Biogas Upgrading: Renewable Natural Gas (RNG)

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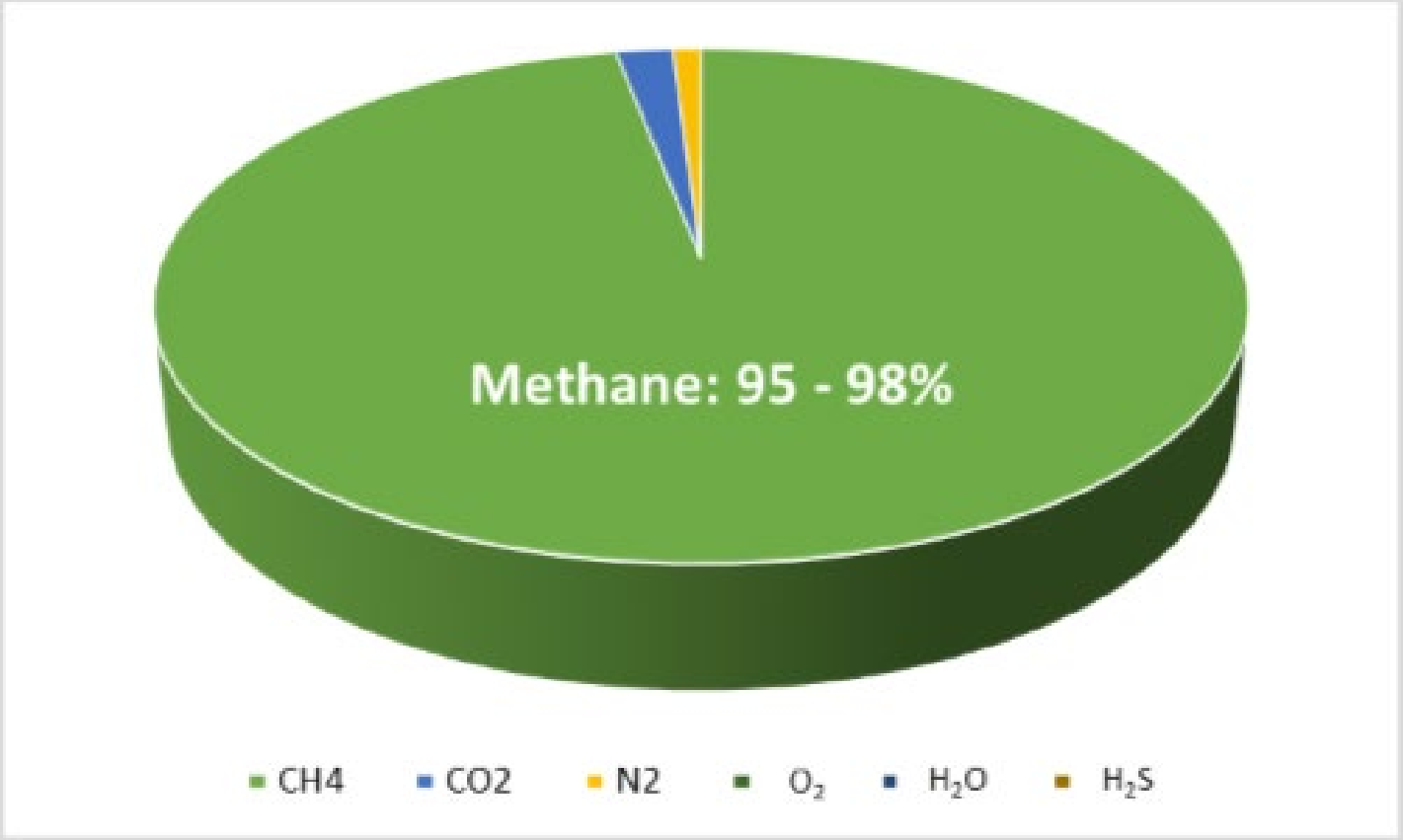
Biogas to RNG

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



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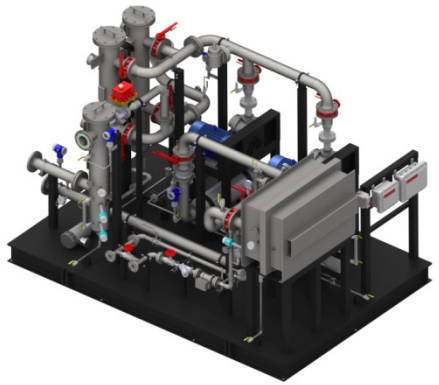
Reducing Capital and Maintenance Costs-H_2S Removal



Digester or Landfill → Hydrogen Sulfide Removal → Gas Compression/ Moisture Removal → Siloxane Removal

Micro Turbine | IC Engine-Generator | Boiler

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Hydrogen Sulfide Removal Systems

Ferric Oxide, Fe_2O_3 coated (reaction)

- Wood based
- Clay based

Ferric hydroxide pellet (adsorption)

Wausau WWTP, WI

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Hydrogen Sulfide Removal Media

- Ferric Hydroxide, FeO(OH)
  - Used on saturated gas
  - Conditioning step – Ca to $CaCO_3$
  - Tolerant of variable or low moisture content
  - Sulfur is pulled into pores and media remains granular
- $2\ Fe(OH)_3 + 3\ H2S \rightarrow Fe_2S_3 + 6\ H2O$
- Exothermic reaction when exposed to oxygen

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Persigo WWTP, Grand Junction , CO

	Persigo WWTP Summary
Start Up Date	April 6, 2015
System Flow	100 scfm
Inlet H_2S:	3,000 ppmv
Oxygen:	0.229%
Moisture:	4-20 mg/l* (*25 mg/l = 100% saturation)
Vessels:	(2) 8' Ø x 12' ss

Media Type	Media Cost/Change out	*Estimated days before change out with saturated gas	Actual days before change out (50 ppmv)
SulfaTreat	$31,394	102	41
Iron Sponge	$17,442	90	60
UNI-H2S	$30,500	150	104

Persigo WWTP, Grand Junction, CO

Sulfatreat and iron sponge both require 100% saturated gas to operate at their optimum.

*Based on percent by weight removal capacity, assuming optimum conditions

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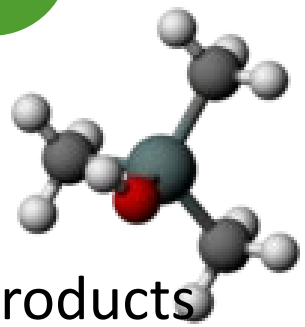
What is a Siloxane?



