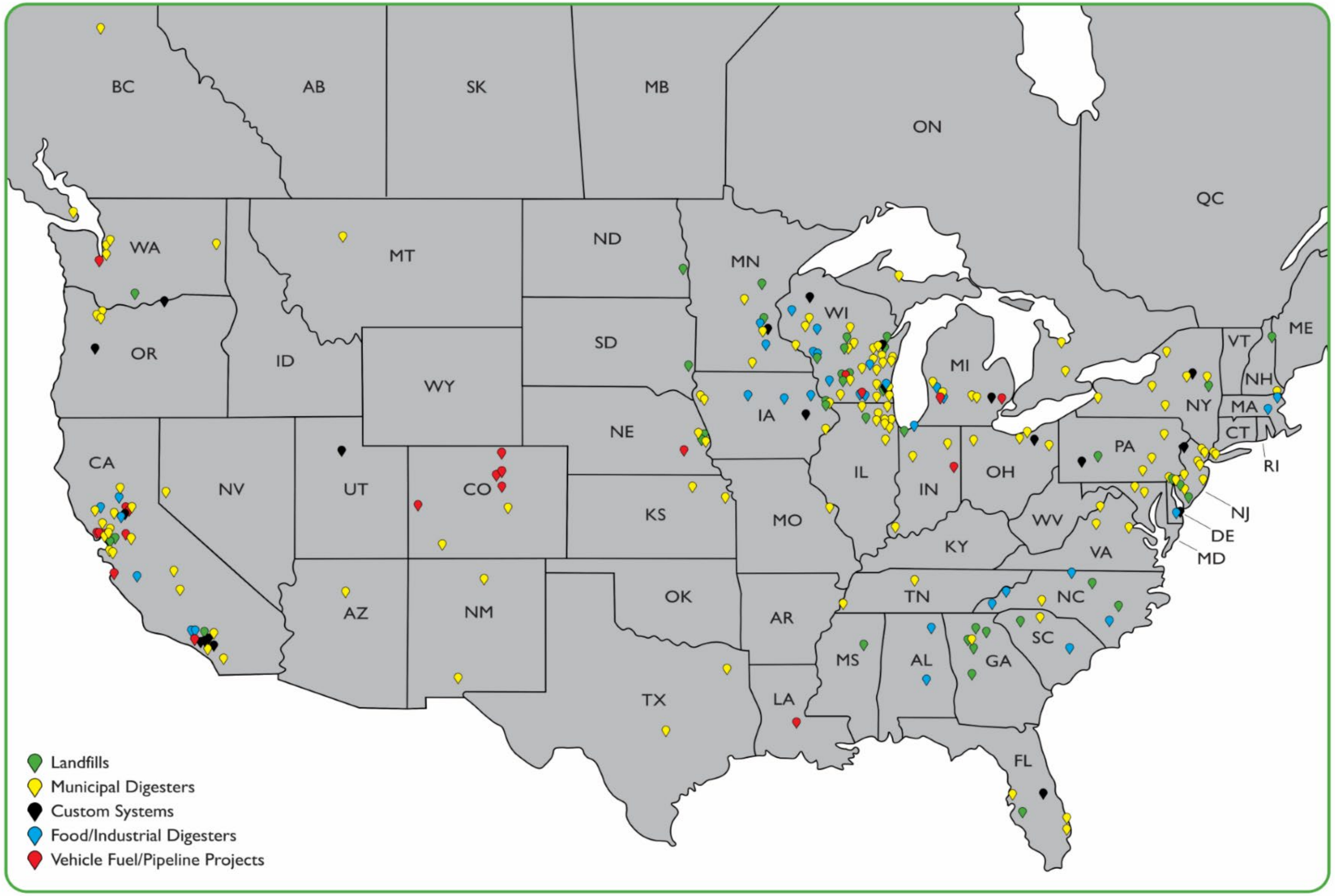
Installations



Unison Solutions, Inc.

- 340 + Installations
- 14 – Direct Vehicle
- 7 – Pipeline Injection

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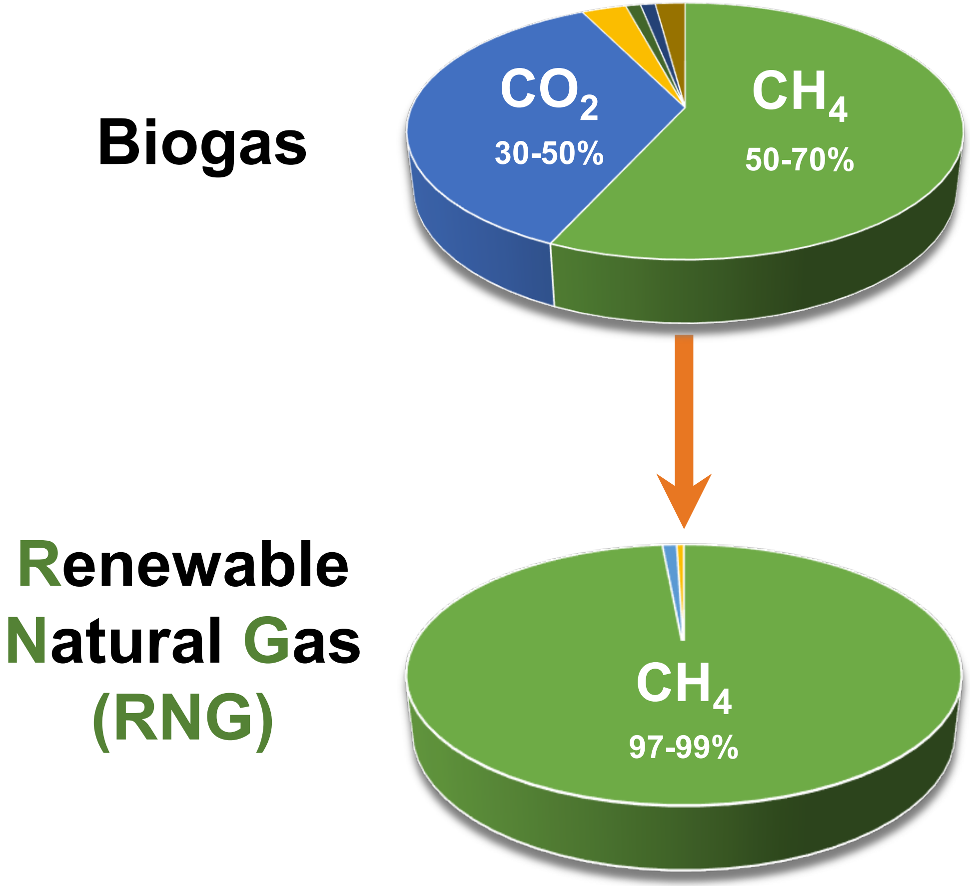
Biogas to RNG

CITY OF LINCOLN NEBRASKA



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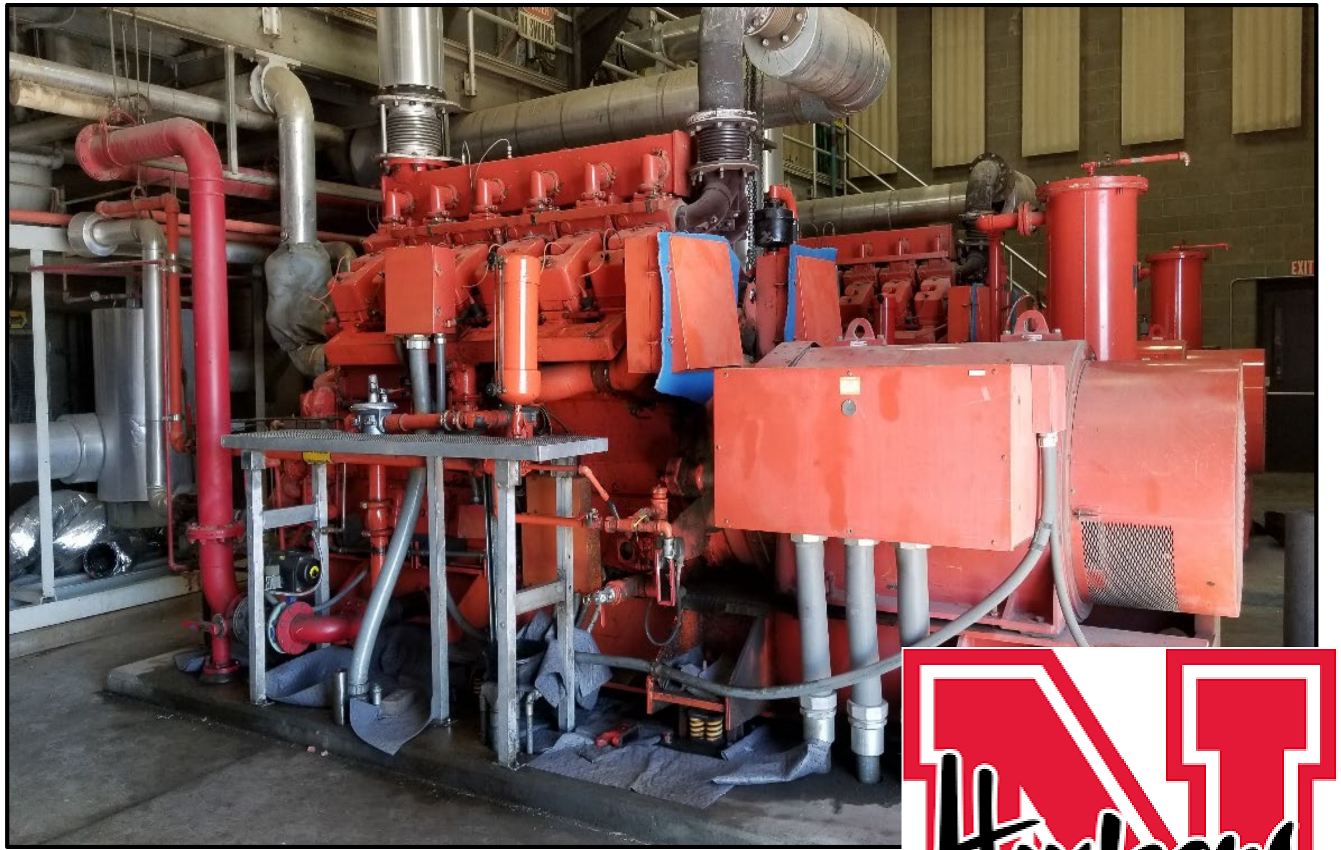
Theresa Street WRRF, Nebraska

