Municipal Case Study

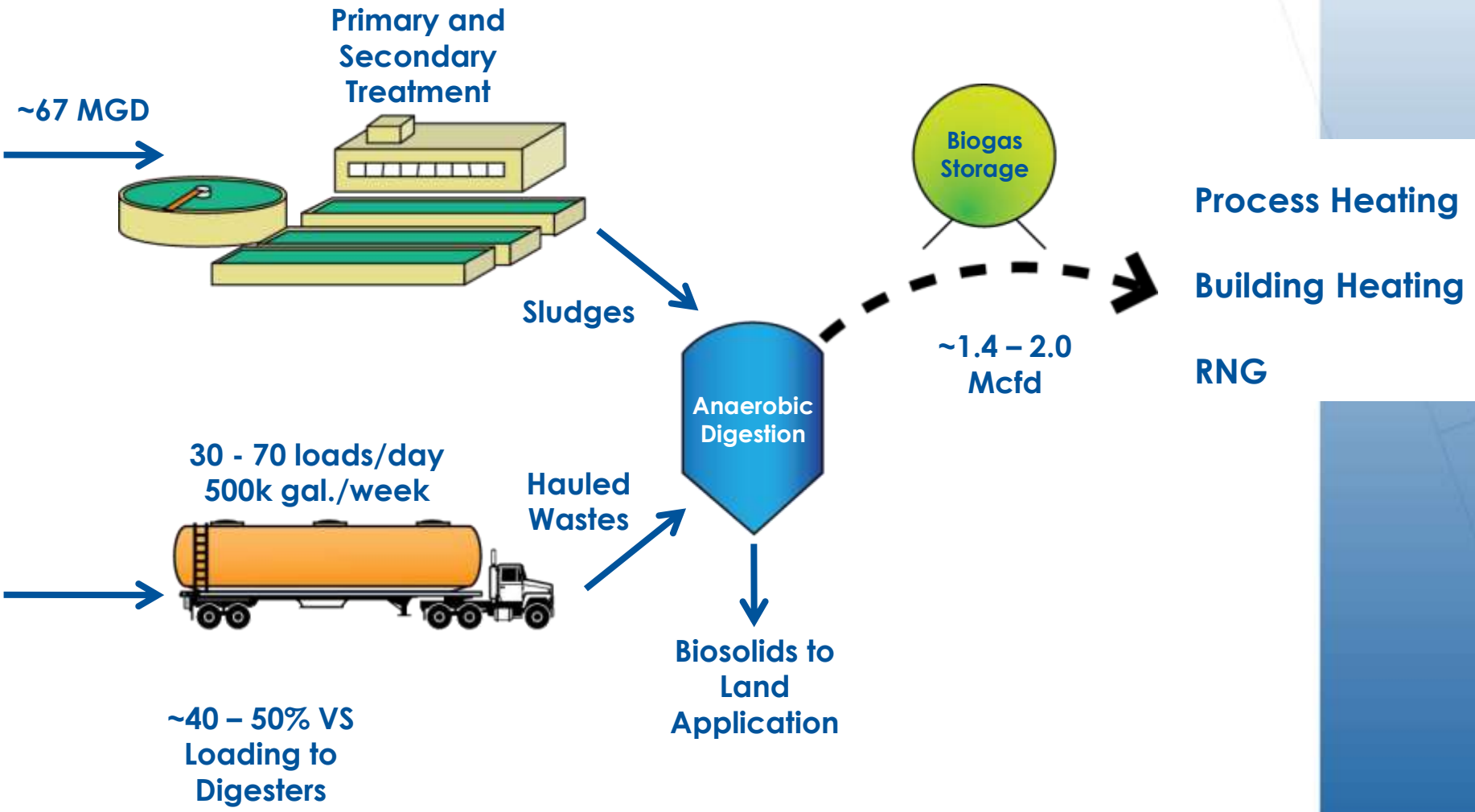
Biogas → RNG → Pipeline Injection

Tim Runde, Des Moines WRA

Des Moines Wastewater Reclamation Authority (WRA)

- WRA Serves 18 member agencies in three counties
- City of Des Moines is the contract operator of the WRA's wastewater reclamation facility (WRF)
- Average dry-weather flows of ~67 million gallons per day (MGD)
- Serves >600,000 residents in greater metro Des Moines area
- Completed $20M Anaerobic Digestion Improvements Project in Spring 2014
- Completed $19M Biogas Injection Project in October 2020

Des Moines WRF Flow Schematic:



Co-Digestion Waste Sources

- Restaurant Grease Trap / Interceptor Waste
- Dairy Waste
- Biodiesel Waste
- Slaughterhouse / Meat Processing Waste
- Lutein / Protein Waste
- Waste Soy Oil
- Sewage Sludge
- Sugar Waste
- Rendering / Gelatin Waste
- Corn Syrup / Mash

Evolution of Hauled Waste Receiving

Simple pipe offloading
~1994 - 2006

Below grade 170k gal.
Receiving Tank
~2007

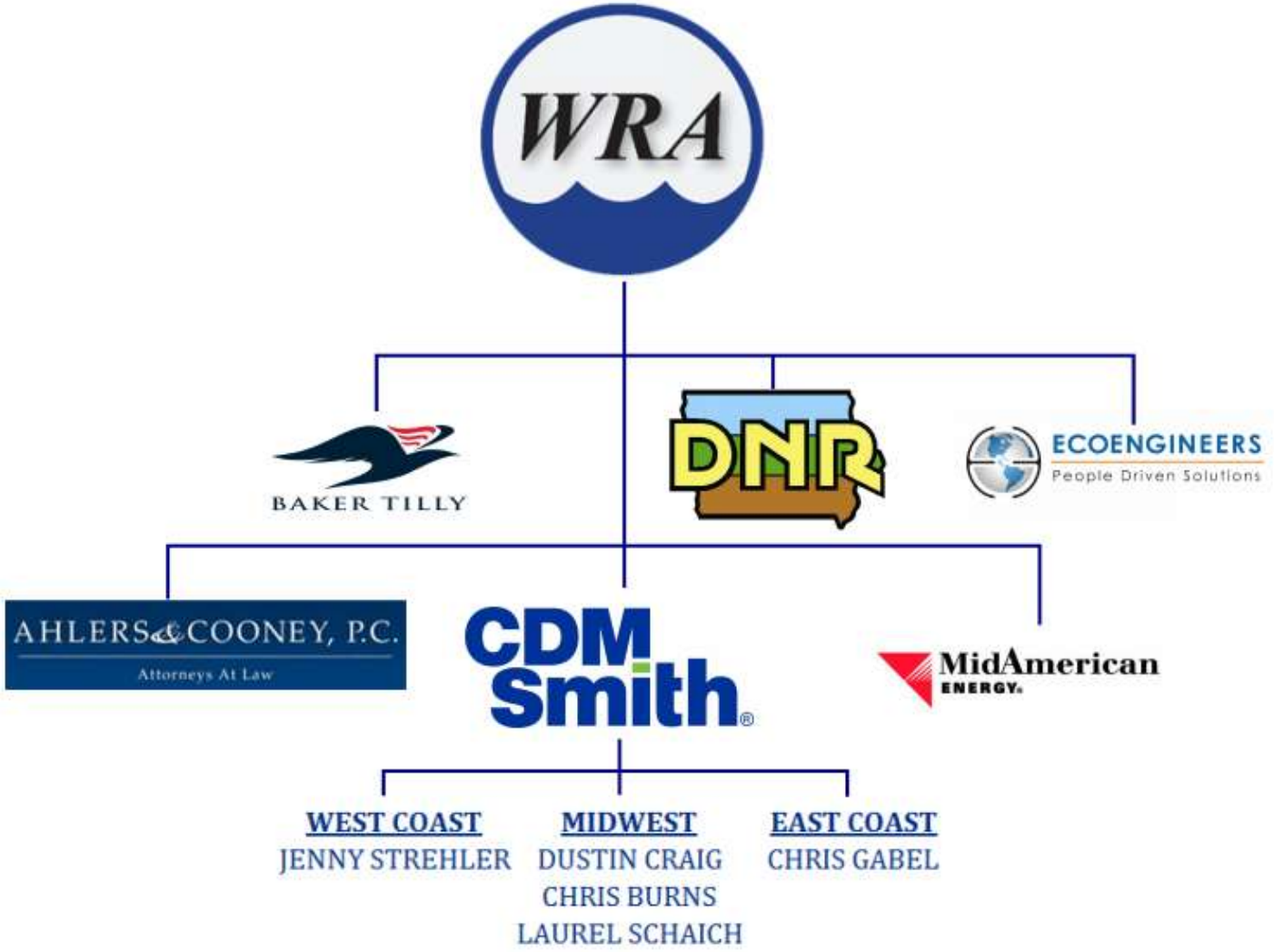
A Wastewater and Hauled Organic Waste Treatment Center


