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Guild Associates

California Rule 21/30 Compliance Made Easy!

Abstract:

This presentation reinforces Guild Associates as a multi-faceted engineering firm who strive to sustain our business by leveraging our technology and applying our creative insights to exploit new market niches, and by serving our customers' satisfaction and retention by streamlining our internal and external cooperation. California pipeline specifications are very extensive and stringent, demanding requirements above and beyond typical pipeline needs. But Guild has risen to the challenge by delivering unique and robust solutions to tackle the various stages of gas separation necessary to meet California Rule 21 and Rule 30. The presentation further explains the details of Guild's technologies, approach to RNG projects, and presents a successful case study of a fielded system meeting California Rule 21 and 30.

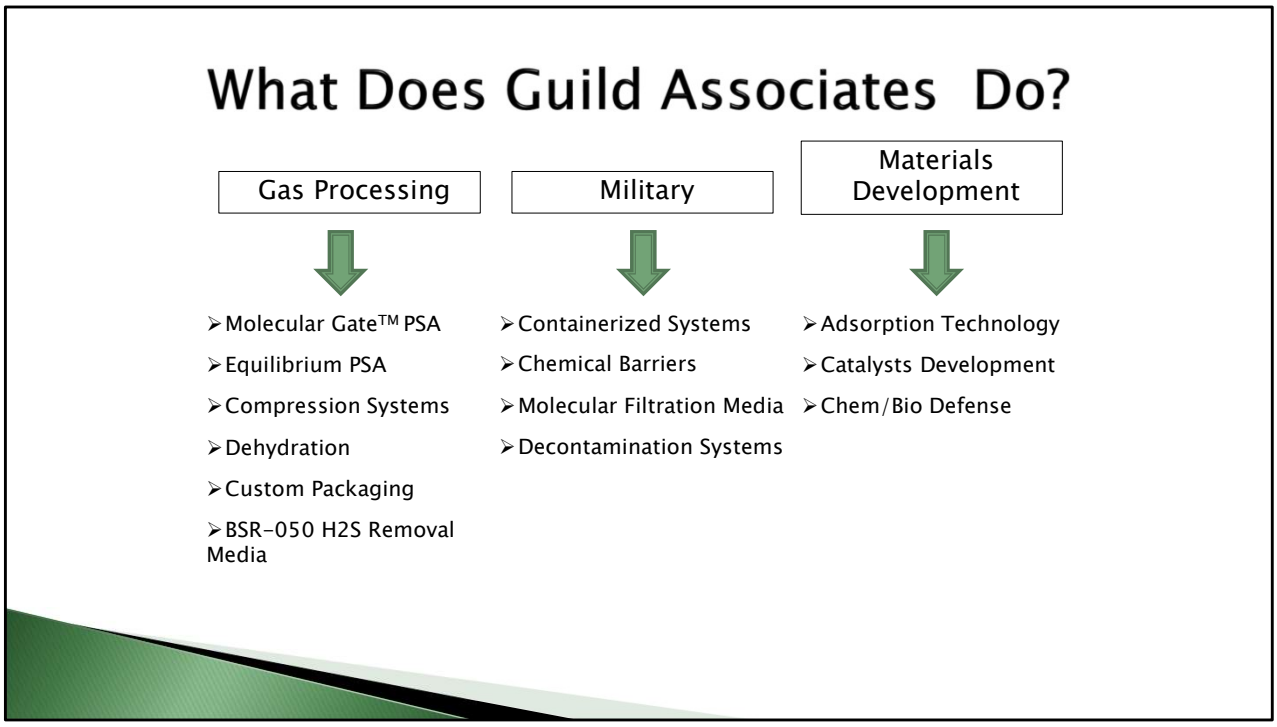
Agenda

- Guild Associates Background
- Rule 21, 30 Requirements
- RNG Project Challenges
- Guild Case Study Meeting Rule 21, 30

Who is Guild Associates?