CITY OF LINCOLN NEBRASKA

Original equipment – Installed in 1994

- 2 – Engine generators, 450 kW
- Digester heat from CHP
- Backup natural gas boiler
- Produced 40% of plants electricity
- High end of life maintenance costs



Evaluation included:

- Replacing the cogeneration system
- Providing biogas to University of Nebraska-Lincoln campus boilers
- Treating for vehicle fueling, bus fleet
- Treating for pipeline injection

Theresa Street WRRF, Nebraska

CITY OF LINCOLN NEBRASKA

- 27 MGD Plant
- 400 scfm, sized for 2033 gas production
- Municipal and industrial waste
- 3 – 1.1M gallon digesters
- Effluent from the plant is sent to UNL's Innovation Campus to heat and cool its building
- Energy Neutral/Net Zero

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CITY OF LINCOLN NEBRASKA

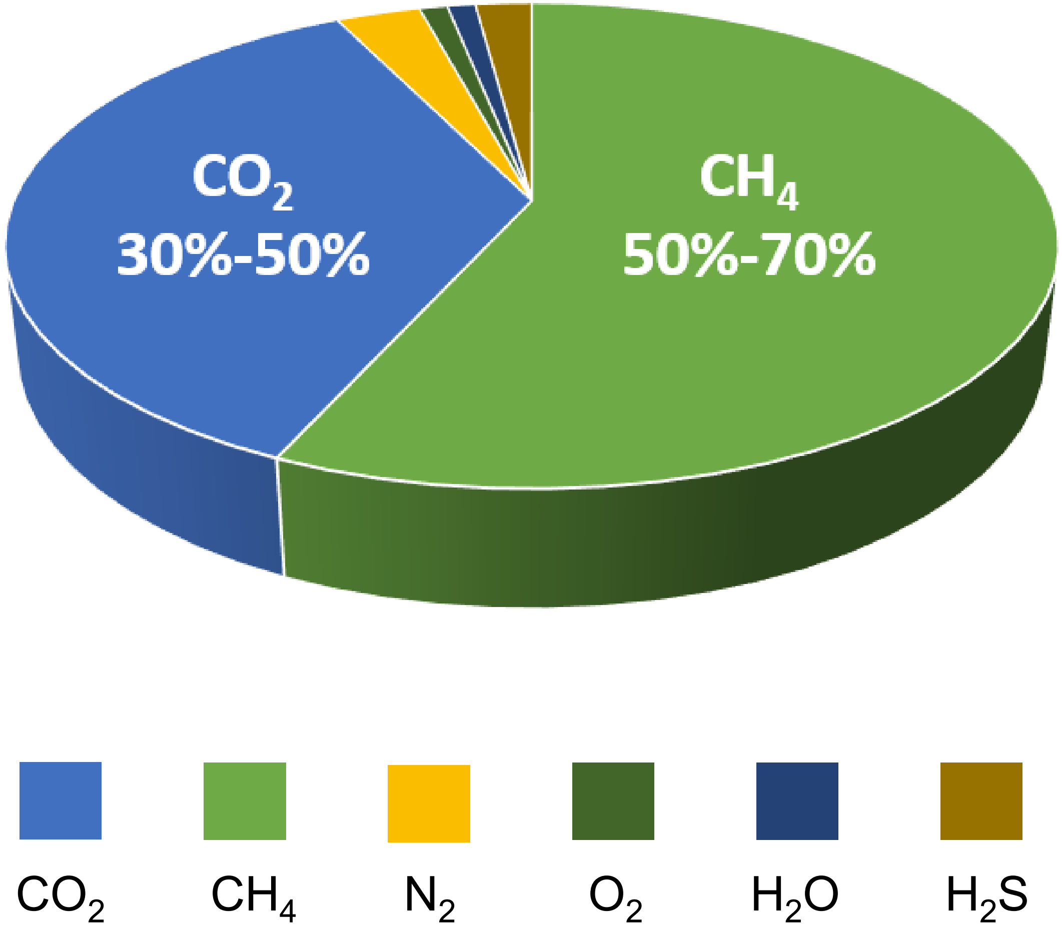
$8.6M project:

- BioCNG_Biogas to RNG System
- Installation of two new boilers
- Construction of new Biogas Treatment System installed within the existing Generator Building
- Construction of new Utility Gas Analyzer Building
- Installation of buried HDPE biogas piping from the digesters to the biogas treatment system, and then to the analyzer building
- Demolition of existing flare system, and installation of a new flare system
- Electrical modifications necessary for the new equipment

Know Your Biogas Quality

bi·o·gas, ˈbīōˌgas/, *noun,*
gaseous fuel, especially methane, produced by the fermentation of organic matter.

- Methane (CH_4)
- Carbon dioxide (CO_2)
- Nitrogen (N_2)
- Oxygen (O_2)
- Hydrogen sulfide (H_2S)
- Moisture
- Particulates
- Siloxanes
- Volatile organic compounds (VOCs)