- Silica and organic compounds are combined (Organosilicon)
- Used in many industrial products and consumer products
  - Deicing fluid
  - Windshield Cleaning Products
  - Silicone caulks
  - Food additives
  - Commercial products for washing fruits and vegetables
  - Shampoo/conditioner
  - Laundry detergents
  - Furniture polish
- Siloxanes break down in landfills and digesters, and combine with the methane gas

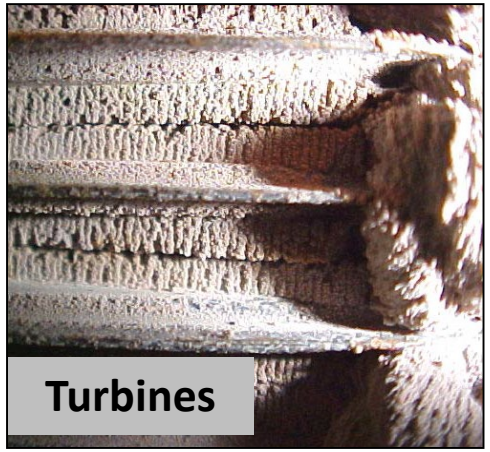
https://hpd.nlm.nih.gov/cgi-bin/household/brands?tbl=chem&id=1784

Suitability Factors for Media Systems:
Inlet Biogas Quality – Siloxanes, Hydrocarbons and VOC's

Siloxanes Organic Compounds with Silica
Tetramethyl silane
Trimethyl silanol
Hexamethyldisiloxane (L2)
Hexamethylcyclotrisiloxane (D3)
Octamethyltrisiloxane (L3)
Octamethylcyclotetrasiloxane (D4)
Decamethyltetrasiloxane (L4)
Decamethylcyclopentasiloxane (D5)
Dodecamethylpentasiloxane (L5)
Dodecamethylcyclohexasiloxane (D6)

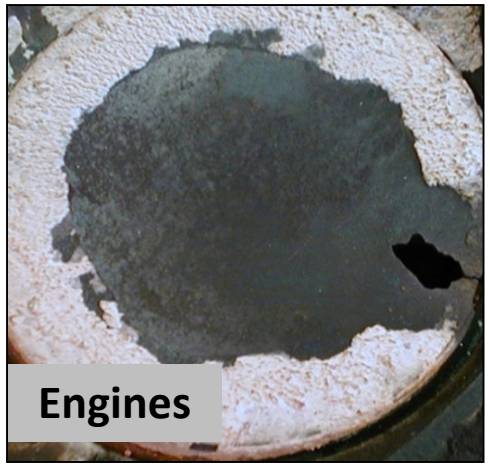
VOC Volatile Organic Compounds (Commonly Found)
Acetone
Benzene
Chlorobenzene
Decane
Ethylbenzene
Heptane
Hexane
Isopropyl Alchohol
Octane
Xylene
Toluene
22-35 compounds typically reported

Siloxane Impact on Equipment



- When methane gas is used as a fuel, the siloxanes form SiO_2 Silicon Dioxide, and precipitate to 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