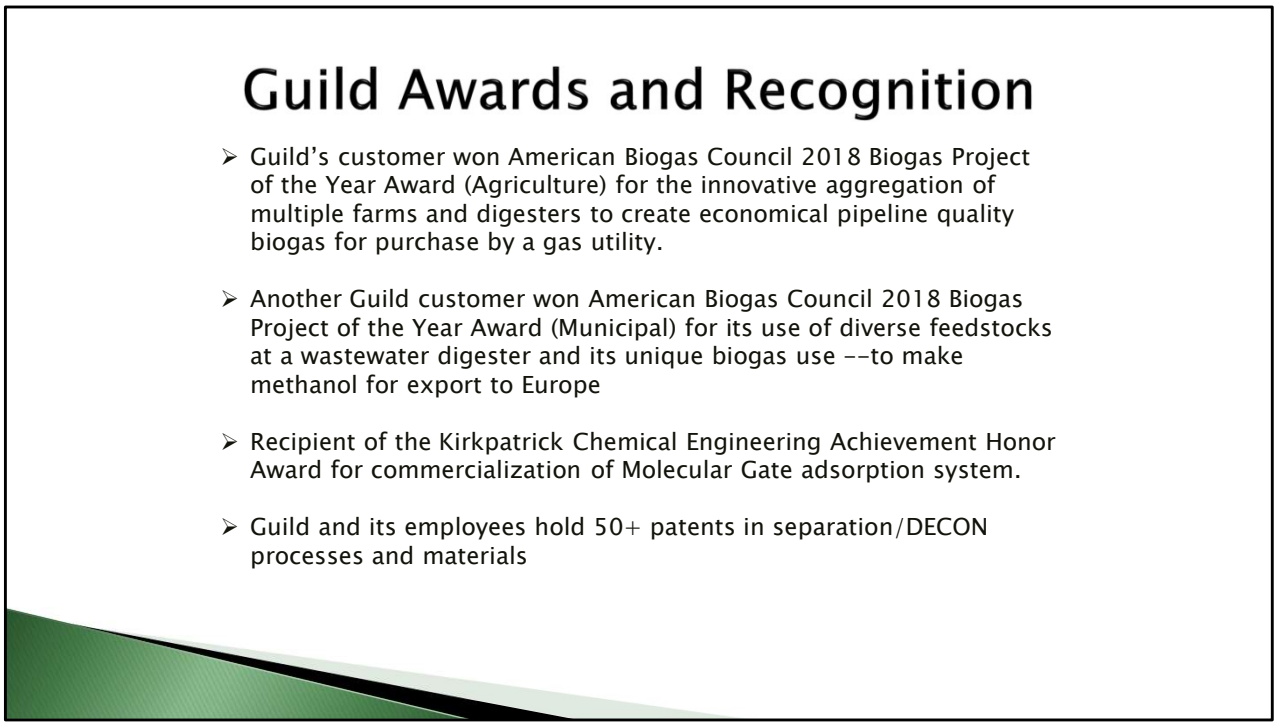
Over 35 years of technology innovation, system integration and engineered product delivery

- Founded 1981
- Headquarters: Dublin, Ohio
- ISO 9001:2015 Certified
- 53,000 ft^2 facility
- 80 employees



Gas Processing Details:

- Molecular Gate PSA – Mature technology used in various gas separation applications described in subsequent slides
- Equilibrium PSA – An immerging technology used as an alternative for N2/O2 removal
- Compression Systems – Capabilities included turn-key skidded systems, flow capacities 60-8000 scfm, pressure capacities 30-4500 psig
- Dehydration – 2-bed TSA regenerable dryers and chiller/air-cooling solutions
- Custom Packaging – Integration into ISO containers, building to foreign electrical classifications, building to extreme ambient conditions
- BSR-050 H2S Removal Media – Manufacturer of Guild's own H2S scrubbing material. See Dr. Joseph Rossin's presentation, "C3.1 BSR-050 – A NOVEL HIGH CAPACITY H2S REMOVAL MEDIA"



The City of Dodge City's Warrior Project won the 2018 Project of the Year Award in the Municipal category presented by the American Biogas Council. The Warrior Project was an addition to the existing Waste Water Treatment plant which treats both Municipal, from the City of Dodge City, and industrial effluent, from National Beef Processors, and processes the resulting biogas for insertion into the natural gas grid. This biogas is sold as transportation fuel to a retailer in the upper Midwest but is also used as a fuel supplement in Europe. Guild Associates provided the upgrading facility equipment as a turn-key Molecular Gate™ CO2 PSA, identical to the unit in this proposal in all aspects of operation and materials with the exception of feed flow rate.

One notable item is the design specifications indicated 6,000 ppm of hydrogen sulfide (H2S) in the feed gas, however shortly before the installation it was discovered to be significantly higher (11,000 ppm). No changes were made to the design of the equipment, and the unit functions today as designed, with less than 4 ppm in the product stream.

Ray Slattery (rays@dodgecity.org, 620-225-8106) the Director of Engineering Services of the City of Dodge City, and Project Manager for the Warrior Project, had kind words to say about the overall Guild Associates performance on the project: "Guild Associates was a **great partner** in the Warrior Project, as we trusted that they would completely handle the entire gas processing train, enabling Dodge City to focus on the other critical parts of the

project. **And they delivered!** Once the equipment was installed, the **customer service** we received from Guild Associates was **unbelievable**."