Know Your Pipeline Requirements

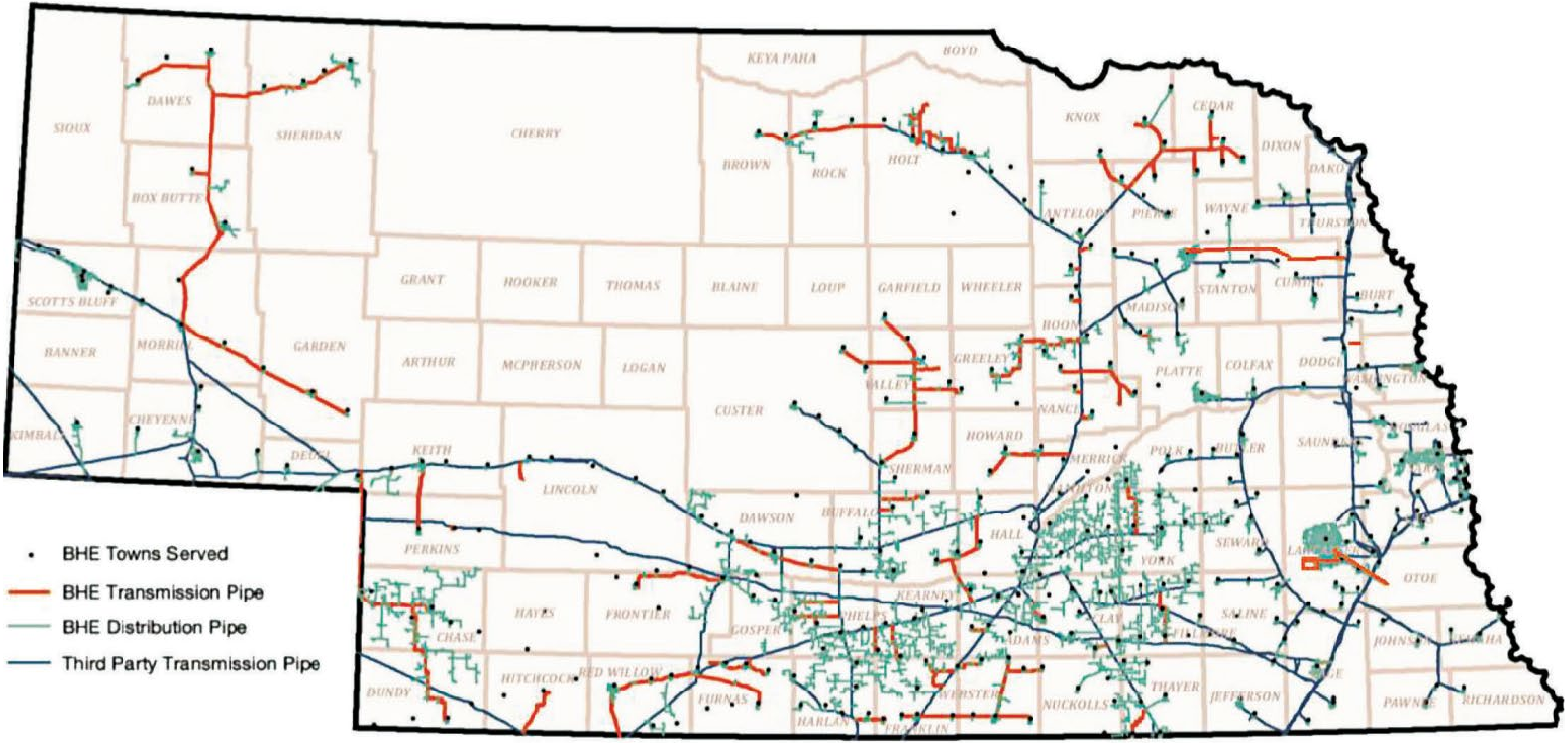
- **Gas quality requirements***
  - BTU Content
    - Methane
  - Carbon dioxide
  - Oxygen
  - Nitrogen
  - Hydrogen sulfide
  - Siloxanes and VOCs
  - Bacteria
  - Water content

- **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

*Requirements vary depending on pipeline tariff

Natural Gas Pipelines



Fuel Quality Specification

Biogas Constituents	Raw Biogas	Natural Gas Pipeline Fuel Quality*	Lincoln, NE_Pipeline spec (Lower limit)
Methane	50-80%		
Wobbe Index		1,400 BTU/ft^3 max	
Higher Heating Value (HHV)		950-990 BTU/ft^3	950 BTU/ft^3
Carbon Dioxide (CO_2) and Nitrogen (N_2)	20-50%	<2%	2%
Oxygen (O_2)	0-1%	6 ppm to 0.2%	0.2%
Hydrogen Sulfide (H_2S)	<1,000 ppm	≤4 ppm	0.25 grains/Ccf
Water Content		3-7#/MMcf	6#/MMcf
Siloxanes and Volatile Organic Compounds	<2,000 ppm	ND to 1 ppm	1 ppm Siloxanes/50 ppm Nonmethane VOC's
Pressure	0-2 psig	50 to 900+ psig	

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*Varies depending on the utility

Steps to a Successful RNG Project

Identify pipeline or direct vehicle fueling → Determine inlet gas quality → Confirm final RNG quality requirements → Determine equipment required

Good working relationship with your engineering, manufacturing and supply partners

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Blower | Hydrogen Sulfide Removal | Moisture/Siloxanes/Bacteria/CO_2 Removal

Heat Exchanger/Glycol Chiller | Gas Monitoring | Flare | Pipeline Injection

Hydrogen Sulfide (H_2S)

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- 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. Proteins in the waste encourage H_2S production
- 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

1 - 10' diameter x 12' straight side vessel

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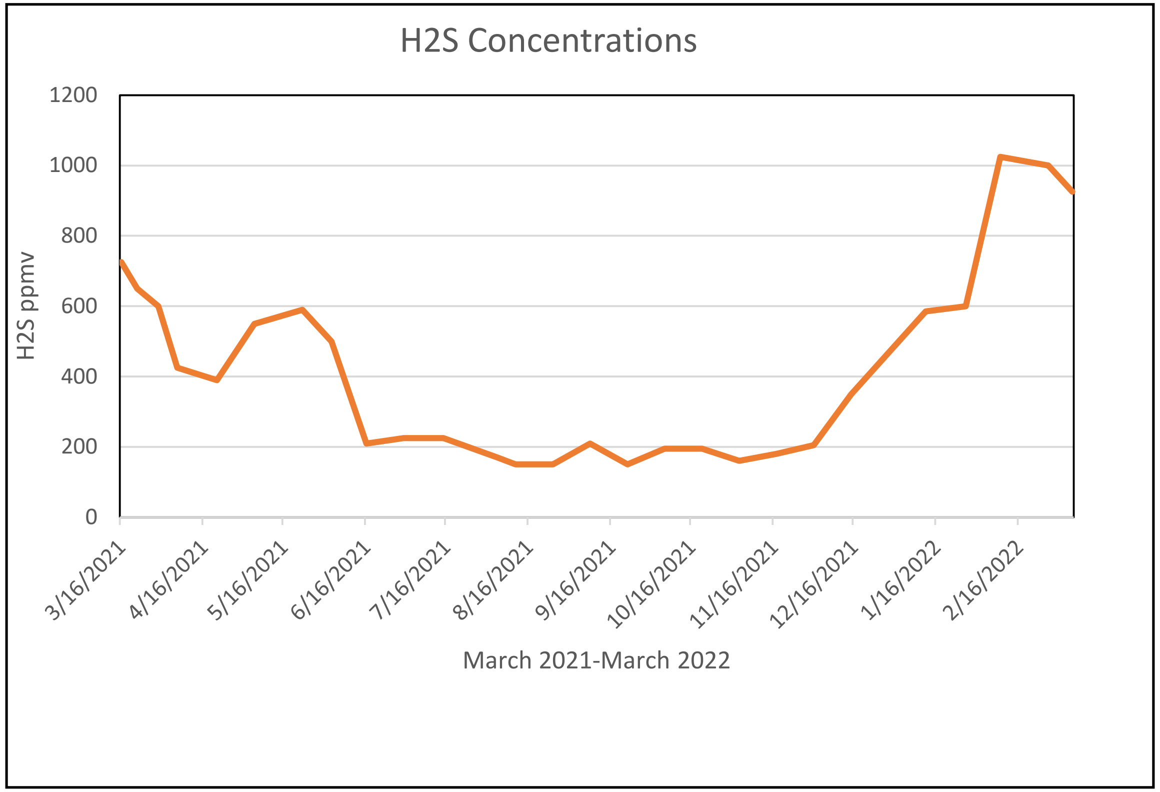
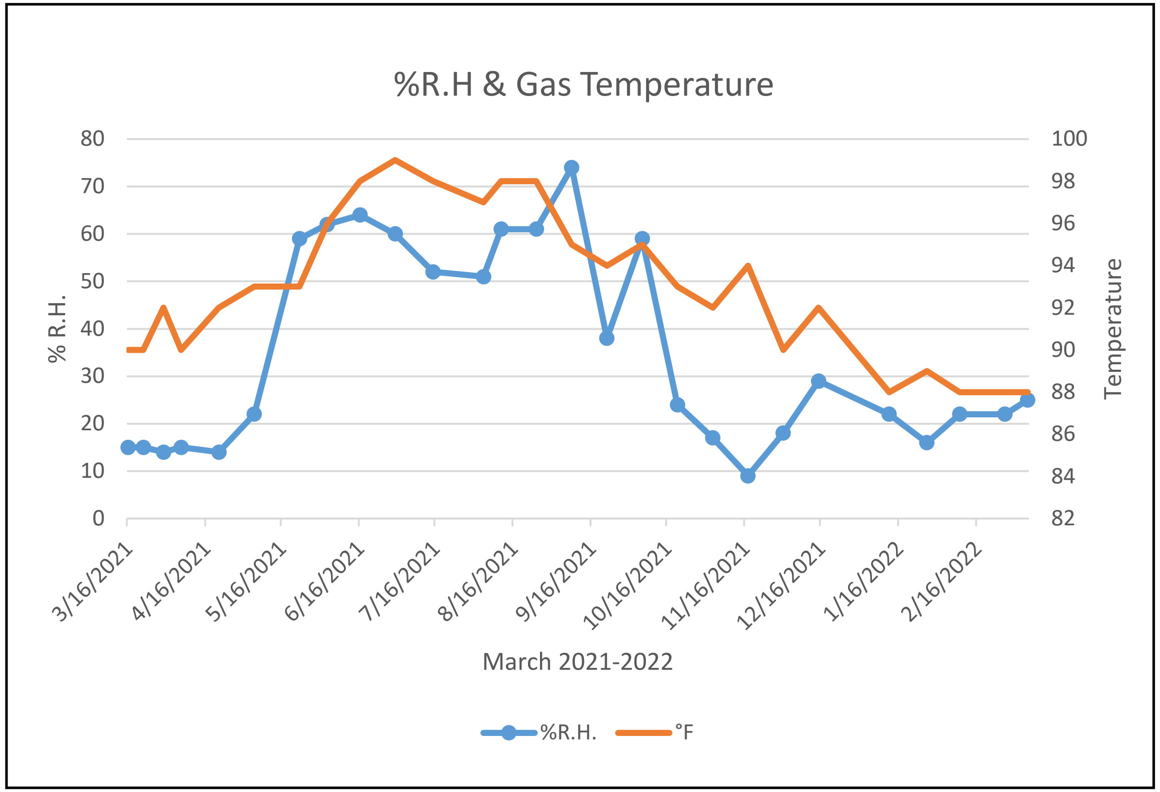
H_2S and moisture: Raw gas testing