1
2
3
4
5
6
©Makeeff
West view of Digestor Complex

Biogas Production at Des Moines

- WRA is producing a significant amount of renewable fuel in digesters
- Capacity to increase biogas production with more hauled waste
- Changes in federal legislation are establishing renewable fuel standards, particularly for use in transportation fuels
- Environmental impacts of biogas
  - Biomethane production is carbon-neutral (does not add to greenhouse gas emissions)
  - Reduces consumption of natural gas, thus lowering CO_2 emissions
- Supports sustainability initiatives and goals of City of Des Moines and WRA

Project Organizational Chart



Development of Bioenergy Model

Financial Inputs

Electricity Cost, $/kwh	$0.0616
Natural Gas Purchased, $/MMBtu	$6.86
Labor, $/hr	$60
Water, $/100 gal	$0.40
Lube Oil, $/gal	$15
Polymer, $/5 gal	$700
Air Emissions Fee, $/ton	$56
Discount Factor	5%
RIN Inflation, %/yr	5%
Utilities Inflation, %/yr	5%
Labor Inflation, %/yr	5%
Maintenance Inflation, %/yr	5%
MidAmerican Tariff Inflation, %/yr	5%
Air Emissions Fee Inflation, %/yr	5%

Process Information

	PSA 1500	PSA 2250	WS 1500	WS 2250
% Recovery	95%	95%	98%	98%
Sales Gas %CH_4	97%	97%	96.2%	96.2%
Sales Gas HHV, BTU/cf	980	980	970	970
Water, gpm	0	0	2.7	4.4
Connected Load, hp	948	1294	842.9	1216.3
Natural Gas, MMBtu/day	48	72	0	0
Polymer, gal/yr	0	0	5	7.5
Compressor Heat Recovery, MMBtu/hr	0	0	0.0	0.0
Tail Gas Heat Recovery, MMBtu/hr	3.4	5.1	0.0	0
Lube Oil, gpd	Included below		4	6.5
Preventative Maintenance, $/yr	$72,000	$91,260	$50,500	$50,500
Labor, hr/yr	0	0	0.0	0.0
Downtime, hr/yr	0	0	0	0

20-Year Economics, Present Value

	PSA 1500	PSA 2250	WS 1500	WS 2250
Capital	$9,855,000	$11,921,000	$9,475,000	$12,086,000
Total Annual Costs	$36,304,000	$52,772,000	$33,288,000	$36,665,000
Total Annual Revenue	$100,162,000	$103,050,000	$98,914,000	$99,784,000
20 Year Overall Revenue	$54,003,000	$38,357,000	$56,151,000	$51,033,000
Payback Period, months	37	57	35	46

Raw Gas Data

Raw Gas, %CH_4	65%
Raw Gas, H2S ppmv	4000
Raw Gas Flow Growth, %	0%

Initial Investment

	PSA 1500	PSA 2250	WS 1500	WS 2250
Equipment Capital, $	$2,350,000	$3,042,000	$2,556,000	##########
Thermal Oxidizer, $	$497,000	$643,351	$350,055	$477,696

See "Capital" tab for more details

Sales Gas Economics

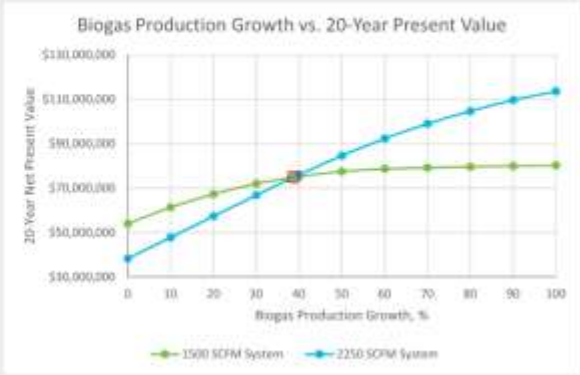
Renewable Gas Sold, $/MMBtu	$5.00
Monthly Customer Charge, $/month	$1,315
Commodity Charge, $/therm transported	$0.00495
Demand Charge, $/MDR therm/month	$0.52886

Environmental Attributes

RIN Value, $/RIN	$0.65
RIN Conversion, RIN/MMBtu	11.727
RIN Value, $/MMBtu	$7.62

Percent of Gas Accepted

1500 SCFM System	99.1%
2250 SCFM System	100.0%



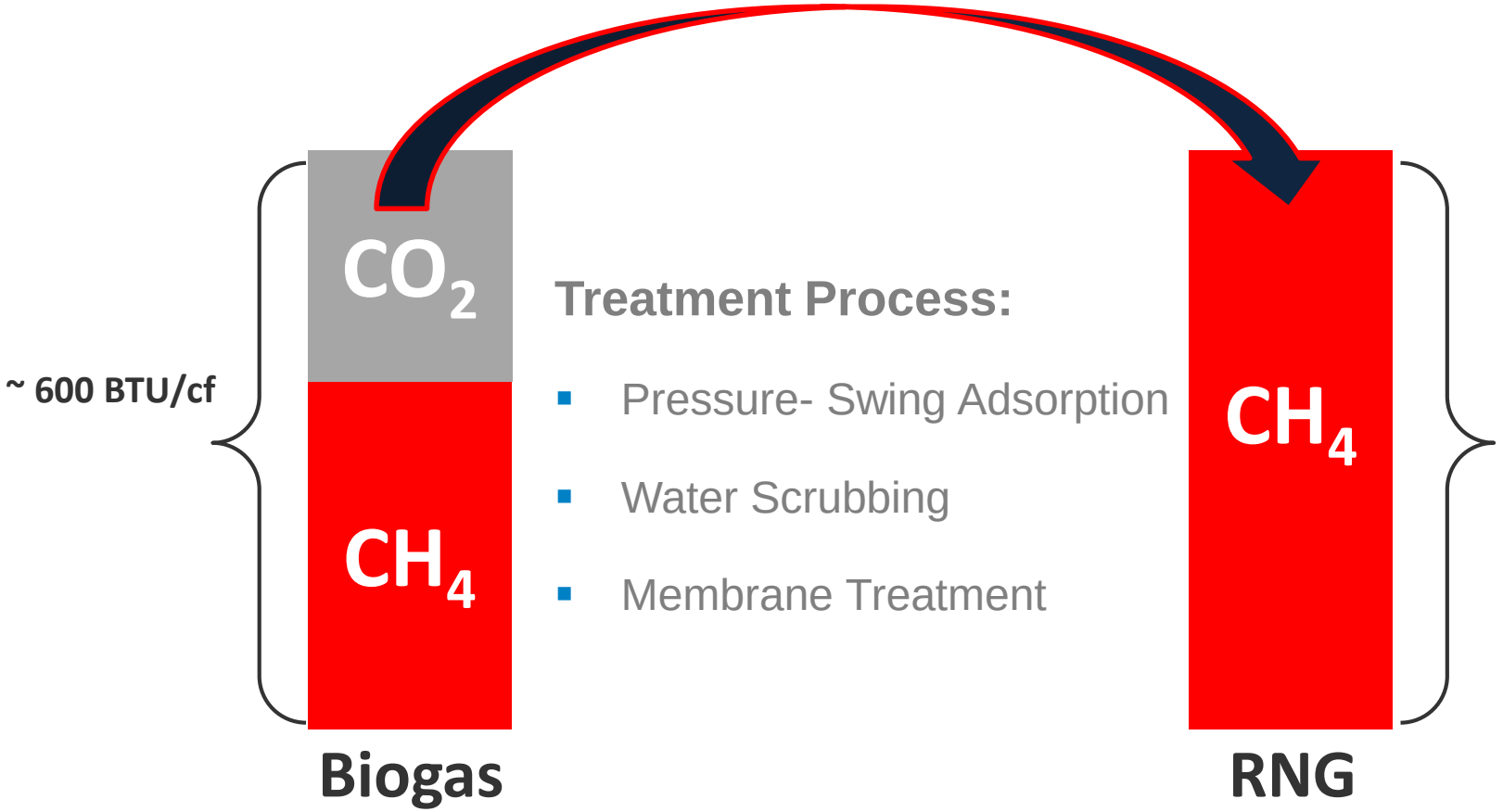
Design Criteria

- Inlet Biogas Flow: 2250 SCFM

Component	Digester Gas	Pipeline Specification
BTU Content	~660 BTU/scf	> 950 BTU/scf
Carbon dioxide	35%	< 3% by volume
Nitrogen	0.7%	< 4% by volume
Total Inerts (N_2 + CO_2)	~36%	< 5% by volume
Oxygen	<0.2%	< 0.3% by volume
Water	Saturated	< 5 lb/mmscf
Hydrogen sulfide	Actual: 50-600 ppm Design: 6,000 ppm	< 0.25 grain/Ccf
Total Sulfur	N/A	< 20 grain/Ccf
Volatile Organic Compounds	10-30 ppm	0 ppm