Siloxane/VOC Removal

Coal

Coconut shell

Wood

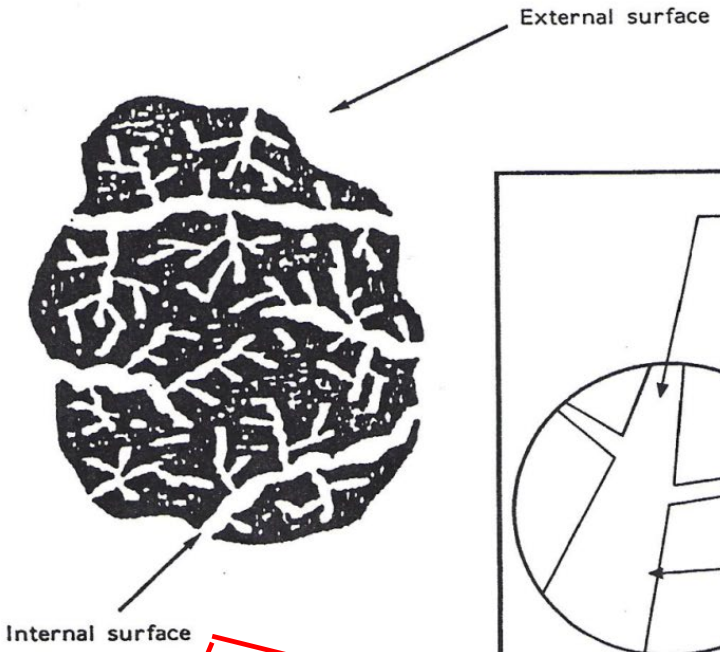
Extruded pellets

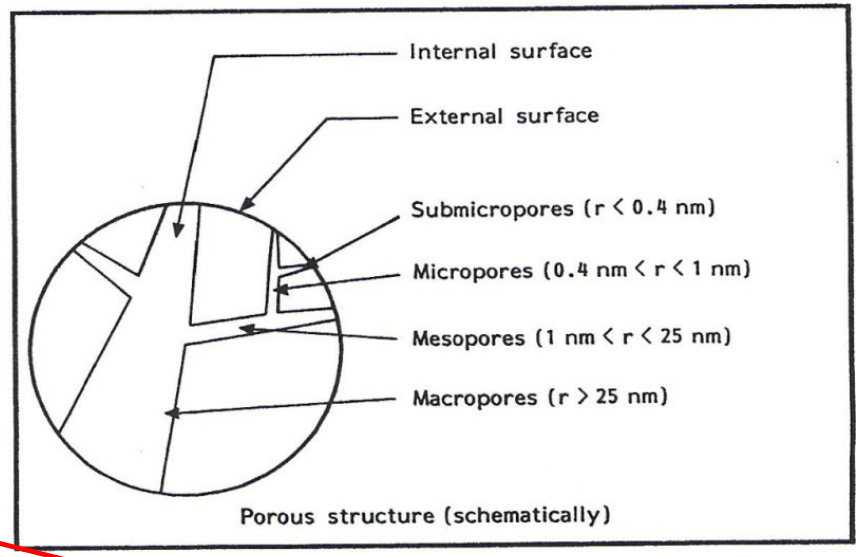
4 x 8 mesh chips

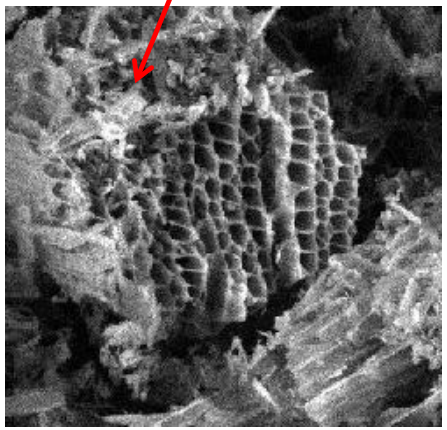
Silica gel - spheres

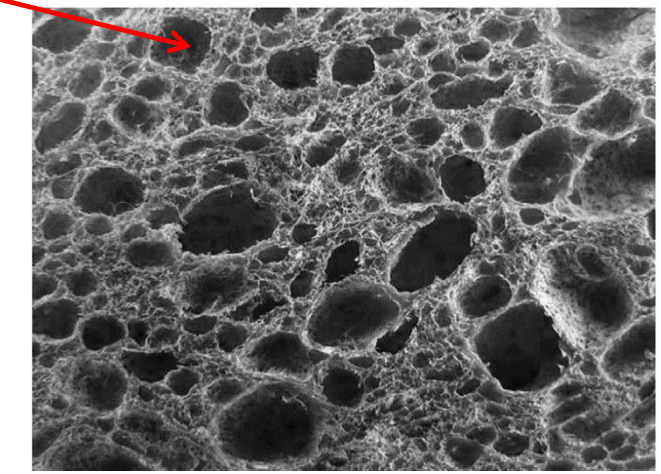
Silica gel – irregular shaped

Media After Activation







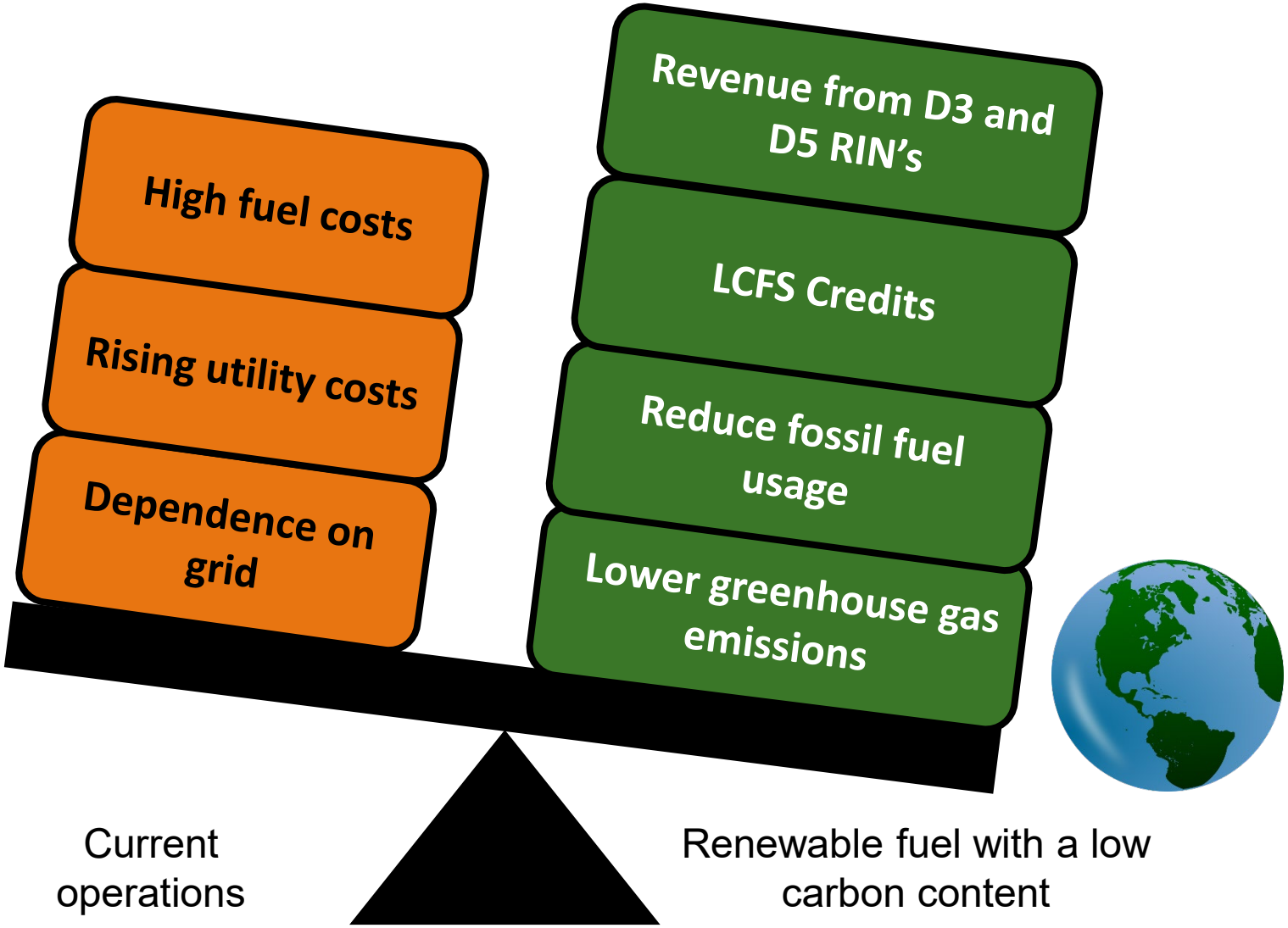


Siloxane Removal Systems

Akron, OH

Evansville, IN

Driving Factors for RNG



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Fuel Quality Specification

Biogas Constituents	Raw Biogas	SAE J1616 CNG Fuel Quality Specification	Natural Gas Pipeline Fuel Quality*
Methane	50-80%	88% or greater	
BTU			950-990 BTU/ft^3
Carbon Dioxide (CO_2) and Nitrogen (N_2)	20-50%	<4.5%	<2%
Oxygen (O_2)	0-1%	<1%	6 ppm to 0.2%
Hydrogen Sulfide (H_2S)	<1,000 ppm	<16 ppm	<4 ppm
Water Content		7#/MMcf	3-7#/MMcf
Siloxanes and Volatile Organic Compounds	<2,000 ppm	ND	ND to 1 ppm
Pressure	0-2 psig	3,000-3,600 psig	50 to 900+ psig

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*Varies depending on the utility

Small Scale Systems

Biogas Inlet Flow (scfm)	Fuel Production (GGE/day)	Fuel Production (DGE/day)
50	185 - 300	160 - 260
100	370 - 600	320 - 520
200	740 - 1,200	640 - 1,040
400	1,480 - 2,400	1,280 - 2,080