Inlet H2S Concentration: 150 – 1025 ppmv

% R.H. Range: 15-74%
Temperature: 88-99°F

Design parameters: 600 ppmv H2S______ 100% R.H.______ 85-105°F

H_2S Removal Media Costs: Media, Removal, Disposal

Which media is best for my system?

- Filtration media
  - Wood-based
  - Clay-based
  - Ferric hydroxide
  - Carbon
- Reaction Process
  - Ferric oxide (Fe_2O_3) coated
    - Wood or clay substrate
  - Ferric hydroxide, FeO(OH)

GOAL: to produce optimum media changeout intervals

- Each media type has specific requirements for inlet gas quality
- Capacity for H_2S removal varies
- Removal and disposal costs

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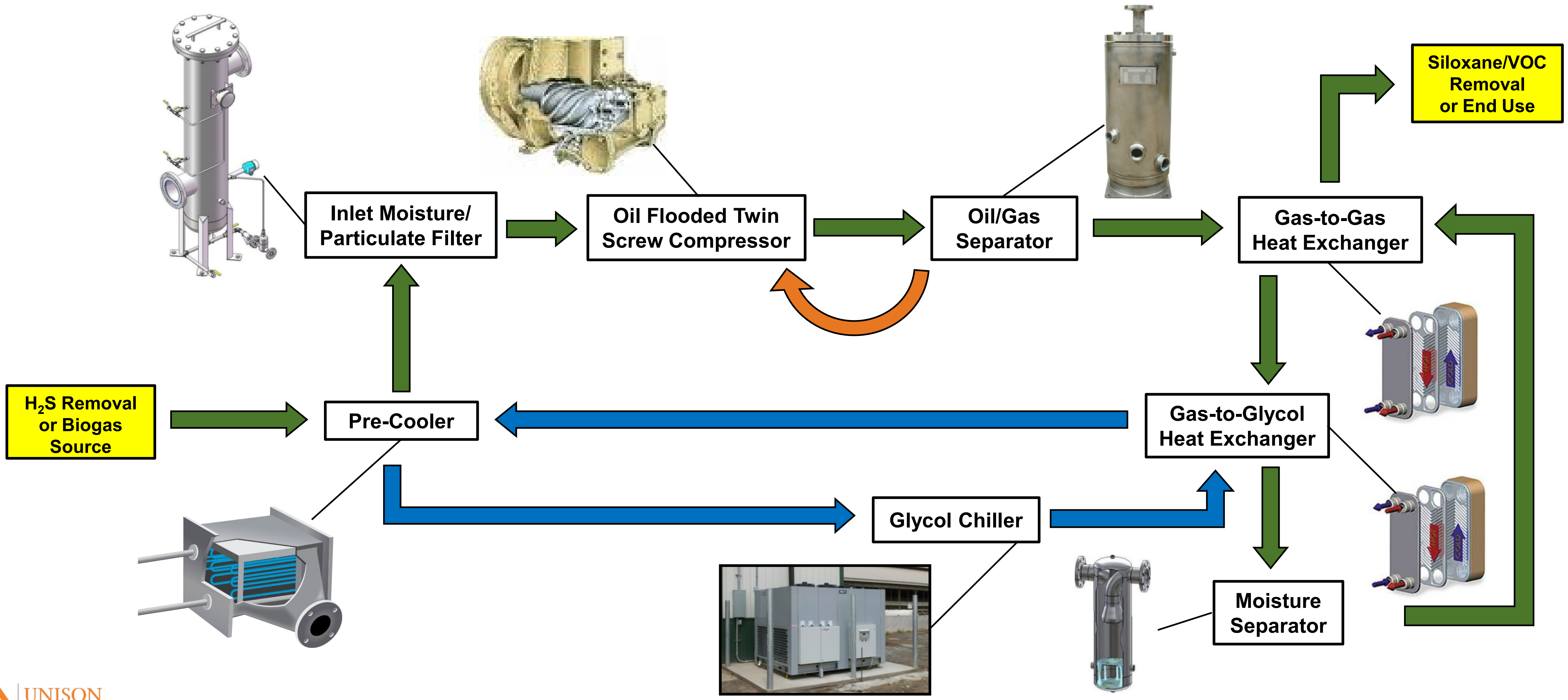
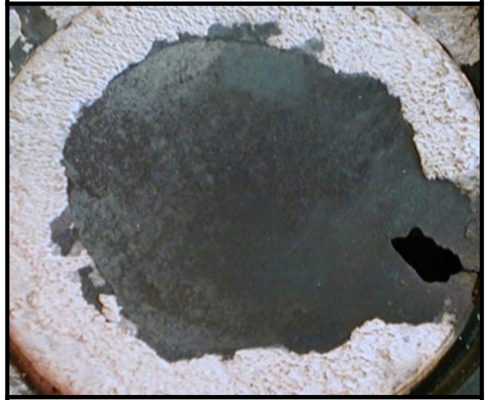
Compression & Moisture Removal



How Siloxanes Affect 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

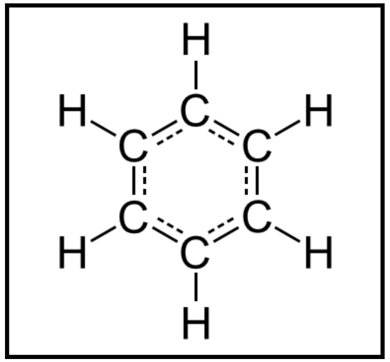

Extruded Pellets


4 x 8 Mesh Chips

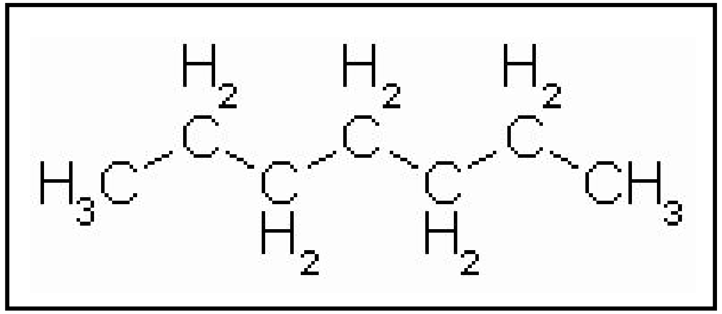

Silica Gel – Spheres


Silica Gel – Irregular Shapes

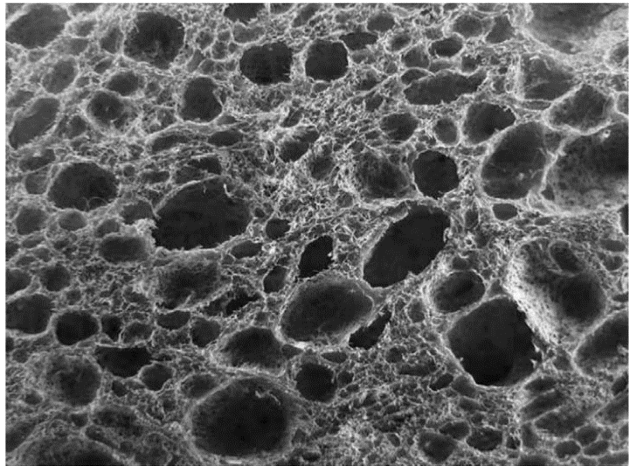
Suitability Factors for Media Systems: Siloxanes, Hydrocarbons, and VOCs

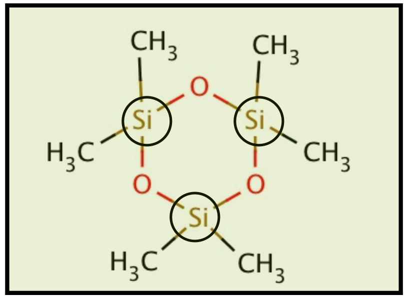


Benzene (C_6H_6)