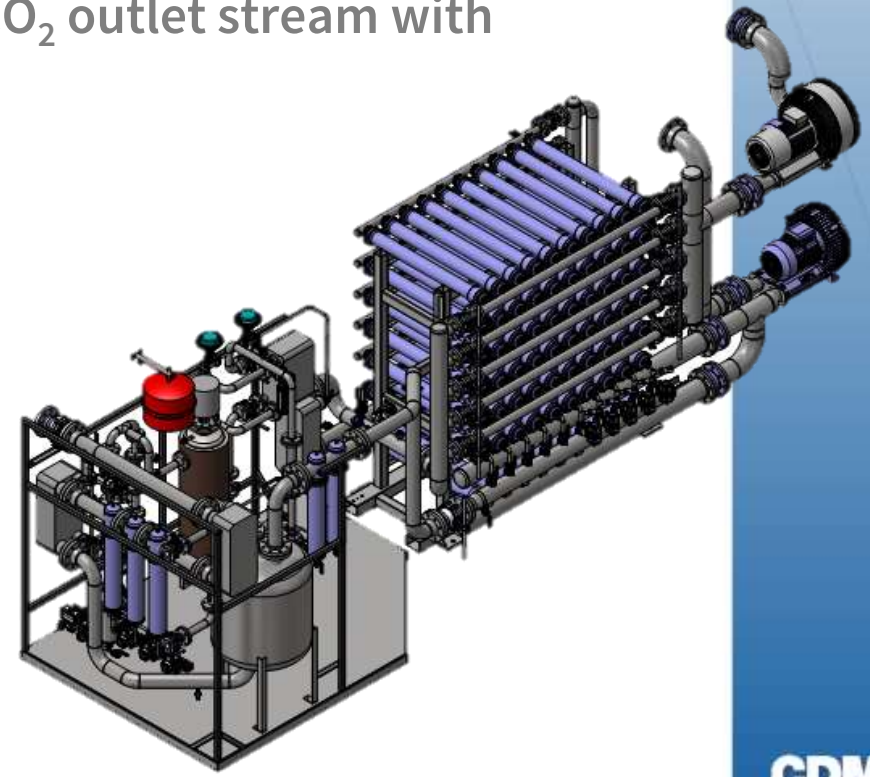
Technology Comparison

Biogas → Renewable Natural Gas (RNG)



Membrane Scrubbing System

- System Description
  - Utilizes physical diffusion process through membranes which use a thin polymer film. Membrane selectively retains CH_4 and some N_2 (~20%) and O_2 (~50%)
  - Generates very high quality CO_2 outlet stream with approximately 1-2% CH_4
- Typical Components
  - Compressor
  - Gas Heat Exchanger
  - H_2S Scrubbing System
  - Siloxane Carbon Filters
  - Chiller
  - Final Polishing Filters
  - Membranes



Membrane Scrubbing System

- Manufacturers
  - DMT Environmental Solutions (Joure, Netherlands)
  - Unison Solutions (Dubuque, Iowa)
  - Greenlane (New Zealand, USA)
- Advantages
  - Removes some O_2 (~50%) and N_2 (~20%)
  - High CH_4 recovery (97-99.5%)
    - *Depending on the number of stages*
  - High level of turndown (~10%)
  - Dry process
- Disadvantages
  - No U.S. Installations
  - H_2S and siloxane pretreatment required
  - Limited data on membrane life and fouling

Liquid Scrubber System

- System Description
  - Separation by physical adsorption in scrubber
  - Water is transfer solvent; performance follows Henry's Law-CO_2 is more soluble in water than CH_4
  - Upflow packed towers with polypropylene media
  - Solvent regenerates in stripping tower and only small daily make-up water demand

- Typical Components
  - Compressor
  - Scrubber Vessel
  - Flashing Vessel
  - Stripping Vessel
  - Compressor Radiator Skid
  - PSA/TSA Adsorber (gas drier)
  - Process Water Chiller

Liquid Scrubber System

- Manufacturers
  - Greenlane (New Zealand, USA)
  - DMT (Netherlands, USA)
  - Malmberg (Sweden)
- Advantages
  - Proven technology – multiple installations globally and in USA
  - Non-toxic solvent (water)
  - Also removes H_2S in inlet biogas
  - Moderate CH_4 losses (~2% slip)
- Disadvantages
  - Increases H_2O, O_2, and N_2
  - Tail gas treatment is required
  - Very tall outdoor vessels

Pressure Swing Adsorption (PSA)

- System Description
  - Biogas is pressurized to flow up through the adsorption vessels
  - Contaminants are trapped by media designed to not capture CH_4
  - Vacuum is applied to depressurize (i.e.; pressure swing) after adsorption to purge contaminants from vessel in tail gas stream
  - Process is batch but use of multiple vessels and rotary valve allow continuous flow

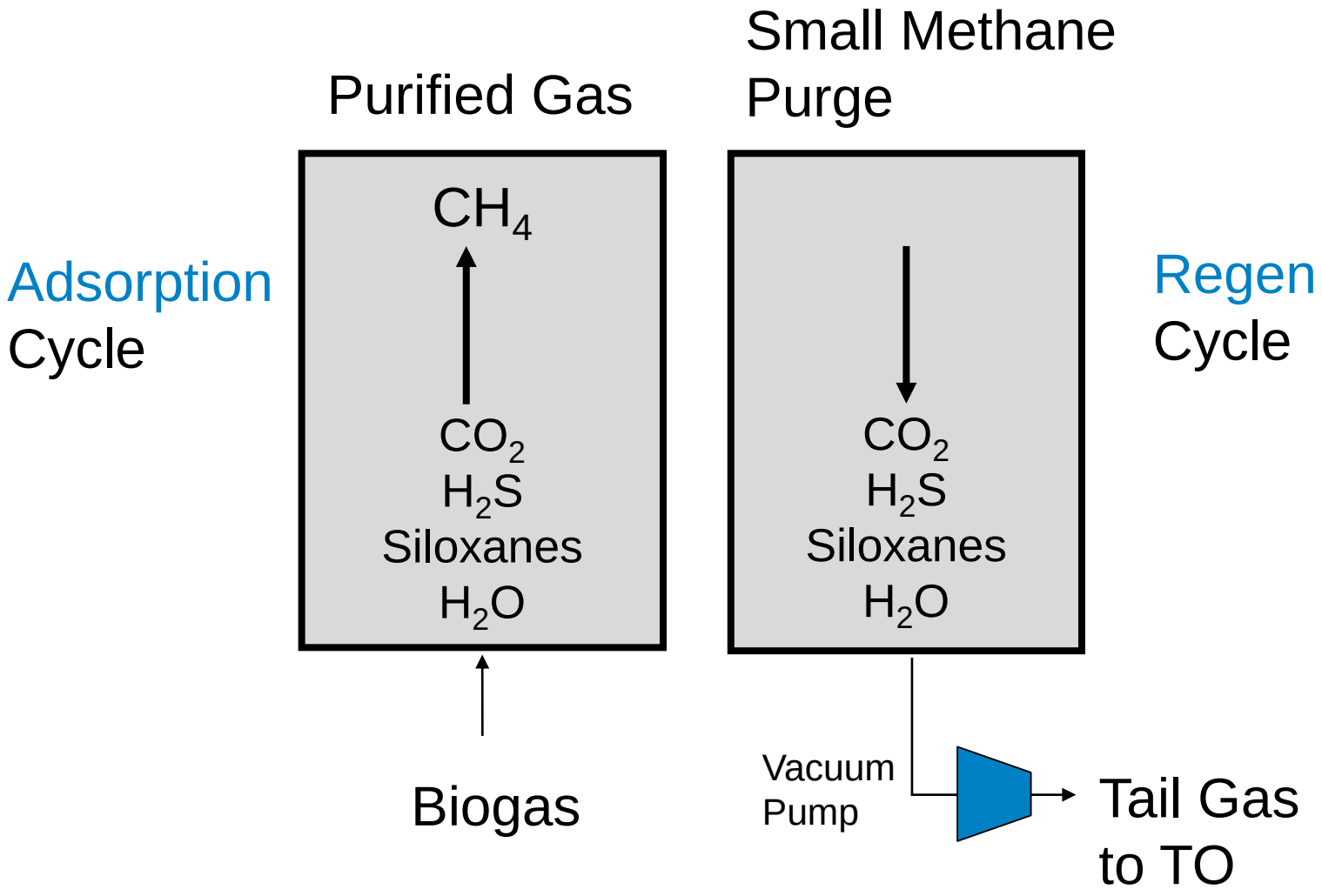
- Typical Components
  - Compressor
  - Water Separator
  - Air Fan Cooler
  - Adsorber Vessels and Valve Skid
  - Vacuum Pumps
  - Buffer Tanks