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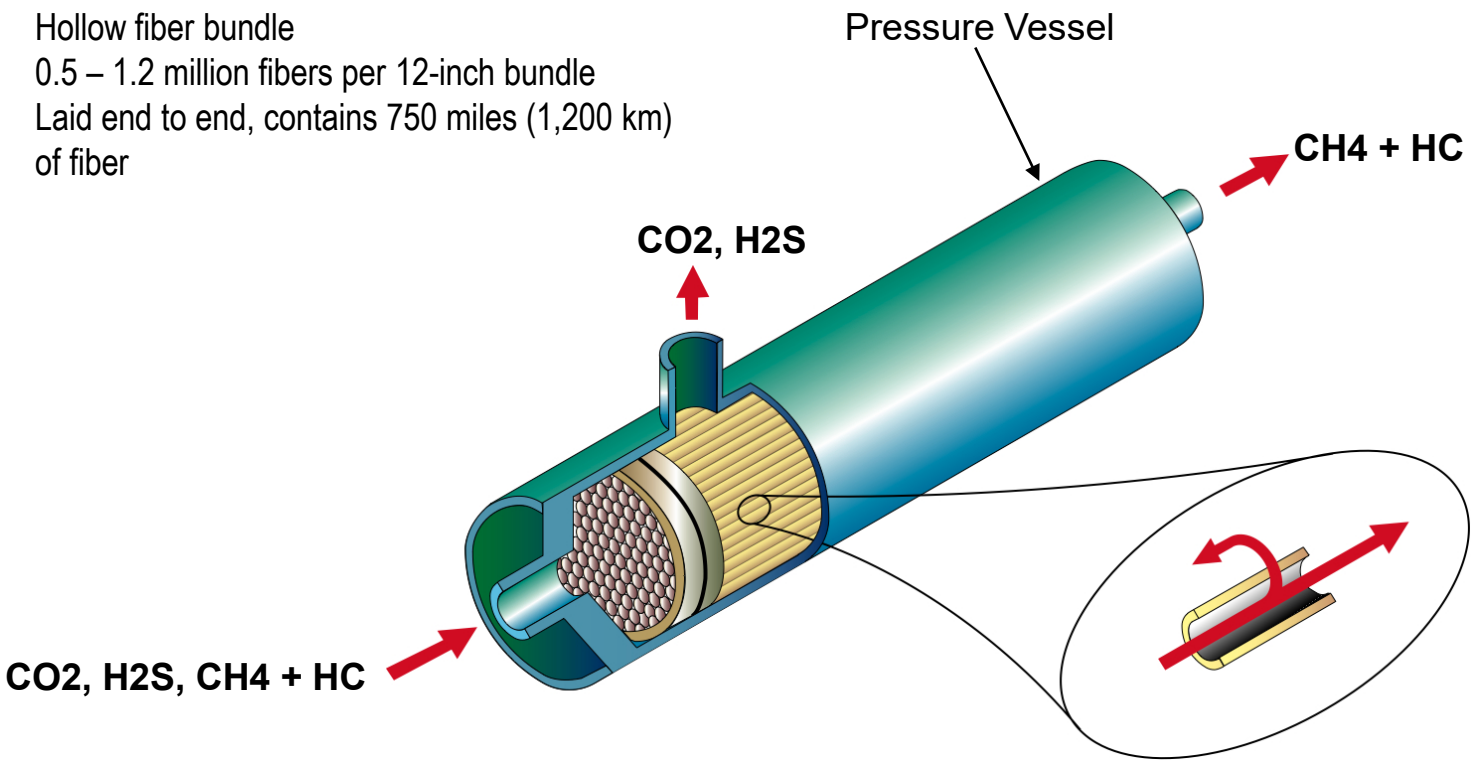
Membrane Separation Schematic

Hollow fiber bundle
0.5 – 1.2 million fibers per 12-inch bundle
Laid end to end, contains 750 miles (1,200 km) of fiber



Epoxy tube sheet
(fibers open on both ends)

Bore Feed Separator
200 psi (13.8 bar) pressure limitation
N2, CO2 separations

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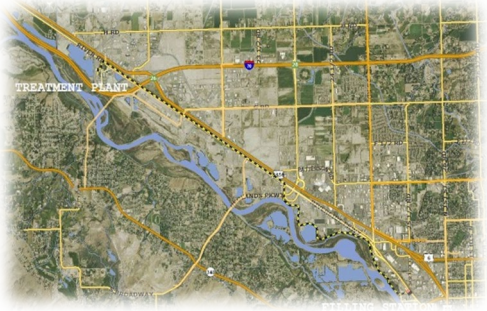
Methods to Deliver RNG

Digester or Landfill → Biogas Upgrading System

↓

CNG for Vehicles

- Fast fill stations
- Time fill stations
- Dedicated Pipeline
- Virtual Pipeline
- Natural Gas Pipeline



Persigo WWTP, Grand Junction, CO Dedicated Pipeline

- Population – Approximately 80,000, Grand Junction and Mesa County
- Located on the Colorado River
- 12.5 MGD municipal plant (Avg. flow 8 MGD)
- 100 scfm of biogas produced

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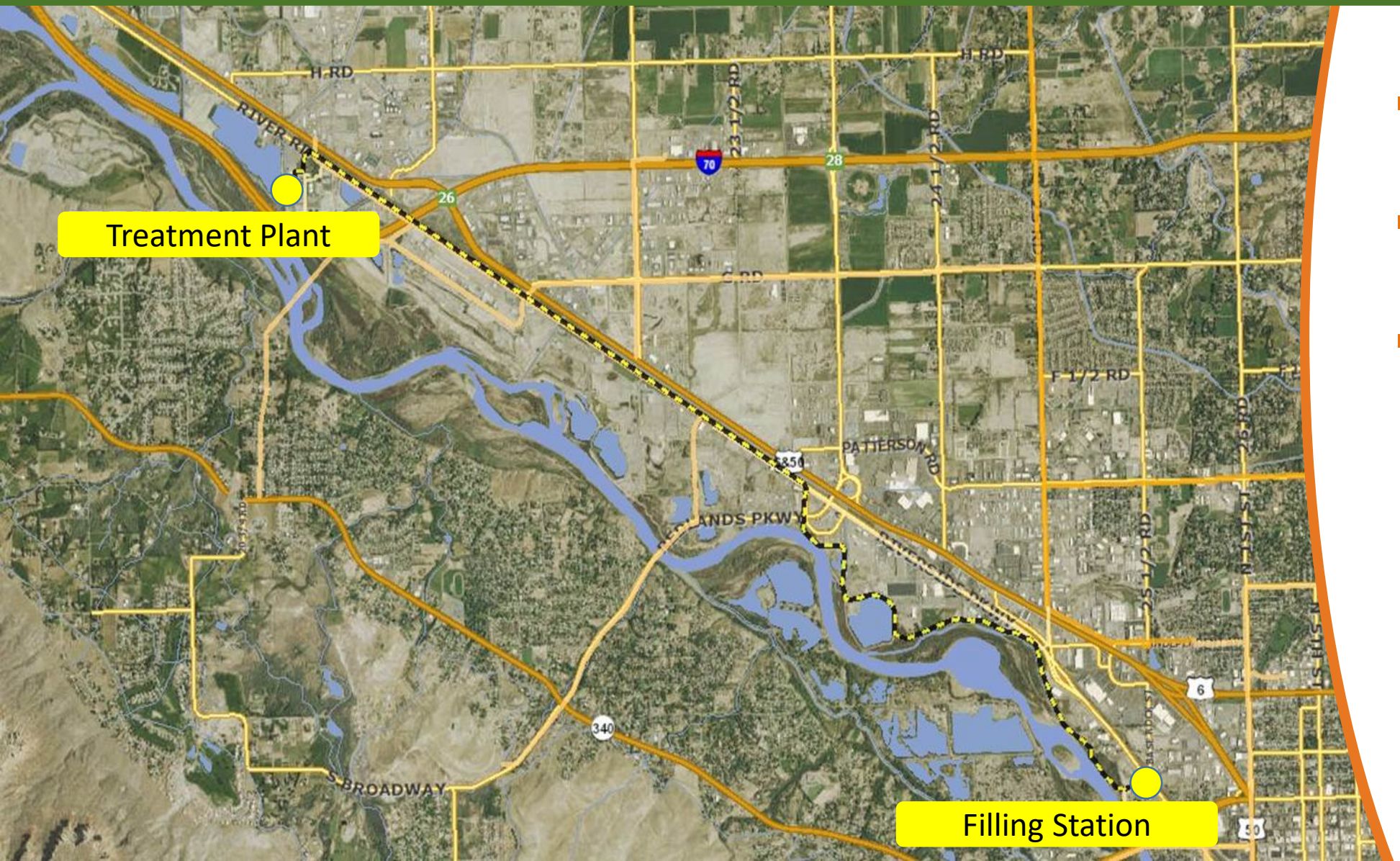
City of Grand Junction RNG Pipeline