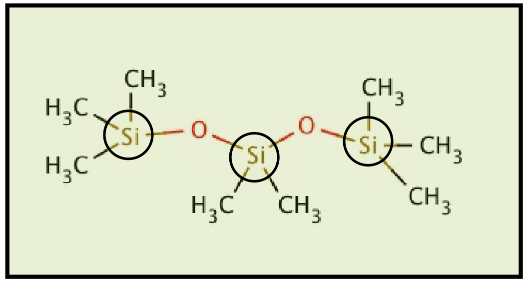


Heptane (C_7H_{16})

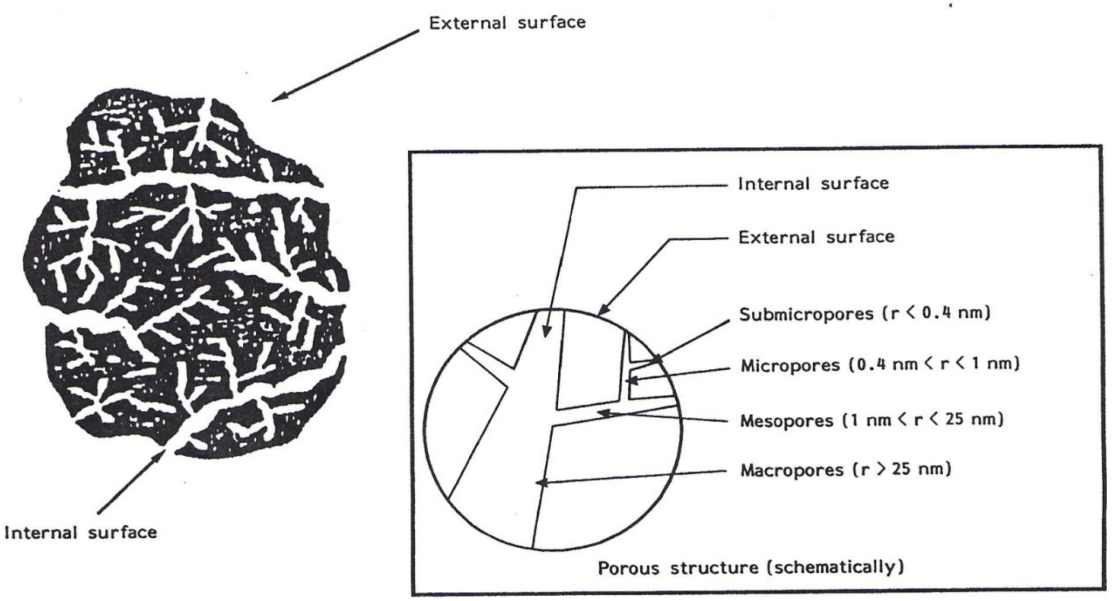




Hexamethylcyclotrisiloxane (D3)



Octamethyltrisiloxane (L3)



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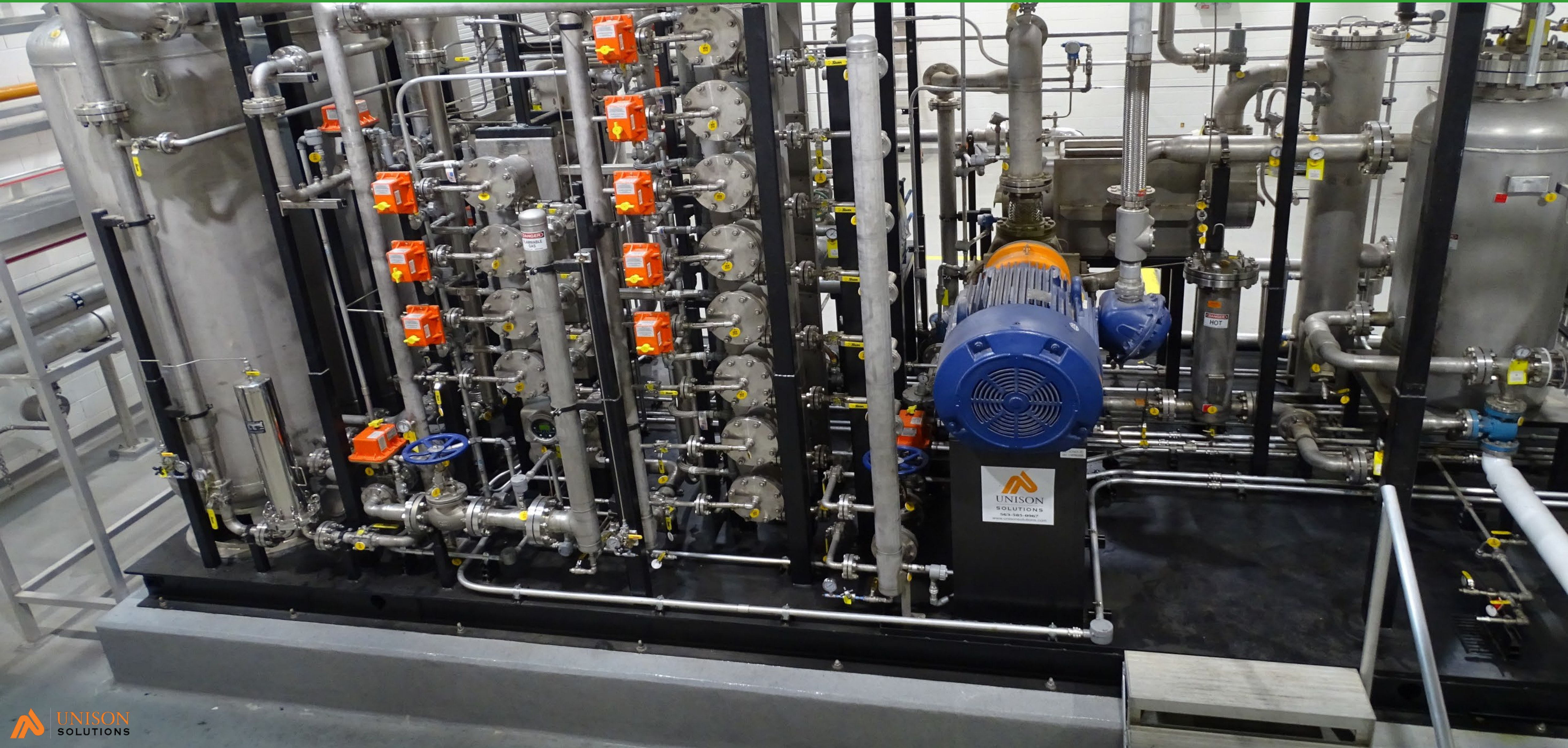

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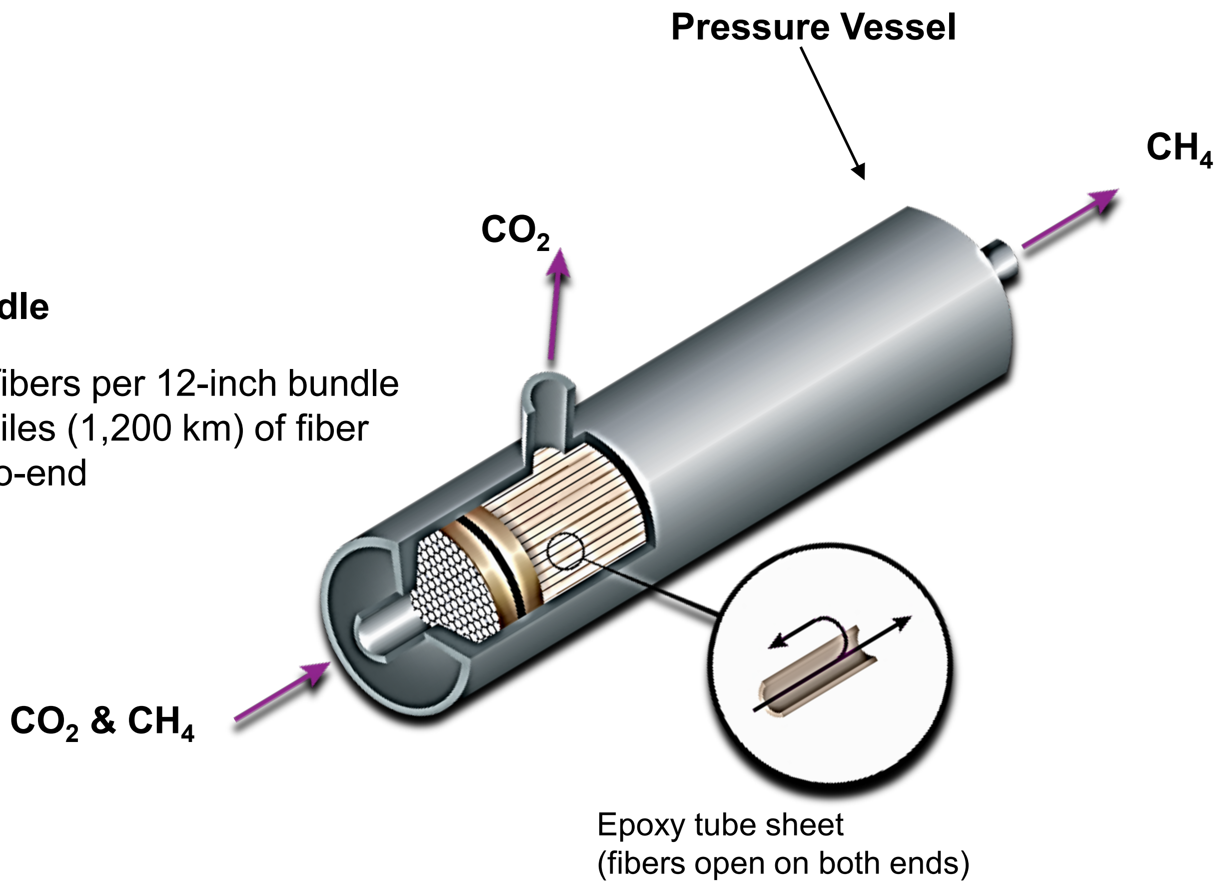
Membrane Separation Schematic_CO_2 removal