Zeolite Media

Pressure Swing Adsorption

- Manufacturers
  - Guild Associates Inc. (Dublin, Ohio)
  - Xebec Adsorption Inc. (Quebec, Canada)
- Advantages
  - No H_2S pretreatment required for <6,000 ppm (Guild only)
  - Simple, one step, dry process that is proven technology
  - Media is regenerative
  - Spare parts are generic. Can be serviced by plant operators or local mechanic
- Disadvantages
  - Methane recovery is lower (95%)
  - Additional PSA vessels required for O_2/N_2 removal if air is in the biogas
  - Tail gas treatment is required

PSA Flow Schematic



PSA Batch Cycles

ADSORPTION	DEPRESSURIZE	VACUUM & PURGE	REPRESSURIZE
REPRESSURIZE	ADSORPTION	DEPRESSURIZE	VACUUM & PURGE
VACUUM & PURGE	REPRESSURIZE	ADSORPTION	DEPRESSURIZE
DEPRESSURIZE	VACUUM & PURGE	REPRESSURIZE	ADSORPTION

Technology Comparison & Selection

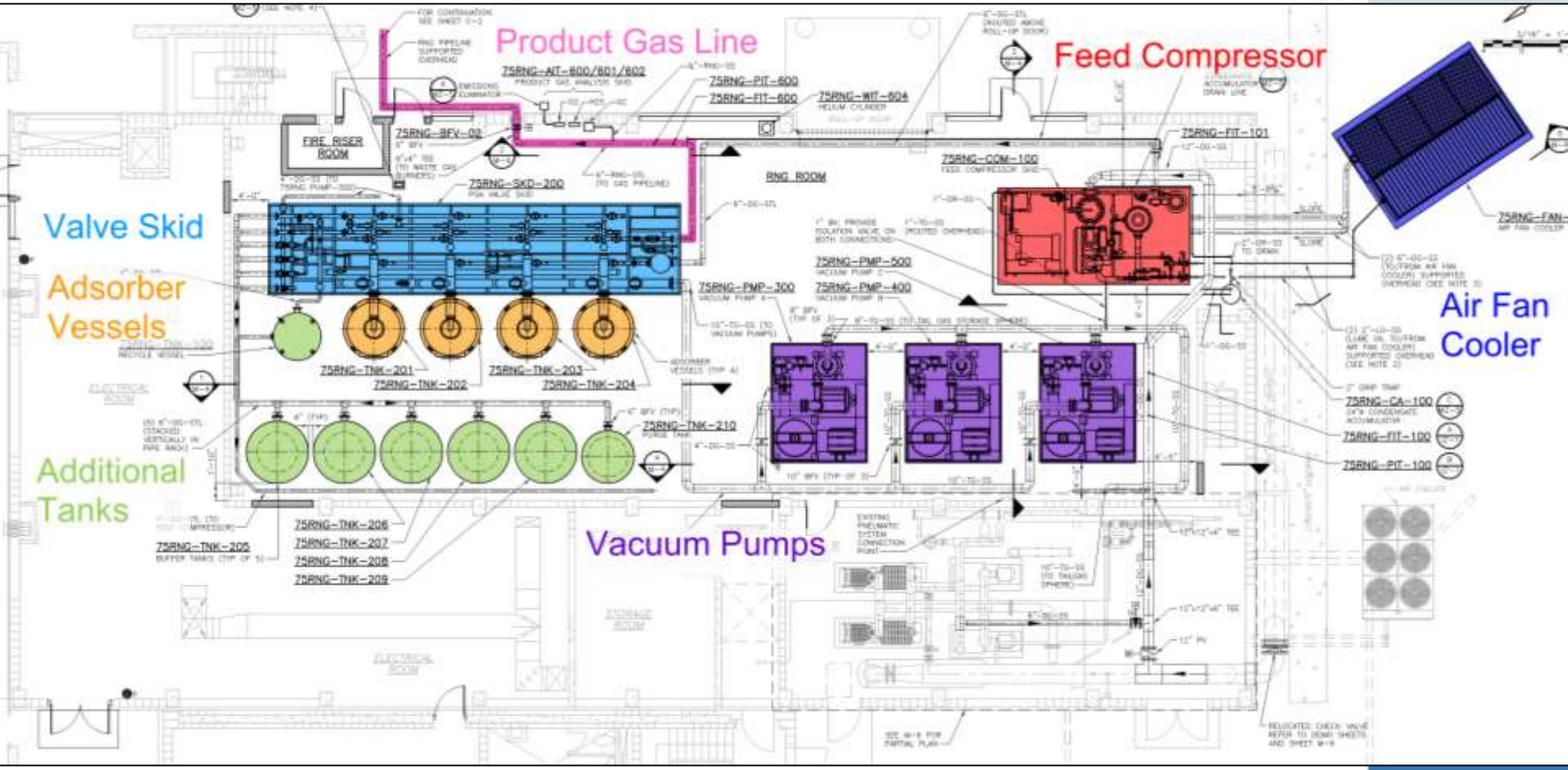
- Hydrogen Sulfide Considerations
  - Membranes: pre-treatment required
  - Water Scrubber: maximum inlet ~2,500 ppm H_2S
    - *Tail gas treatment required (biofilter or RTO)*
  - PSA: maximum inlet ~ 6,000 ppm H_2S
    - *Tail gas treatment required (TO)*

- System Recovery Performance
  - Membranes: high methane recovery
  - Water scrubber: high methane recovery, increases oxygen
  - PSA: lower methane recovery

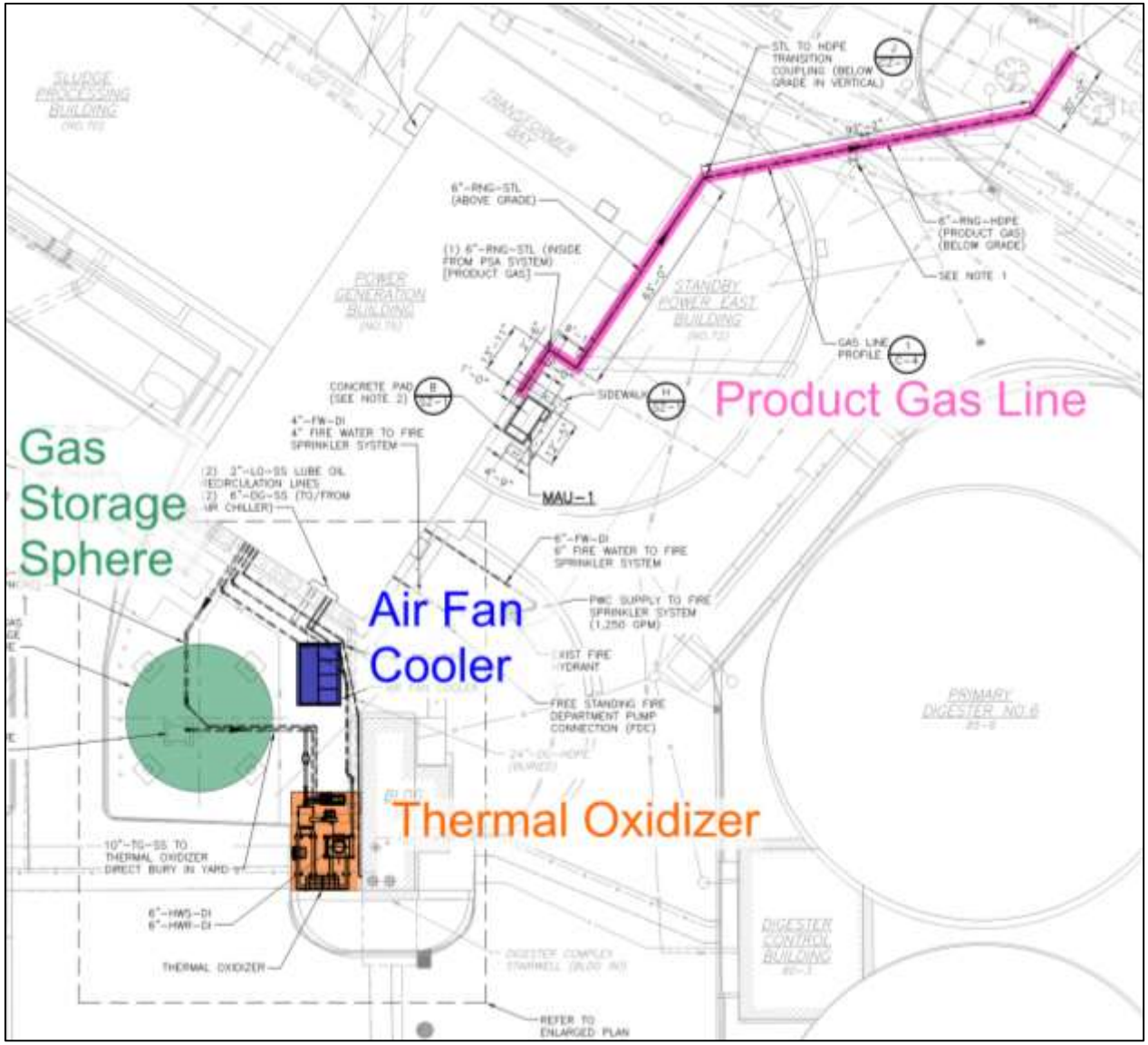
- Technology Selection:
  - PSA System
  - Capacity of 2,250 scfm inlet biogas flows
  - Thermal Oxidizer with heat recovery