- Dedicated 5.8 mile pipeline
- Located on the Colorado River
- Extends from WWTP to existing fueling stations

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Persigo WWTP
Grand Junction, CO

- April 2015 – Startup

Gas Conditioning Equipment

- Hydrogen sulfide removal
- Gas compression/Moisture removal
- Siloxane removal
- Carbon dioxide removal

BioCNG™

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Time Fill – Fueling Station

- Time Fill for CNG-Fueled collection trucks and city buses
- Fast Fill for emergency fill ups
- Dedicated 5.8 mile pipeline
- 142,000 gallons of gasoline diverted
- CO_2 Reduction of 3 million pounds/year
- 2017 - 62 city and county vehicles total being used
- Saved $179,000 on gasoline

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Biogas to Pipeline

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- Hydrogen Sulfide, H_2S
- Moisture
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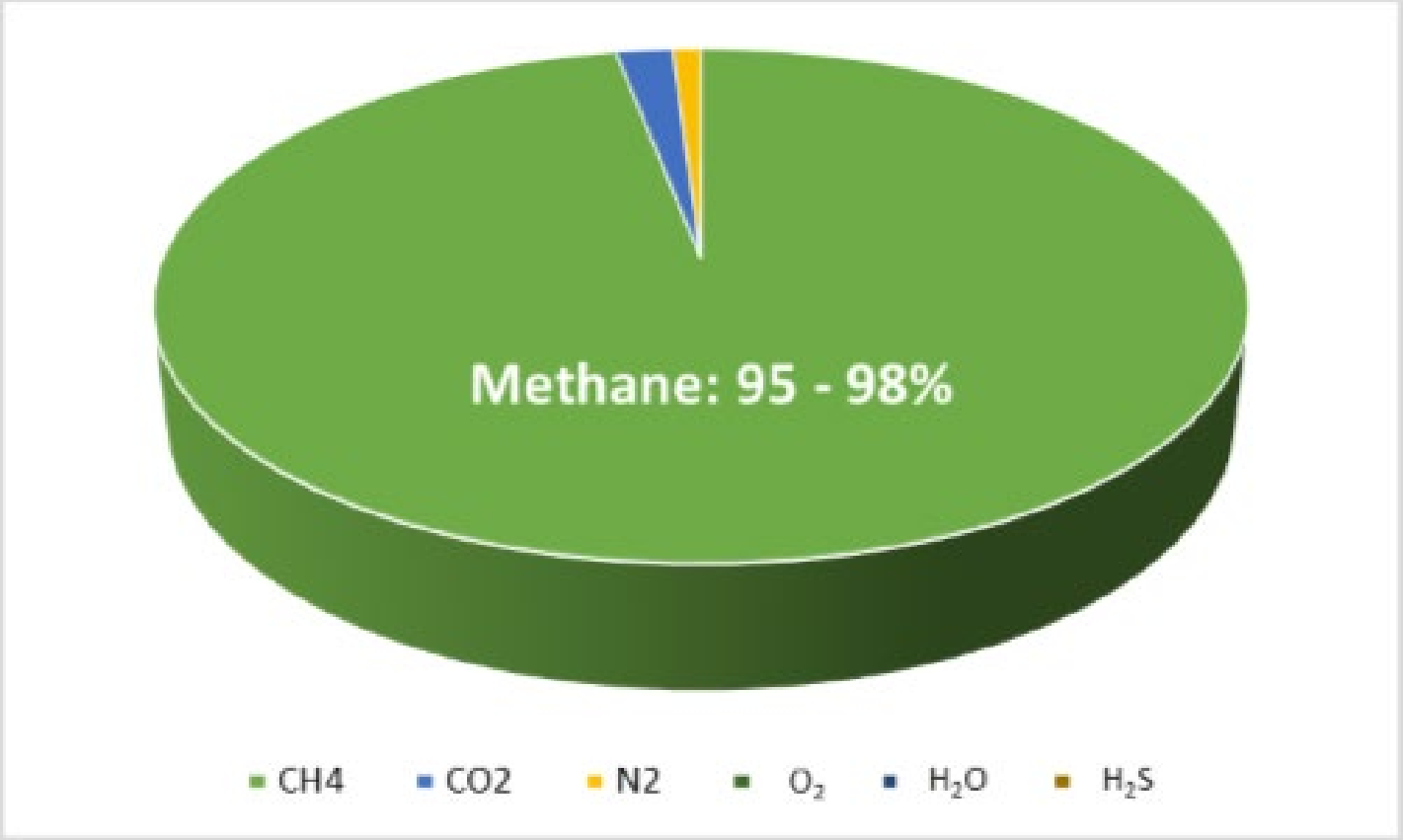
- Siloxanes
- Volatile Organic Compounds