Hollow Fiber Bundle

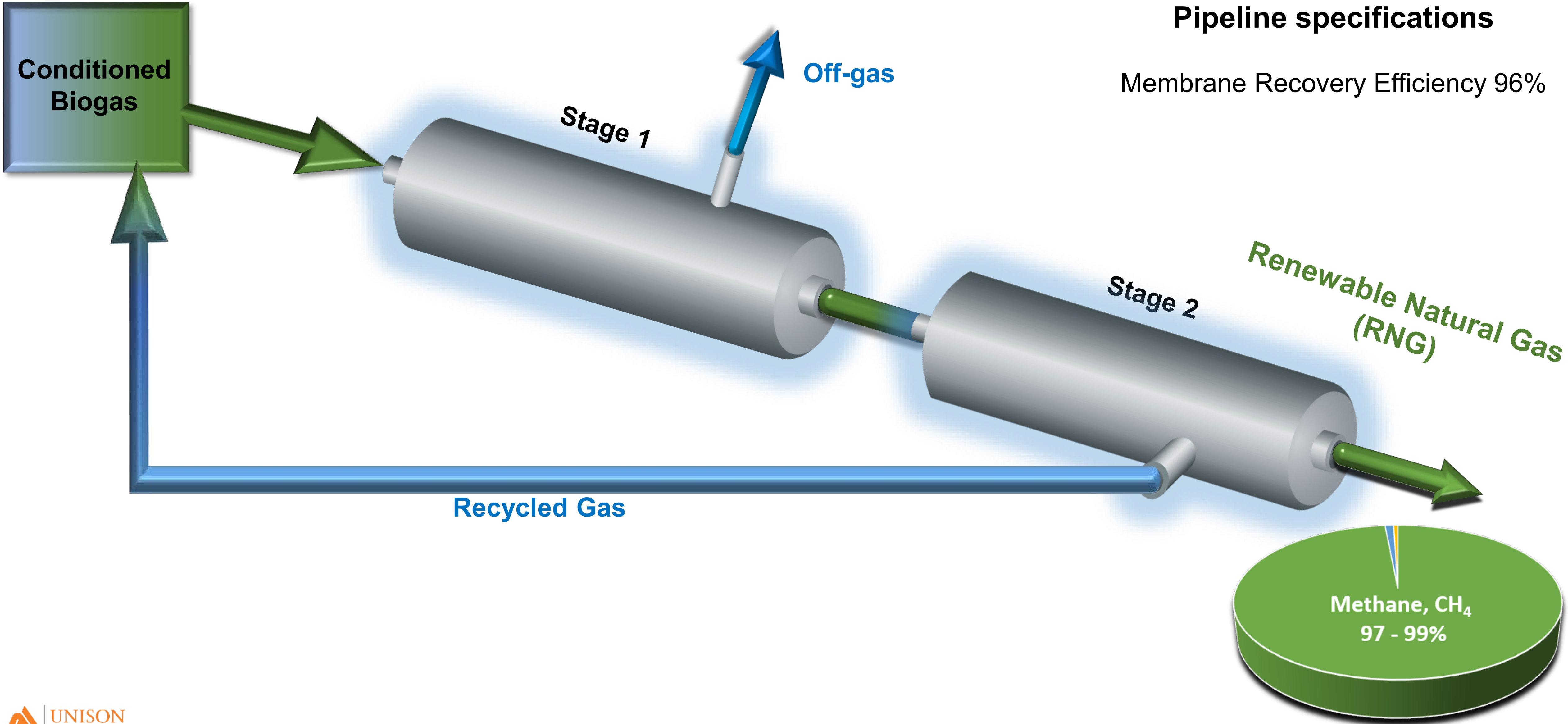
- 0.5–1.2 million fibers per 12-inch bundle
- Contains 750 miles (1,200 km) of fiber when laid end-to-end



Dual/Two-Stage Membrane Process

Pipeline specifications

Membrane Recovery Efficiency 96%



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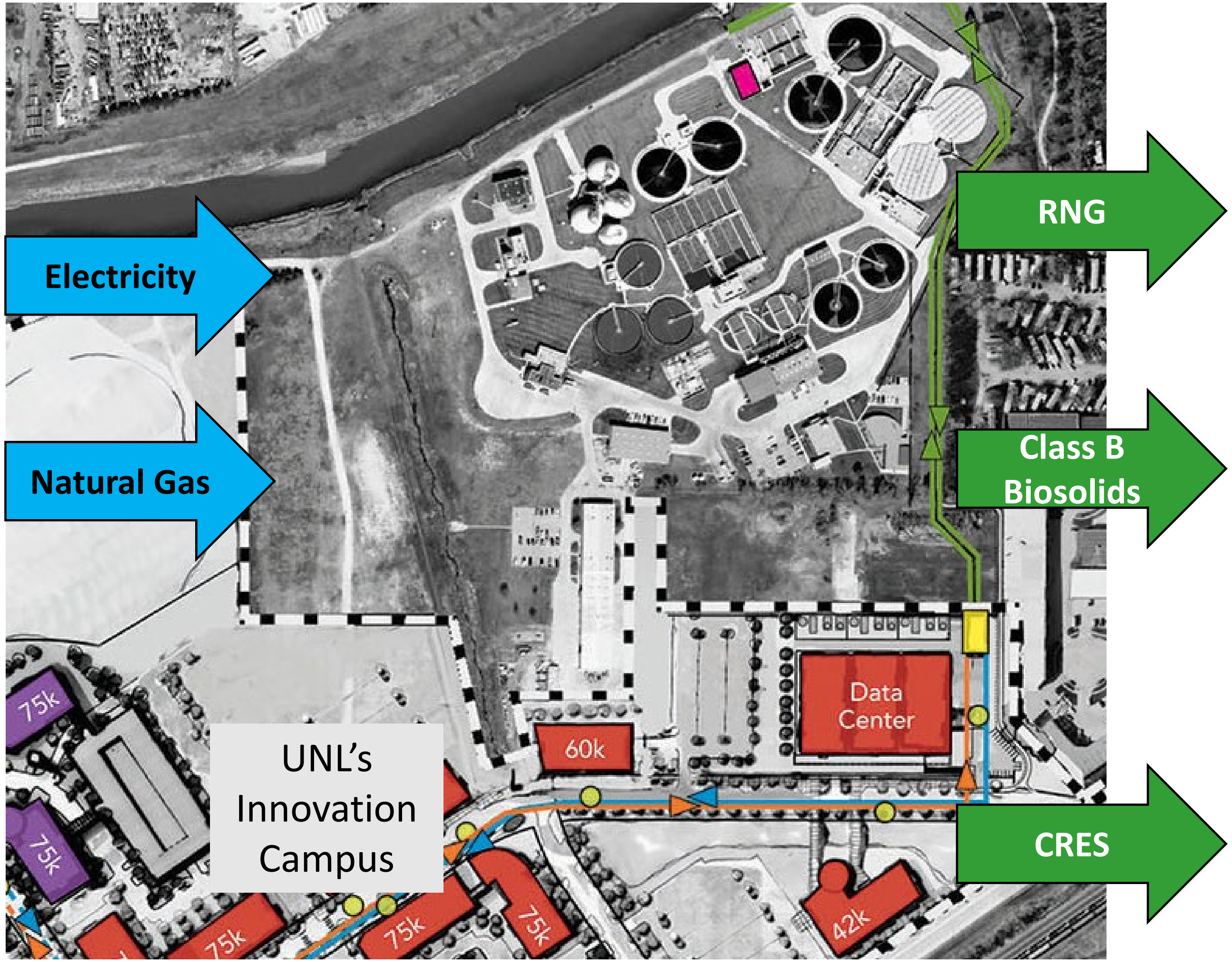
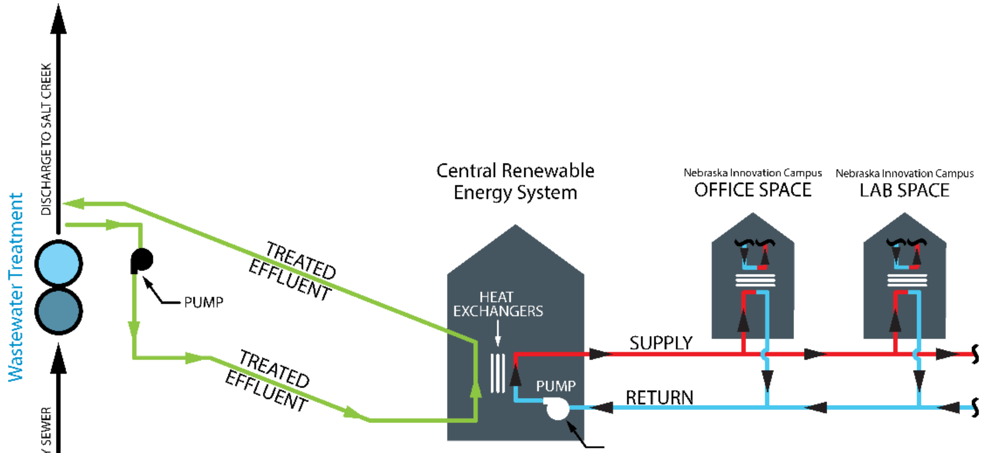
Energy Neutral