Project Design

System Layout



Site Plan


Product Gas Line
Gas Storage Sphere
Air Fan Cooler
Thermal Oxidizer
MAU-1

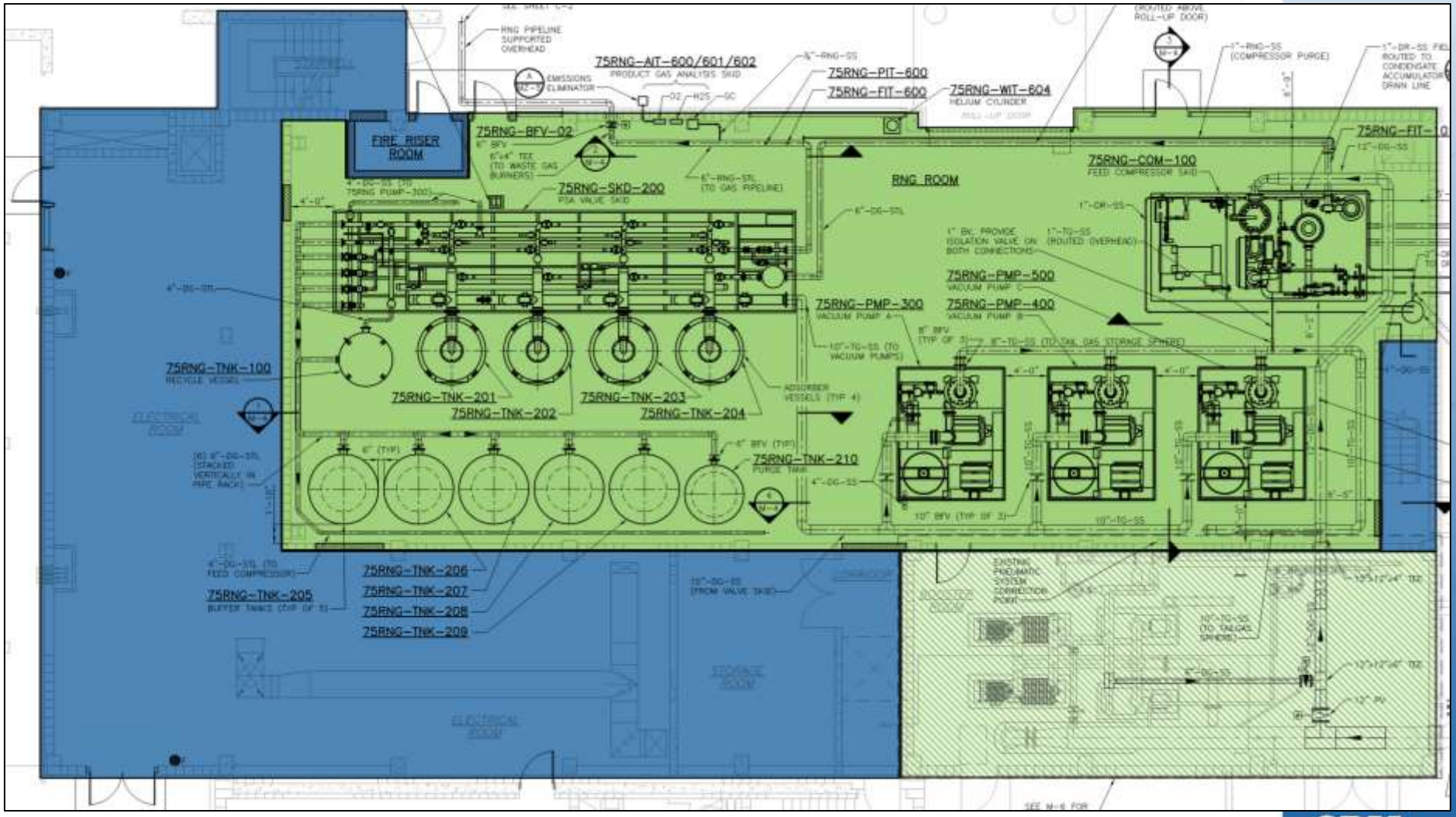
Area Classification & Building Modifications

- NFPA defines requirements of "Digester Gas Processing Rooms" involving biogas compression, handling, and processing equipment

Row	Location and Function	Ventilation Rate	Extent of Classified Area	NEC Area Electrical Classification	Material of Construction & Fire Protection Measures (2)
Row 18a	DIGESTER GAS PROCESSING ROOMS (Gas compression, handling, and processing)	No ventilation or ventilated at less than 12 air changes per hours	Entire room	Class 1, Division 1, Group D	NC, CGD, H, FE
Row 18b		Continuously ventilated at 12 air changes per hour	Within 1.5m (5-ft) of equipment	Class 1, Division 1, Group D	NC, LC, CGD, H, FE
Row 18c		Continuously ventilated at 12 air changes per hour	Entire Room	Class 1, Division 2, Group D	NC, LC, CGD, H, FE

NC – Noncombustible Material; LC – Limited-combustible material; CGD – Combustible Gas Detection System; H – Hydrant Protection; FE – Portable Fire Extinguisher