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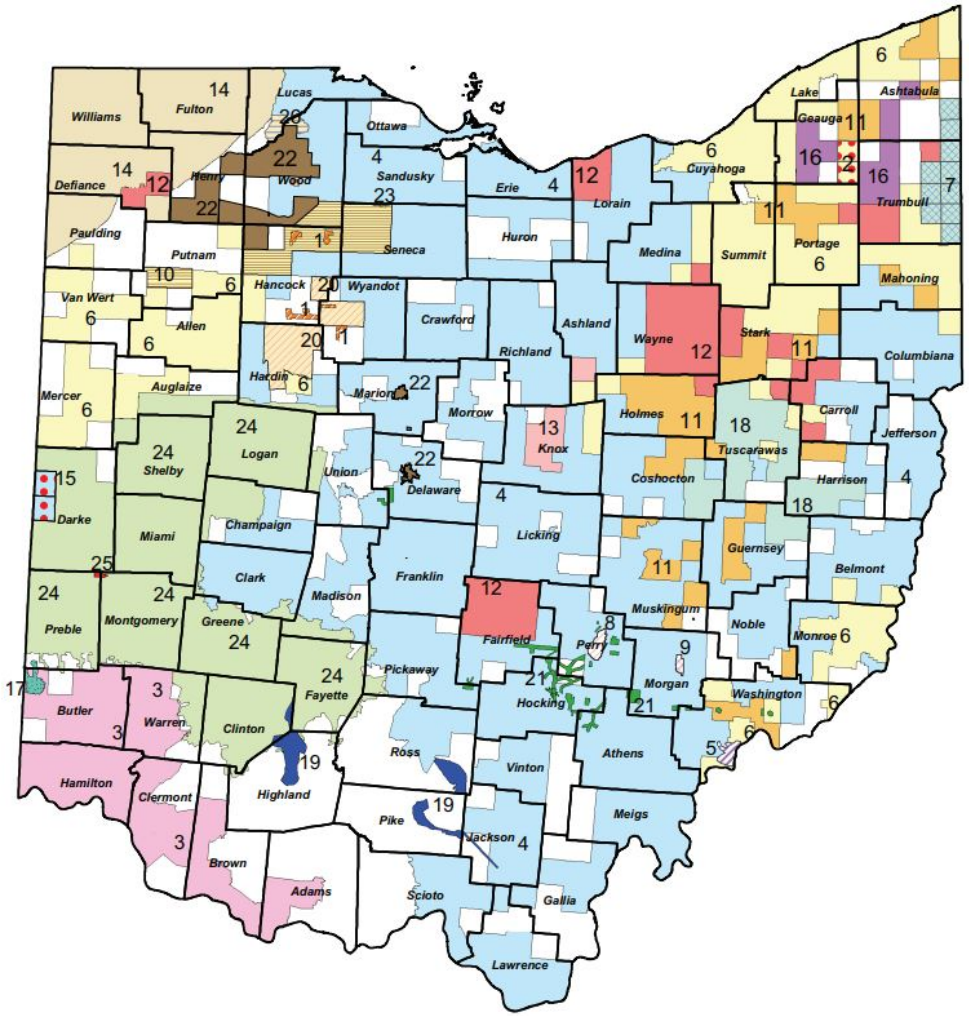
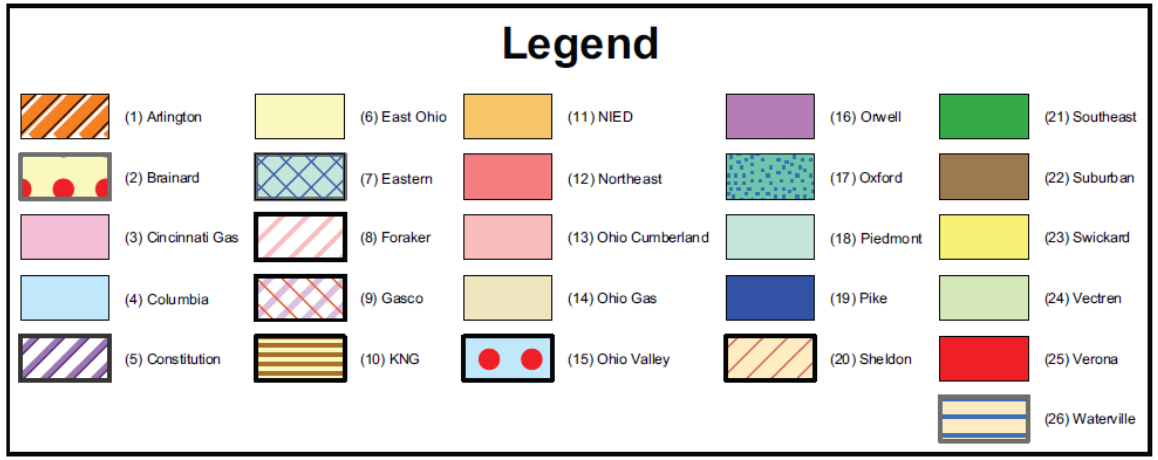
Regulated Natural Gas Utilities





Public Utilities Commission of Ohio, 2002
http://www.PUCO.ohio.gov

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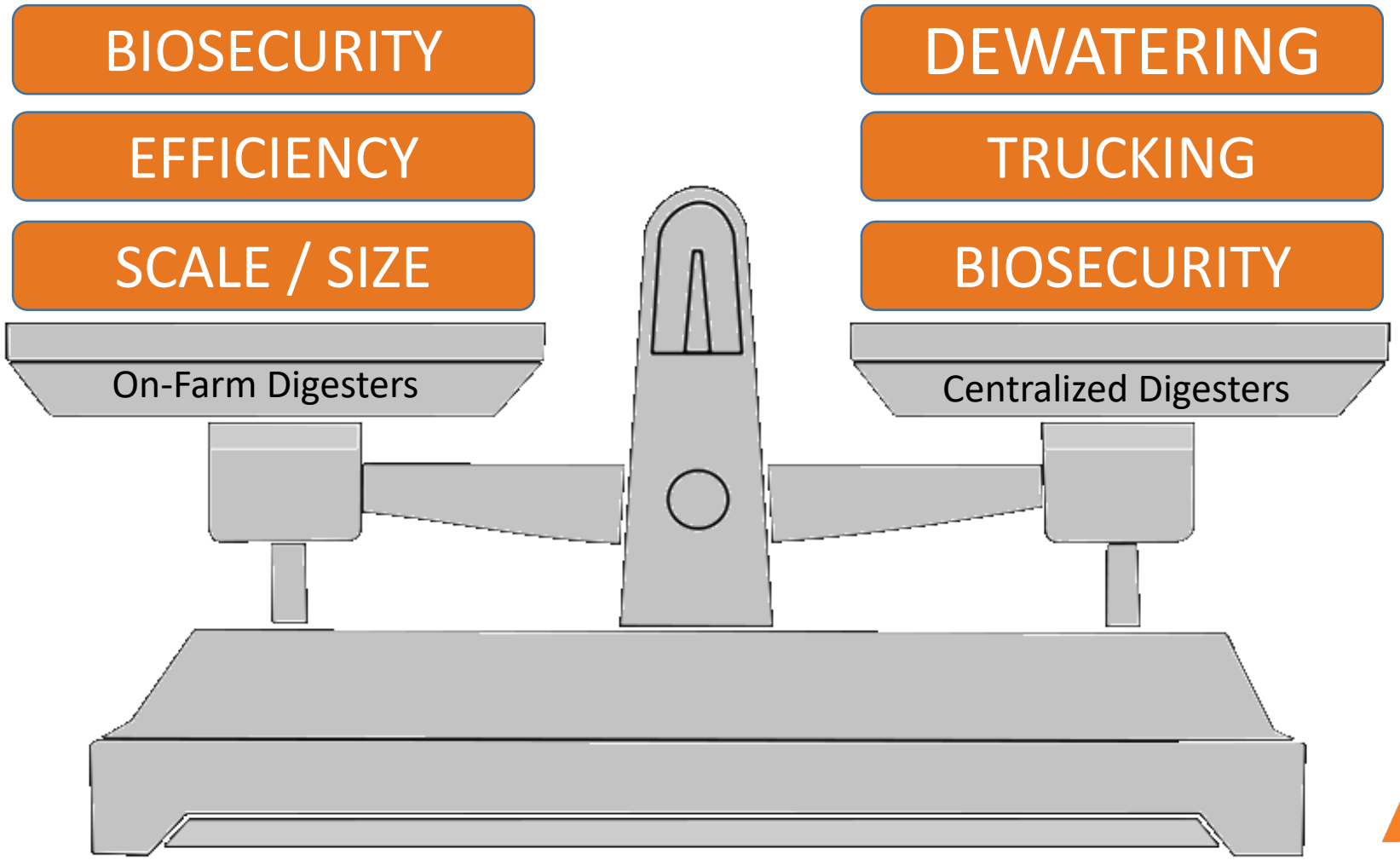
Weighing the Options