Revenue from D5 RINs and LCFS: $2M/year
(D3 RINs are still being pursued with EPA)

Continuation of an existing program



Centralized Renewable Energy System

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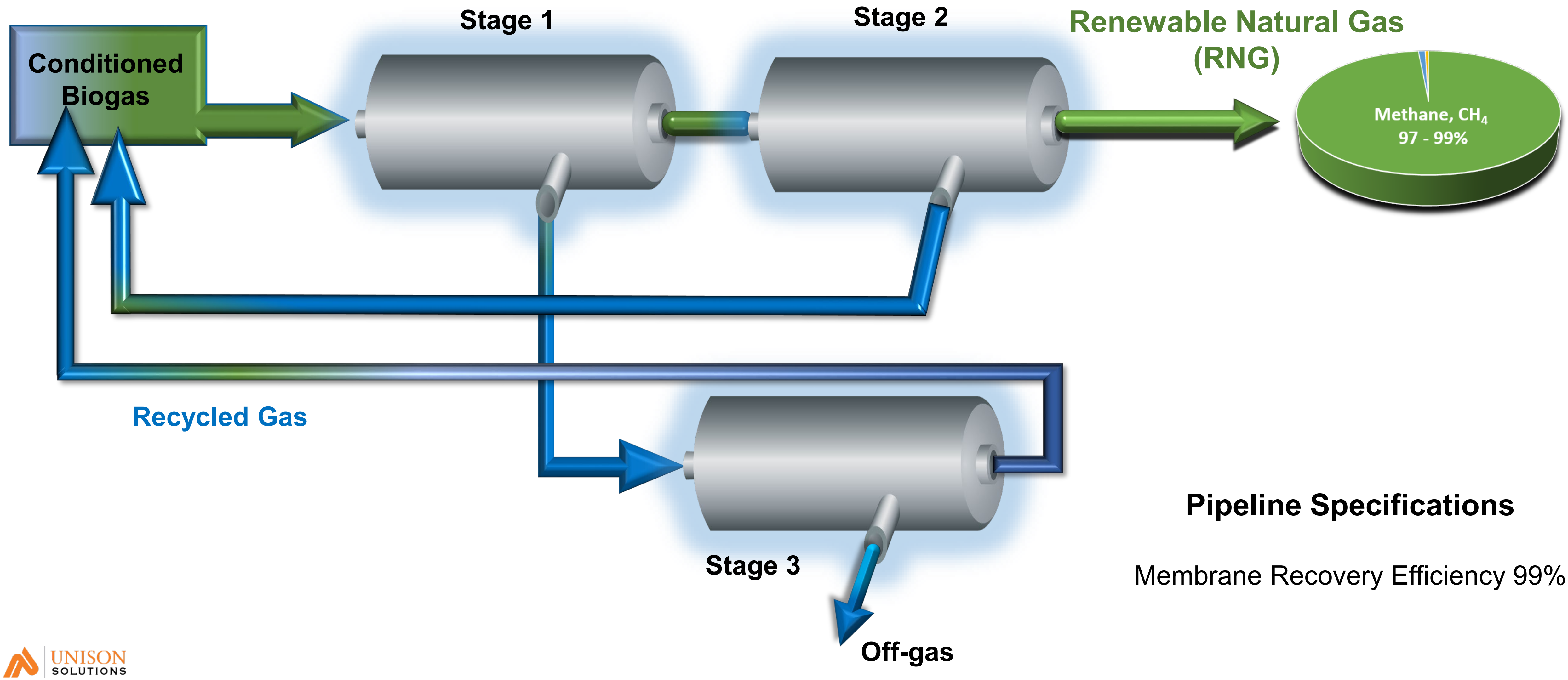
Three-Stage Membrane Process



Pipeline Specifications

Membrane Recovery Efficiency 99%

Grand Rapids WRRC, Michigan

CITY OF GRAND RAPIDS

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

Moisture, Bacteria, CO_2 ,and Siloxane Removal

3 Pass system for higher methane recovery

- Helps meet emission requirements
- Increases CI (carbon intensity) score

H_2S Removal

PSB Industries_Deox System

Pipeline Injection – DTE Energy Pipeline

Thank You!

Please contact us directly to discuss your biogas upgrading or custom manufacturing requirements.

Eric.Wilgenbusch@unisonsolutions.com

sales@unisonsolutions.com

www.unisonsolutions.com

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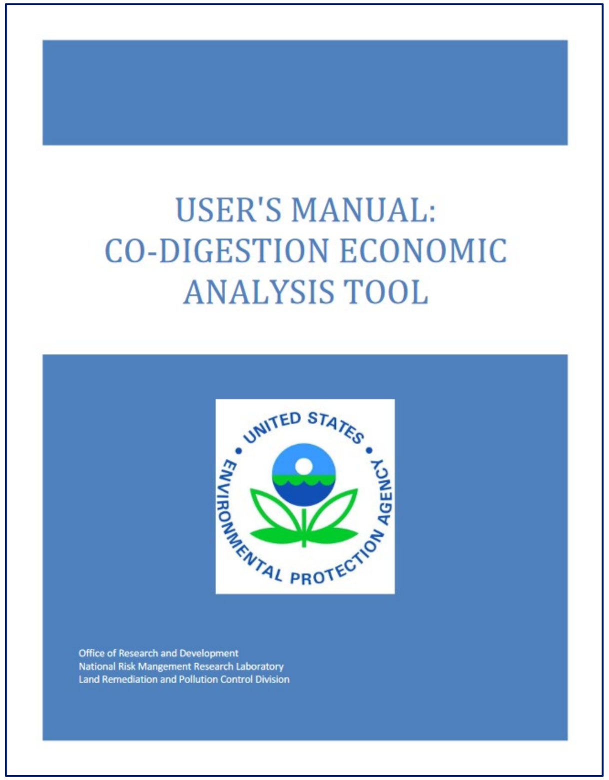
TEACH AD – Educational Assistance

- In person workshops (2)
  - Onsite events
  - Tour of the site
  - **April 2022: Kishwaukee Water Reclamation District for**
  - **Visit erc.uic.edu/bioenergy/teachad/in-person-workshops/**
- Webinars (10)
  - Will cover different aspects of an anaerobic digestion project
  - **Join us again in November for our 8th Webinar**
  - **Visit erc.uic.edu/bioenergy/teachad/teach-ad-webinars/**
- Project profiles (8)
  - Will highlight successful AD projects
  - **Project profiles covering UW Oshkosh, Urbana Champaign Sanitary District, Kishwaukee WRD**
  - **Visit https://erc.uic.edu/bioenergy/teachad/project-profiles/**