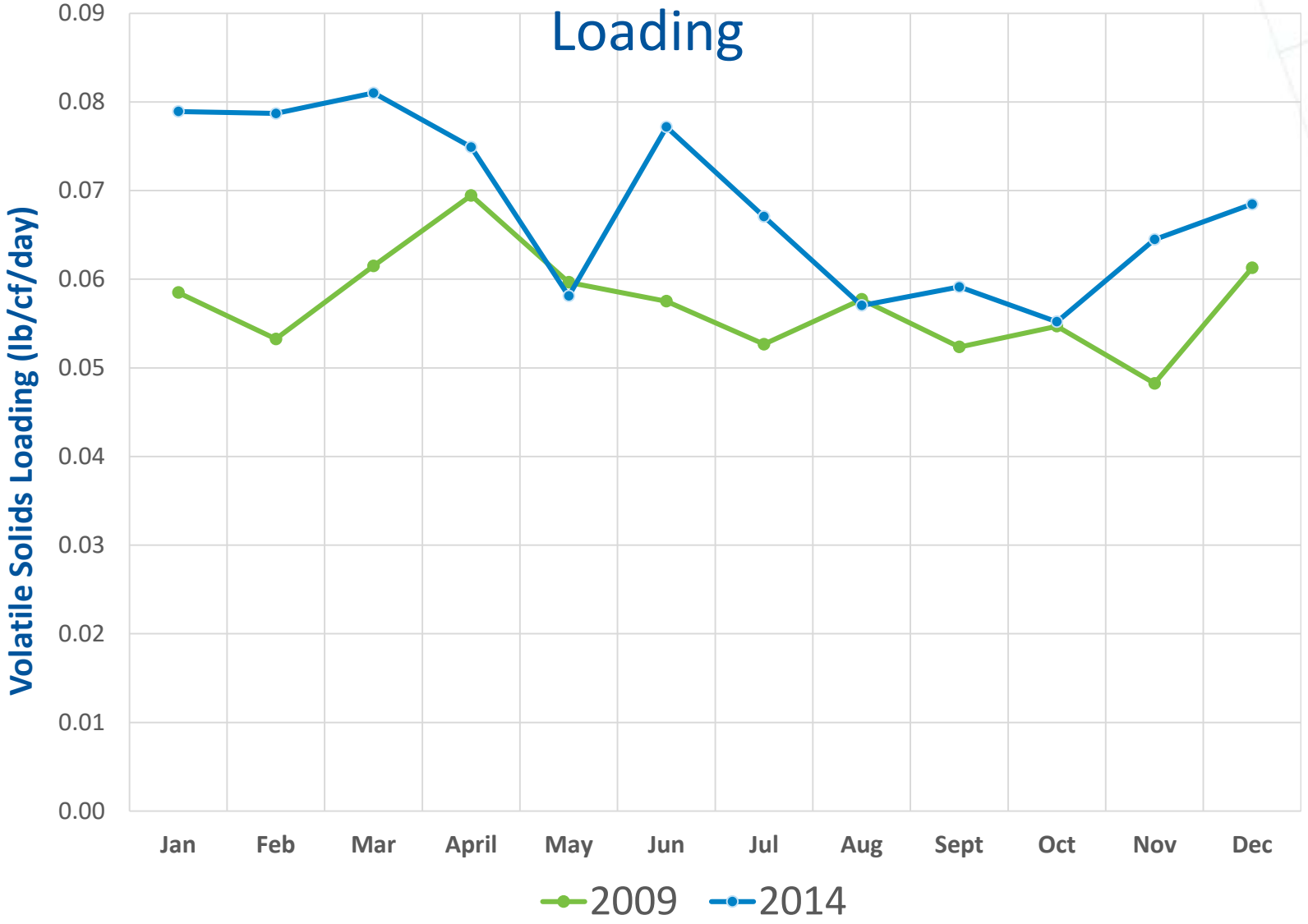
Area Classification Plan



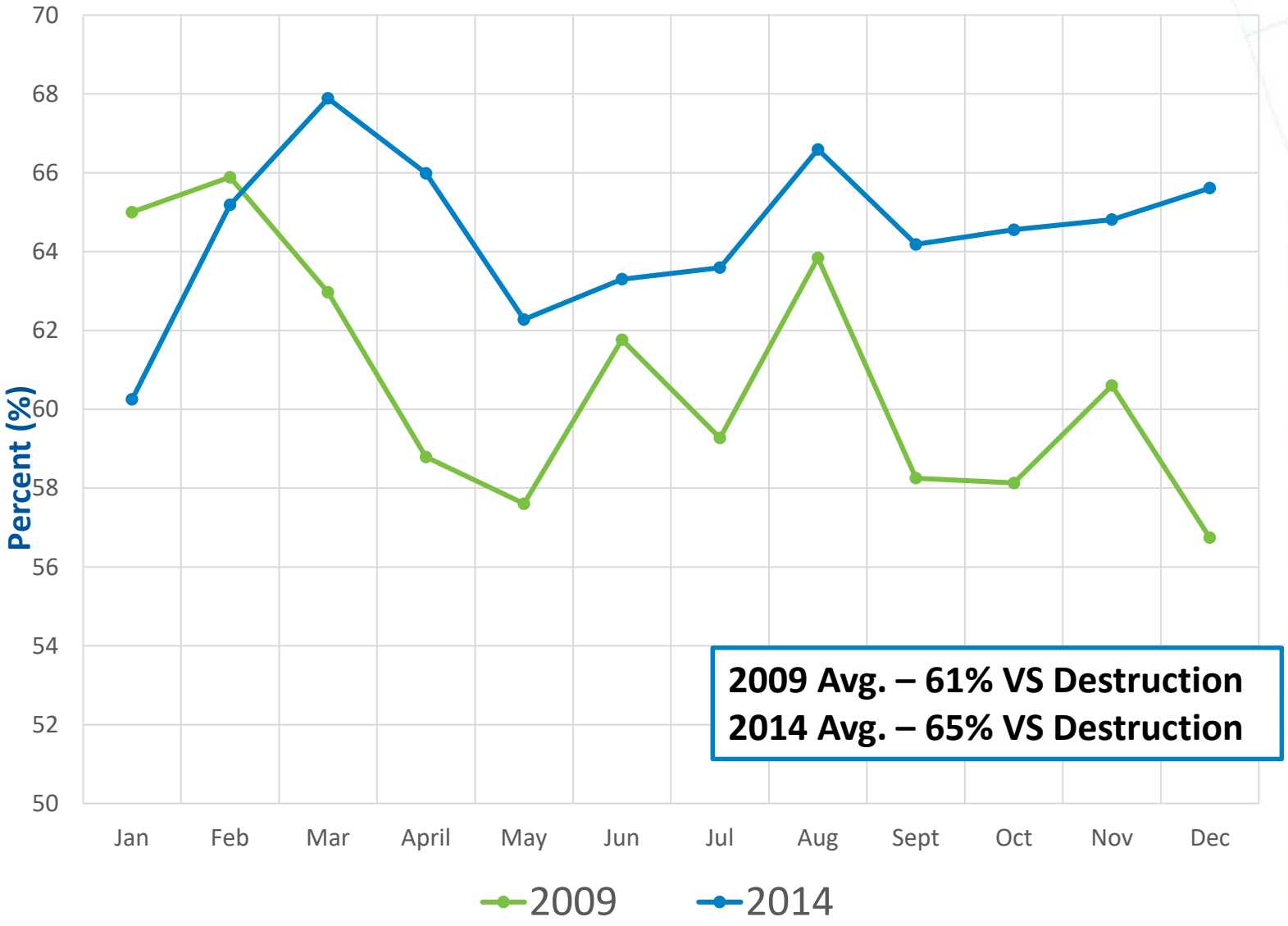
Current Project Status

- 100%: October 2016
- Construction duration: approximately 1 year
- Construction Capital Costs ~$12M
- Project Payback of ~4yrs
- Current value of RNG Injection + RIN credits is $10k a DAY!

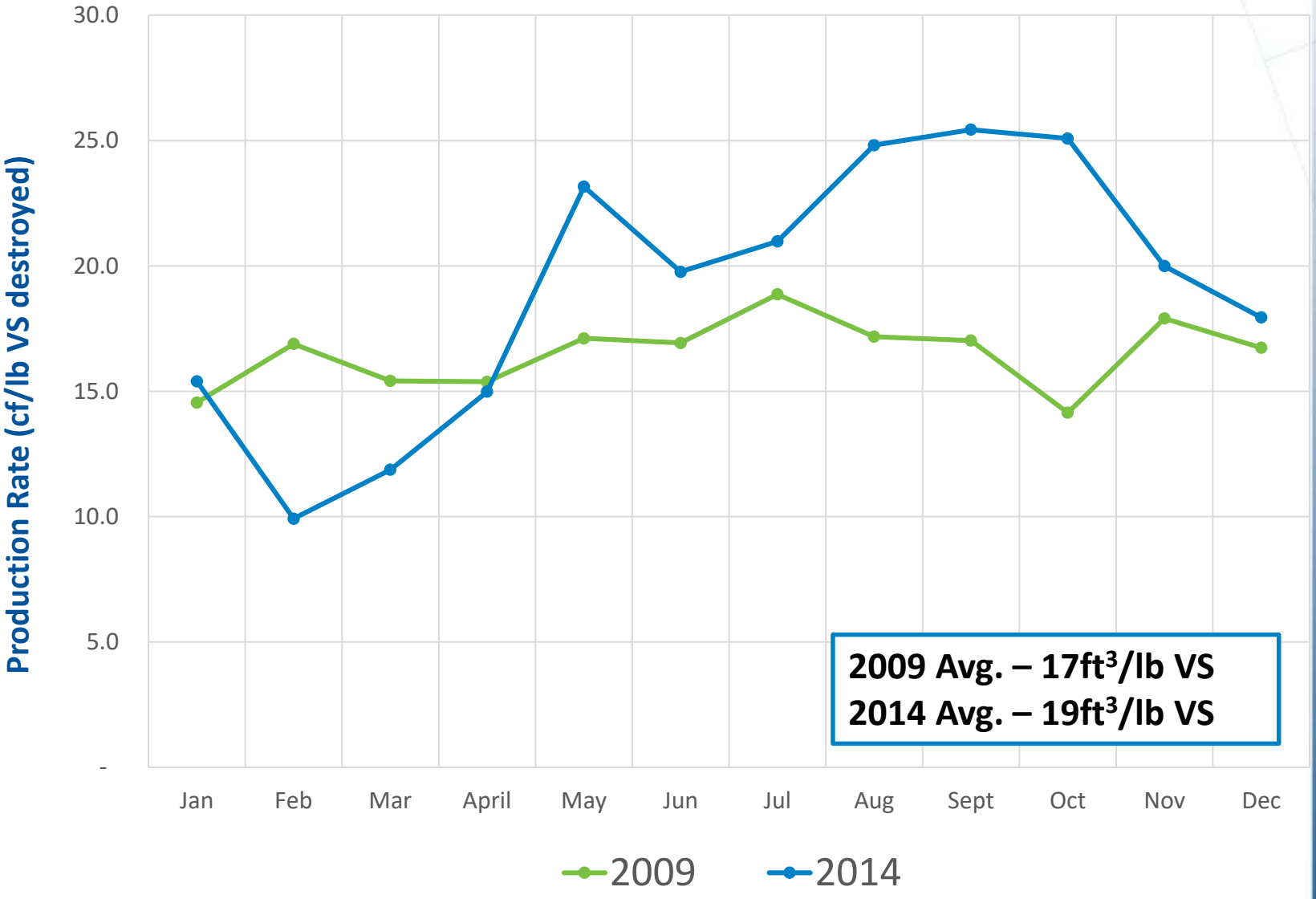
Blended Sludge Feed – Volatile Solids Loading