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Optima KV – Key Points

- 80,000 MMBtu/y (11,000 MWh)
- 15-Year Agreement with Duke Energy
- Biogas upgraded to natural gas
- Injected into existing pipeline, Piedmont Gas
- Used to fuel
  - H.F. Lee Power Plant, near Goldsboro
  - Sutton Power Plant in Wilmington
    - <1% of total fuel

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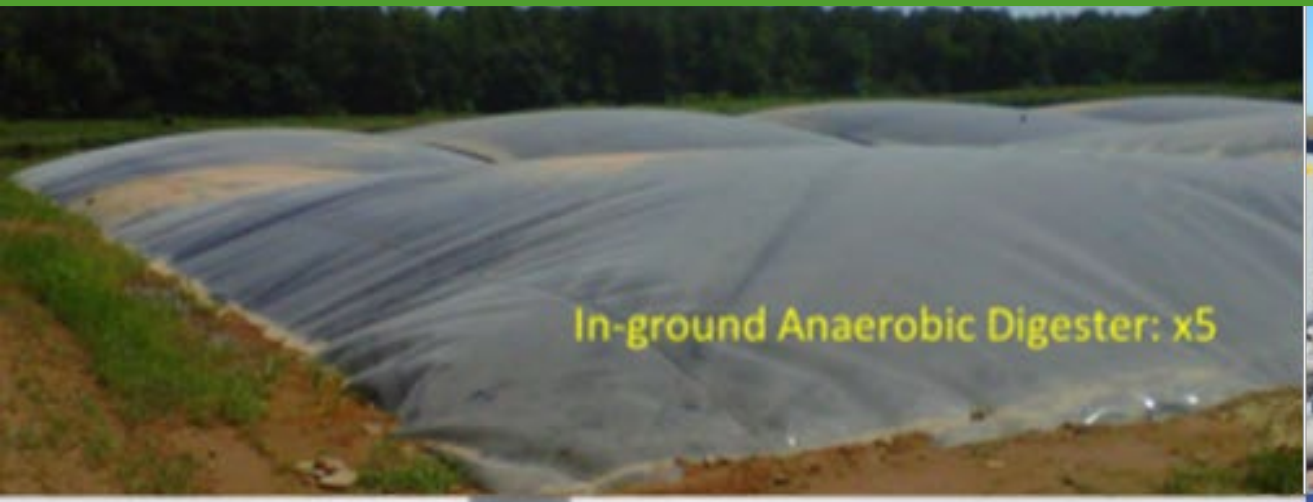
How it Works



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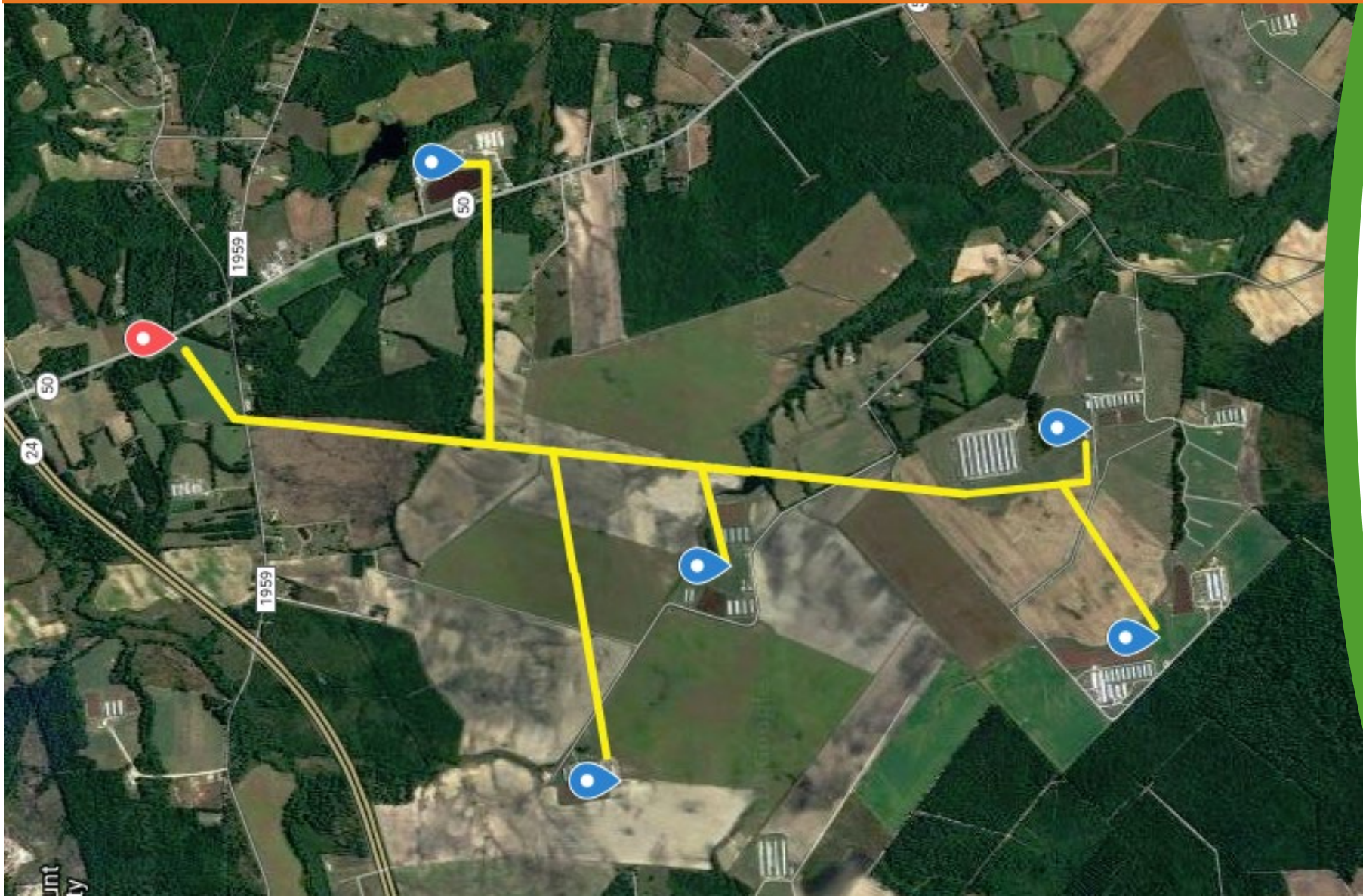
Dedicated pipeline to central processing