TEACH AD – Technical Assistance

- Anaerobic Digestion Technical Assessments
  - Tailored technical assistance to each client
  - Initial economic and physical feasibility assessment for (co)digestion of organic wastes
  - Assess opportunity for using U.S. EPA's Co-Digestion Economic Analysis Tool (CoEAT)
  - Report presentation and follow up with next steps

INITIAL DATA REQUEST → MEETING WITH THE SITE → REPORT PRESENTATION → FOLLOW UP


USER'S MANUAL:
CO-DIGESTION ECONOMIC
ANALYSIS TOOL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Office of Research and Development
National Risk Mangement Research Laboratory
Land Remediation and Pollution Control Division

Visit erc.uic.edu/bioenergy/teachad/technical-assessments/

TEACH AD – CoEat Analysis

	Current	Future A	Future B	Future C	Future D	
Biogas Produced (cf/yr)	13,862,185	26,169,378	26,169,378	26,169,378	26,169,378	37,978.59 cfd
Total Biogas Heating Energy (MBTU/yr)	6,307	11,906	7,620	11,906	0	71,696.92 cfd
Total Energy Needed for Heating (MBTU/yr)	3,853	4,421	4,421	4,421	4,421	49.7895311 cfm
Max Capacity of Digester (gal)	1,115,000	1,115,000	1,115,000	1,115,000	1,115,000	
Feedstock Feed Rate (gal/day)	13,215	16,907	16,907	16,907	16,907	
% Solids of Feedstock Fed to Digester (%)	3.8%	5.2%	5.2%	5.2%	5.2%	
Percent Volatile Solids Reduction (%)	57%	57%	57%	57%	57%	
Actual Hyraulic Retention Time (days)	67.8	53.0	53.0	53.0	53.0	
Target Hydraulic Retention Time (days)	15.0	15.0	15.0	15.0	15.0	
Available Capacity (Gal/day)	46,519	42,827	42,827	42,827	42,827	
Additional Volume Needed to Treat Feedstock (gal)	0	0	0	0	0	
Mass of Biosolids (Tons/yr)	450	704	704	704	704	
Biosolids Cost ($/yr)	($58,608.55)	($88,792.80)	($88,792.80)	($88,792.80)	($88,792.80)	
Biosolids Revenue ($/yr)	$0.00	$0.00	$0.00	$0.00	$0.00	
Tipping Fees ($/yr)	$0.00	$127,622.25	$127,622.25	$127,622.25	$127,622.25	
Avoided Natural Gas Costs ($/yr)	$33,995	$66,038	$28,222	$0	($39,006)	
Avoided Electricity Costs ($/yr)	$0	$0	$129,613	$0	$0	
Avoided Vehicle Fuel ($/yr)	$0	$0	$0	$305,983	$486,629	
Annualized Cost of Plant Upgrades ($/yr)	$0	($36,833)	($113,230)	($134,973)	($149,467)	
Annual Operations and Maintenance ($/yr)	($5,000)	($5,000)	($67,566)	($87,632)	($121,673)	
Net Annualized Value ($/yr)	($29,614)	$63,035	$15,869	$122,208	$215,312	
Simple Payback (yr)	NA	NA	7.7	5.8	4.9	

Return to Inputs/ GUI

Restore Default Formulas

Print Input Values

TEACH AD – CoEat Analysis

Current: Use biogas to heat digester and incomming feedstock. Value is given to excess heat. If digester heating demand is not met, expense for natural gas will incur.

Future A: Use biogas to heat digester and incomming feedstock. Value is given to excess heat. If digester heating demand is not met, expense for natural gas will incur. This scenario is not achievable as the plant does not have enough heat demand.

Future B: Use biogas in CHP to heat digester and incomming feedstock and generate electricity. Value is given to the electricity generated and excess heat. If digester heating demand is not met, expense for natural gas will incur.

Future C: Use biogas to heat the digester and convert the rest to vehicle fuel. If digester heating demand is not met, no biogas will be available for CNG and an expense for natural gas will incur.

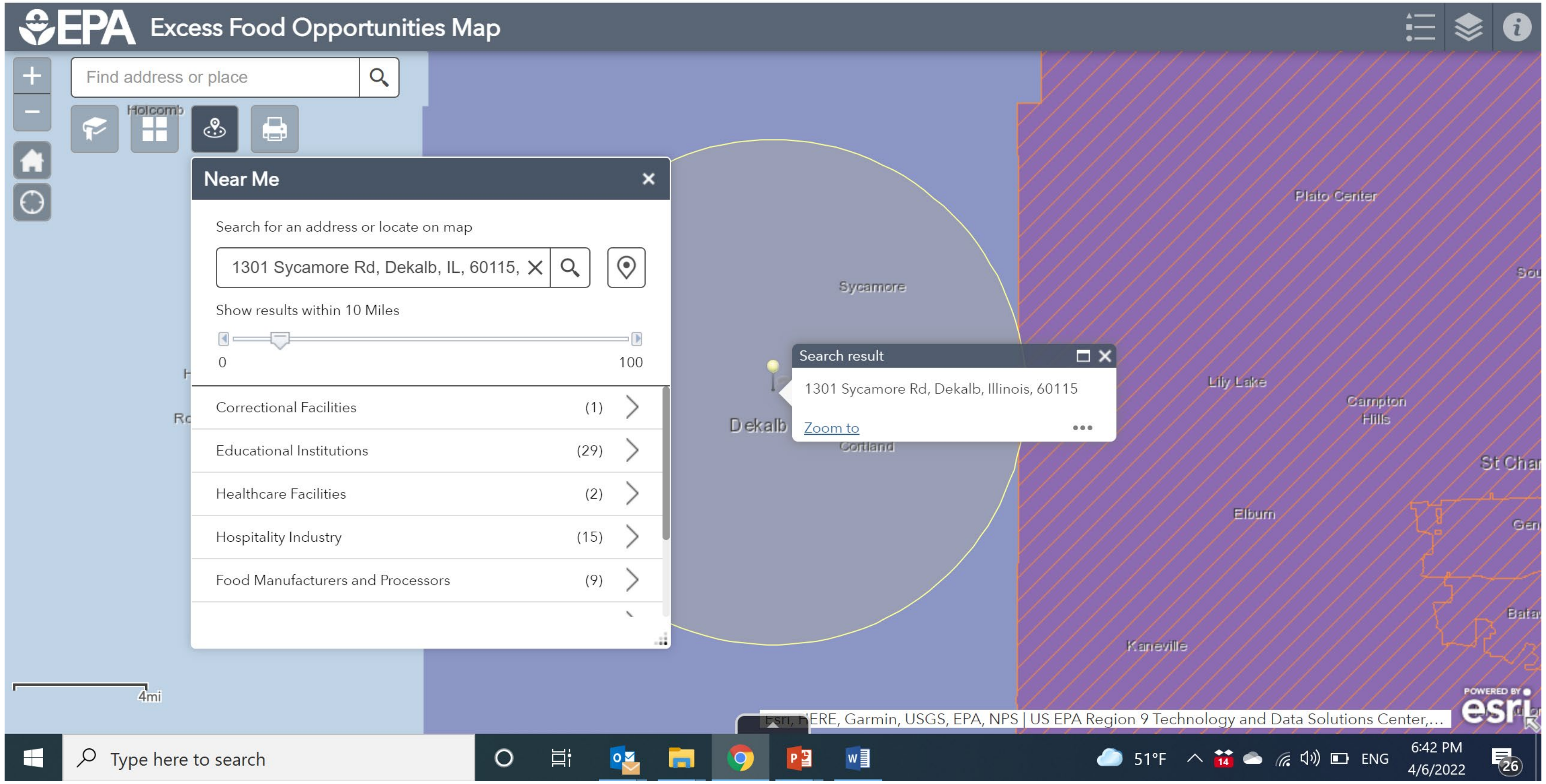
Future D: All biogas is converted into vehicle fuel. Cost of natural gas to meet the heating demand of the digester and incomming feedstock will incur.

For a detailed review of the calculations and assumptions, please observe the "4. Biogas Use" worksheet.

Analysis

Percent increase in heating demand =	14.7%	
Percent increase in biogas production =	88.8%	
Percent increase in biosolids =	56.3%	
Additional volume needed to treat feedstock =	None	[gal]
Size of CHP =	149	kW

TEACH AD – EPA Food Waste Map



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TEACH AD - Contact

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Questions & Answers

Marcello Pibiri

Senior Research Engineer

UIC Energy Resources Center

Eric Wilgenbusch

Sales & Application Engineer

Unison Solutions

UIC ENERGY RESOURCES CENTER

TEACH AD Webinar Series

Join us again in **November** for our **8th Webinar**!

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Thank You

Please fill out our survey.

A recording of today's webinar will be posted, and you will be emailed a link by early next week.

Thank You

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