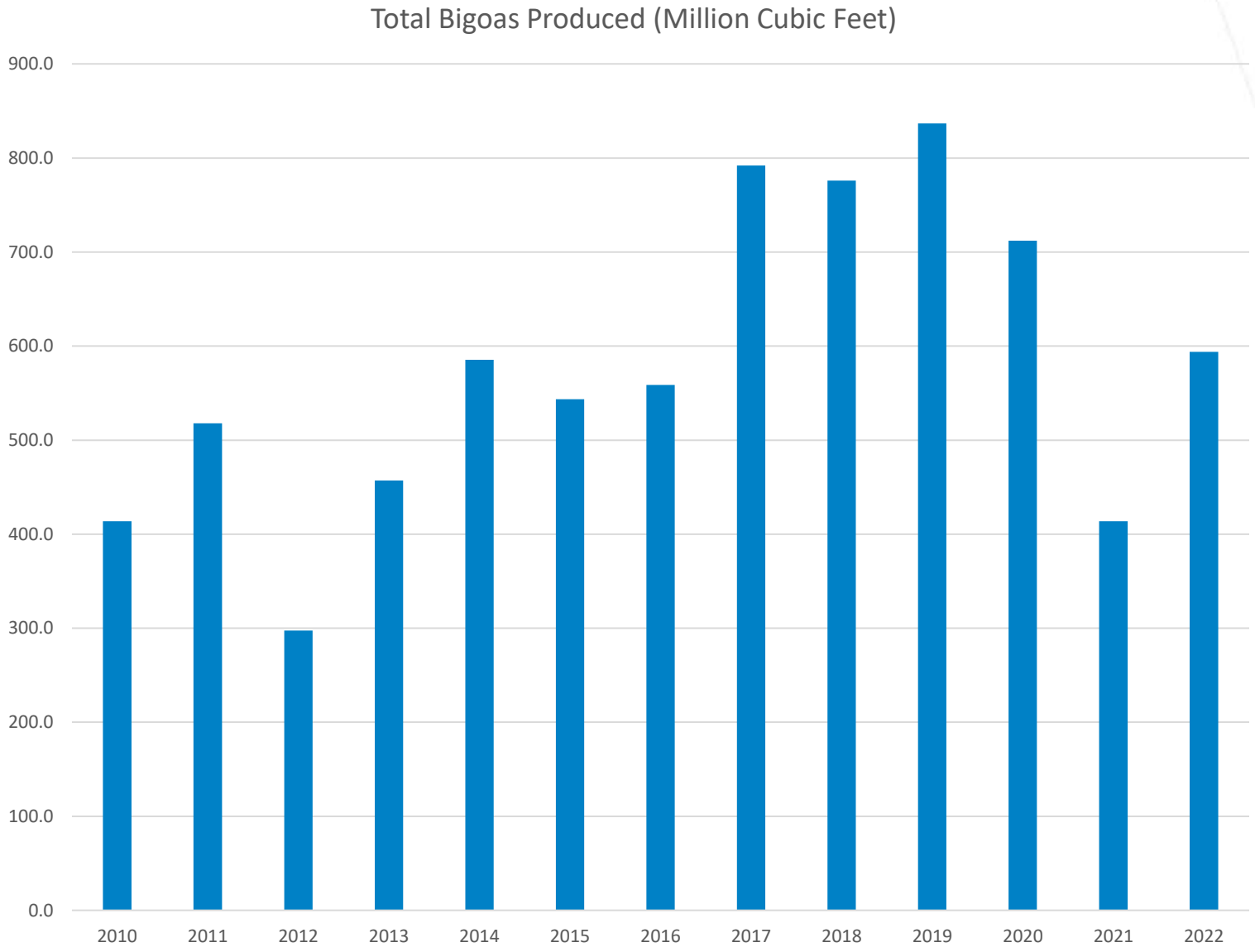


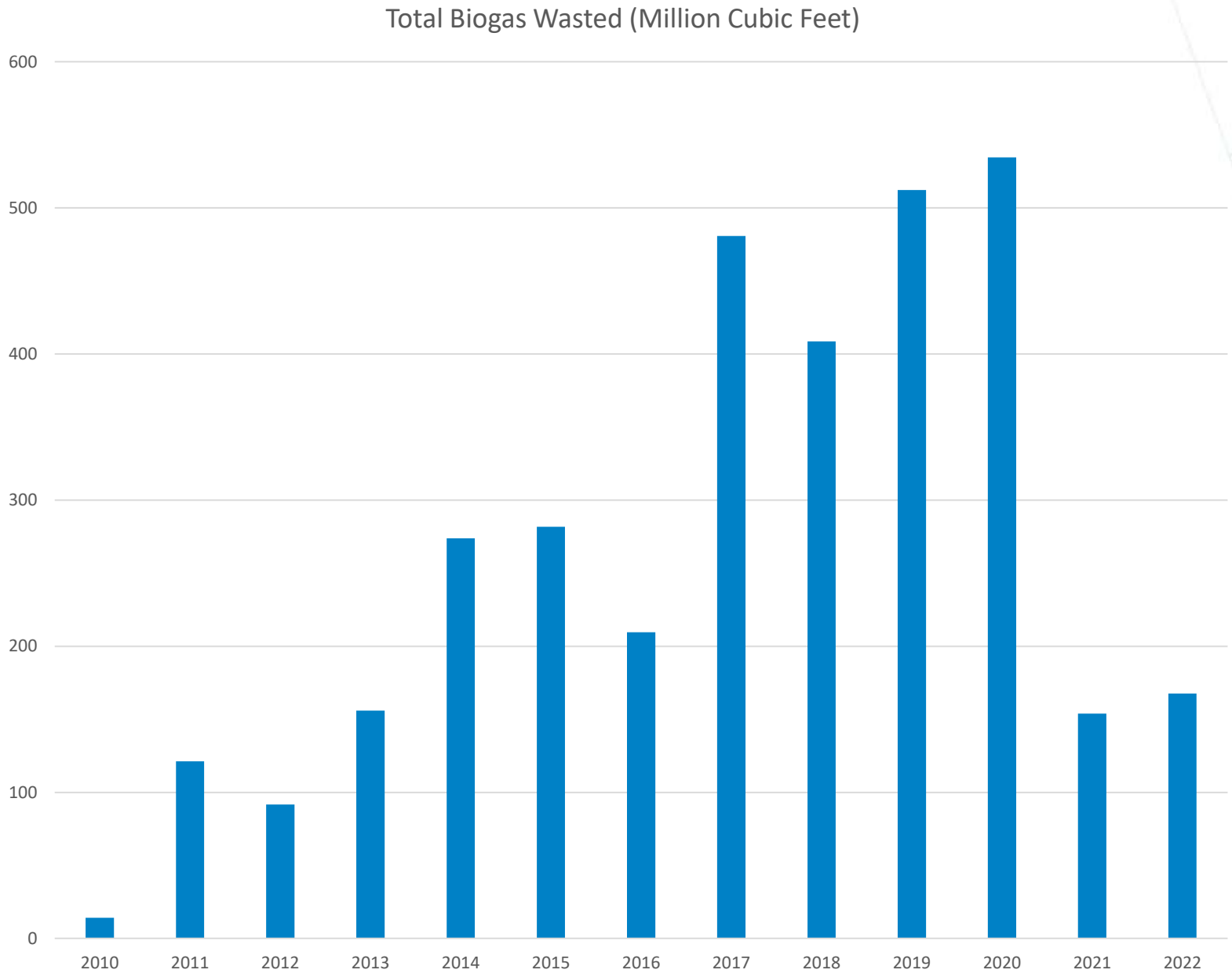
Volatile Solids Reduction



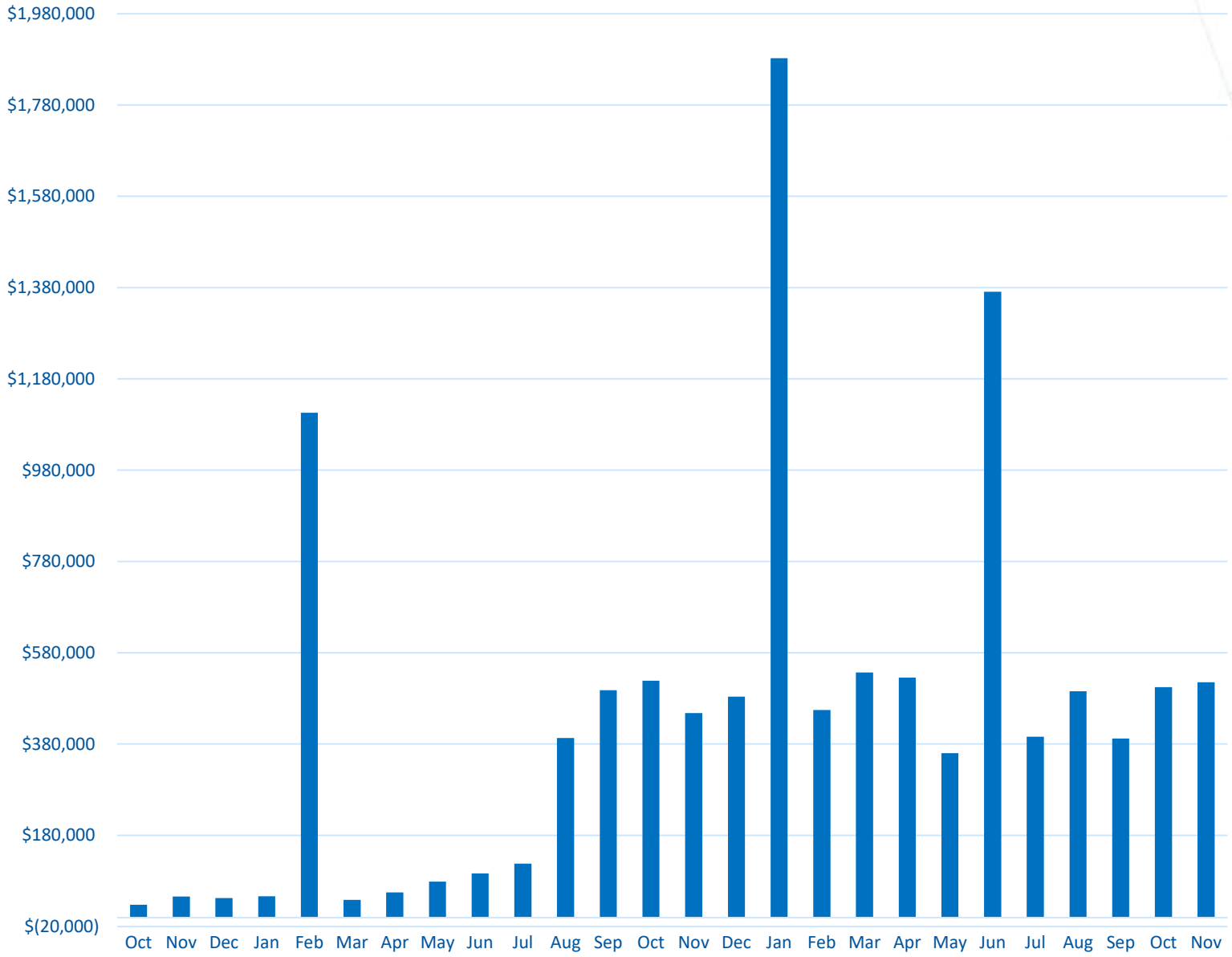
Average Biogas Production Rate

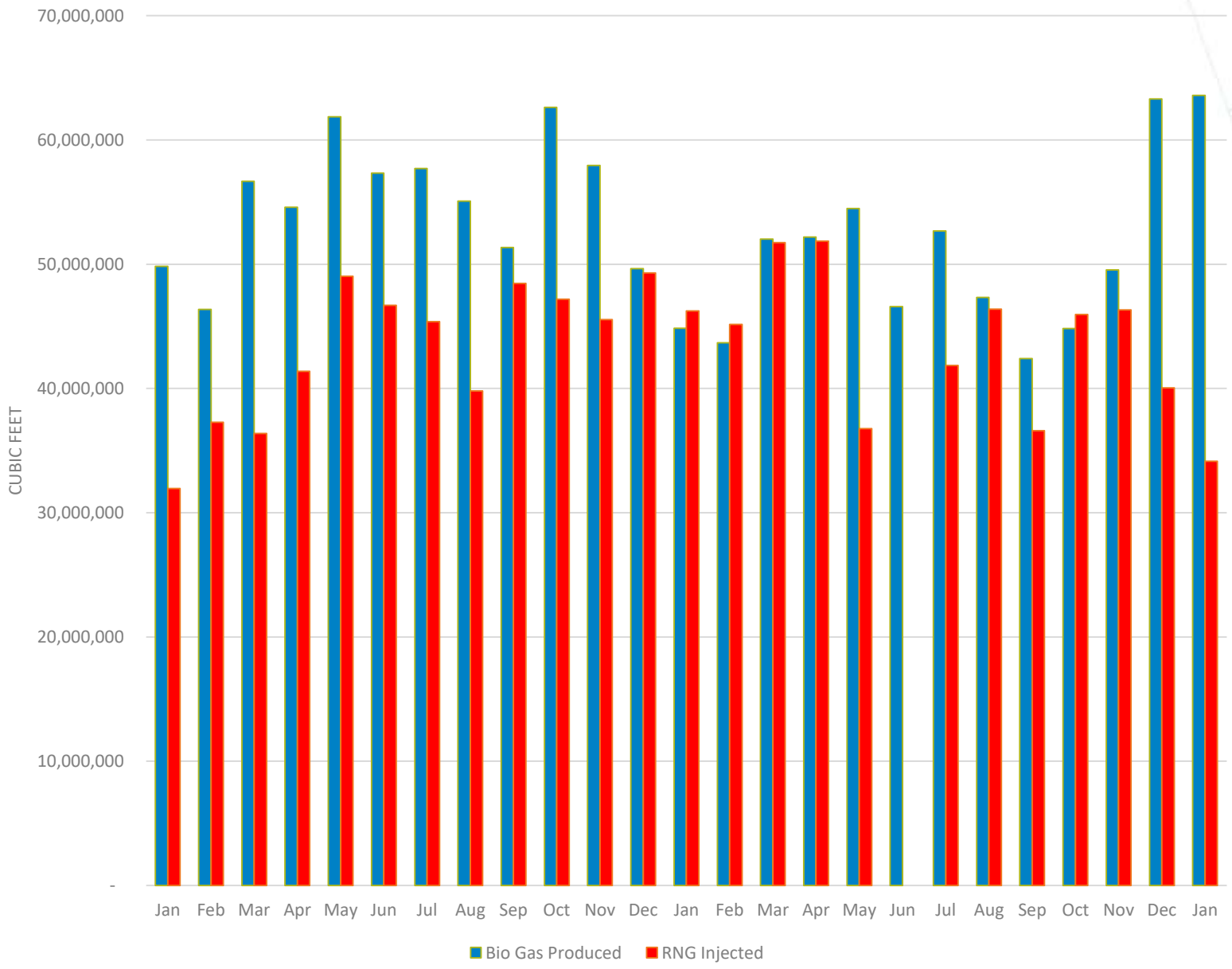



Total Bigoas Produced (Million Cubic Feet)
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022


Total Biogas Wasted (Million Cubic Feet)
600
500
400
300
200
100
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

Renewable Natural Gas - Net Revenue Earned




Bio Gas - RNG Process 2021/2022/2023
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
-
CUBIC FEET
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Bio Gas Produced
RNG Injected