- 3 Farms, 5 In Ground Digesters ≈ 60,000 Hogs
- (4) 60scfm Compression/Moisture Removal
- (1) 140 scfm Compression/Moisture Removal
- (2) Injection Compressors (1,050psig)

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Biogas Upgrading Technology

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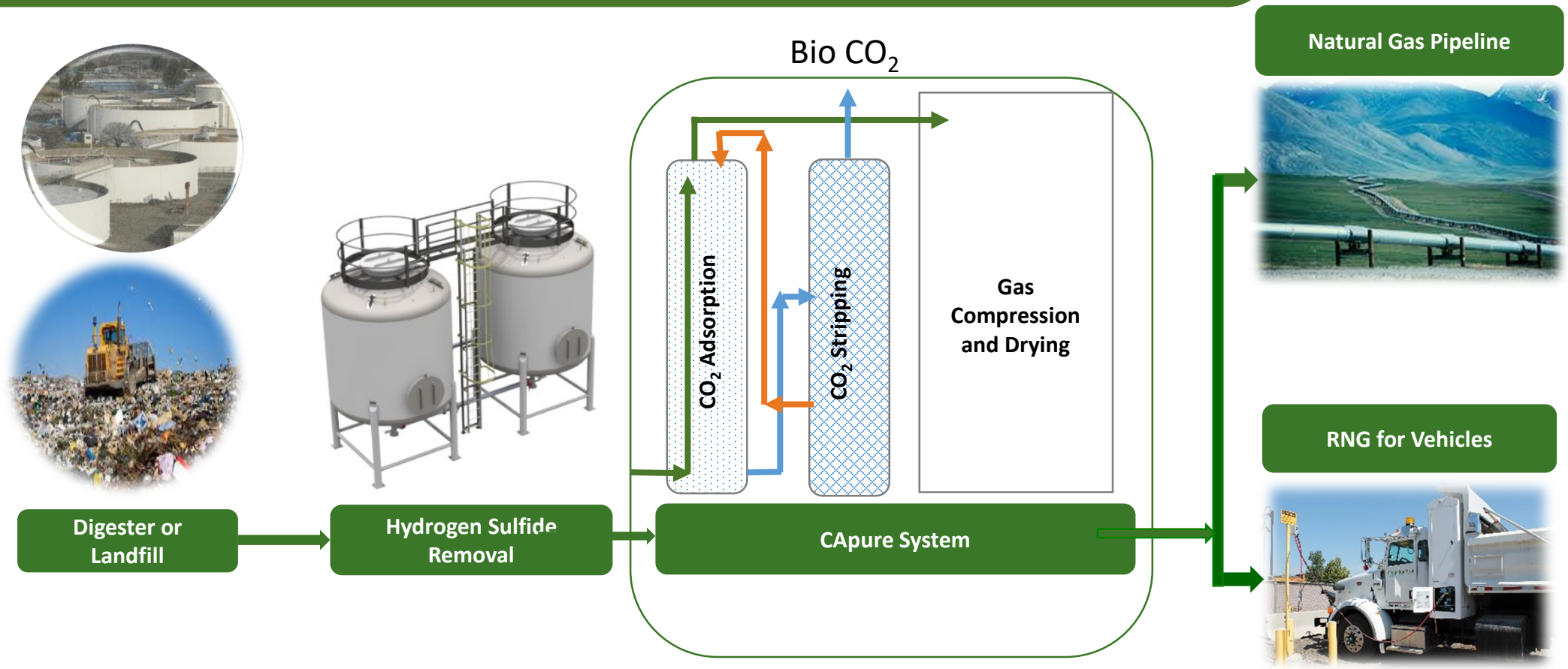
PUREGAS SOLUTIONS

Unison Solutions, Inc. and Puregas Solutions are bringing a new Biogas Upgrading Technology to the U.S. market

CApure Process



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CAPURE TECHNOLOGY

99.9% Methane Efficiency

- Less than 0.1% methane slip
  – Protecting our environment
- No hidden additional cost or energy requirement associated with treating the tail gas
- 99.9% of the methane in the biogas can be sold
  – Always the highest revenue

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Integrated Biogas Upgrading Solutions

- Lüderode, Germany since 2013
- 440 scfm
- Agricultural waste from crops
- Biogas to natural gas pipeline grid

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Riverside Biogas - Scotland

- 1,060 scfm biogas from spent malt
- 99.9% methane efficiency
- Heat supplied from CHP
- Back up biogas boiler
- Injects 690 scfm biomethane direct to the gas grid
- Propane enrichment and gas network entry facility

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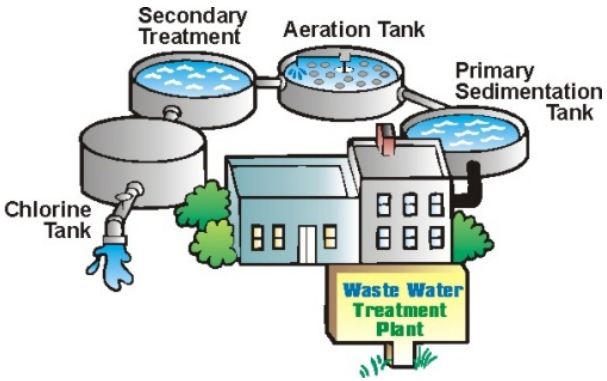
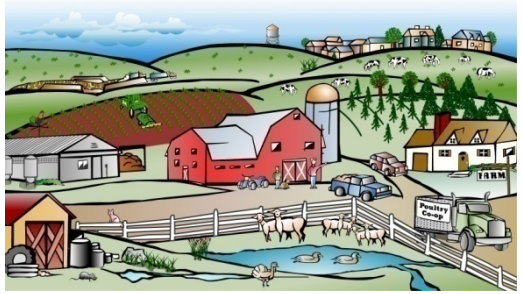
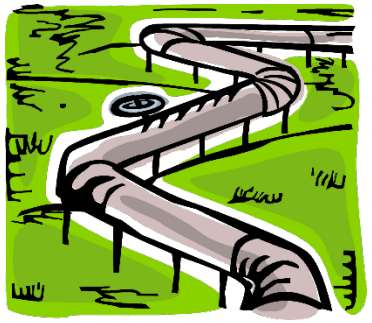
Q & A





Biogas

Electricity, Heat, Fuel for Vehicles, Grid Injection



Thank you!

www.unisonsolutions.com

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