The Optima KV swine-waste to energy project won Project of the Year for the Agricultural Category. Optima BioEnergy LLC and Cavanaugh Solutions (Gus Simmons, 910-619-0072, gus.simmons@cavanaughsolutions.com) utilized Guild Associates Molecular GateTM CO2 PSA, identical to the unit in this proposal in all aspects of operation and materials with the exception of feed flow rate. This project routed the biogas generated from digesters at five hog farms to one central location where the Guild Associates equipment removed CO2, H2S, water and VOCs to meet pipeline quality and insert the gas to the grid. The Optima Bio team has purchased and installed two additional Guild Associates Molecular GateTM systems for their newly completed project, the Optima TH project in Tar Heel, NC.

Overview of Rule 21/30 Requirements

	PG&E 21	SoCal Gas 30
Heating Value, BTU/SCF	(defined at each insertion pt)	970
CO2	1%	3%
O2	0.1%	0.2%
Wobbe	(defined at each insertion pt)	1279 – 1385

Note: H2S, Mercaptan Sulfur, Total Sulfur, H2O specs are all within normal pipeline standards.

Typical pipeline requirements are as follows:

Heating Value – 950-975

CO2 - <2%

O2 < 0.2%

Wobbe -1250-1280

H2S – 0.25 g/100ft3 gas

Mercaptan Sulfur – 0.3 g/100ft3 gas

Total Sulfur – 0.75 g/100ft3 gas

H2O – 7 lbs/MMcf

Trace Level Constituents

	Trigger level, ppmv	Lower Action Level, ppmv	Upper Action Level, ppmv
Chemical, Carcinogenic			
Arsenic	0.006	0.06	0.15
p-Dicholorobenzene	0.95	9.5	24
Ethylbenezene	6.0	60	150
n-Nitroso-di-n-propylamine	0.006	0.06	0.15
Vinyl Chloride	0.33	3.3	8.3
Chemical, Non-Carcinogenic			
Antimony	0.12	1.2	6.1
Copper	0.02	0.23	1.2
Hydrogen Sulfide	22	216	1080
Lead	0.009	0.09	0.44
Mercaptans	12	120	610
Methacrolein	0.37	3.7	18
Toluene	240	2400	120000
	Trigger level, [C]	**Lower Action Level, [C]**	**Upper Action Level, [C]**
Chemical, Pipeline Intefrity			
Ammonia	0.001 vol%	TBD	TBD
Biologicals - Acid producing bacteria (APB)	4x10^4/SCF	TBD	TBD
Biologicals - Iron-oxidizing Bacteria (IOB)	4x10^4/SCF	TBD	TBD
Biologicals - Sulfate-reducing Bacteria (SRB)	4x10^4/SCF	TBD	TBD
Hydrogen	0.1 vol%	TBD	TBD
Mecury	0.08 mg/m^3	TBD	TBD
Siloxanes	0.01 mg Si/m^3	0.1 mg Si/m^3	TBD

Rule 21 last revised July 17, 2019, Rule 30 last revised July 7, 2019.

Trigger Level: below line requires annual monitoring, above requires monthly monitoring

Lower Action Level: Above this limit causes a review, too many constituents above this level can cause a shut-in (calculated risk)

Upper Action Level: Immediate shut-in

California RNG Project Challenges

1	Project Expenses
2	RNG Technology Selection
3	Gas Delivery Specification

The following 3 items are what Guild focuses on when building a solution for potential clients.

1. Project Expenses

- Pipeline Interconnect Cost
  - $3-$5 Million Dollars Has Been Reported.
- The interconnect cost alone kills many small projects.
- Acceptance Tests periods prolong high revenue credits
- Prohibits market entry for small businesses.
- RNG testing costs can be expensive

2. RNG Technology Selection

CO2 Removal Systems

- **Amine Wash / Water Wash**
  - Complicated Operation
  - High Waste Disposal Cost
- **Membrane**
  - Simple Operation
  - Pre-treatment Required
  - Varying Feed Gas Composition Causes Unpredictable Pre-Treatment Efficiency
  - CFC Breakthrough highly likely
  - 50% Recycle
- **PSA**
  - Automated Operation
  - No Pre-Treatment
  - Single Step Removal of Bio-Gas Impurities
  - Feed Gas Variation has less effect on performance
  - Only Regenerable Media Needed to Meet Pipeline Specification
    - H2S Media may be Required if H2S cannot be burned in TOU (Air Permitting Requirement)

The market has many different choices for technologies to work for your application. Understanding the pros and cons of each type is important to see before selecting one for your application.

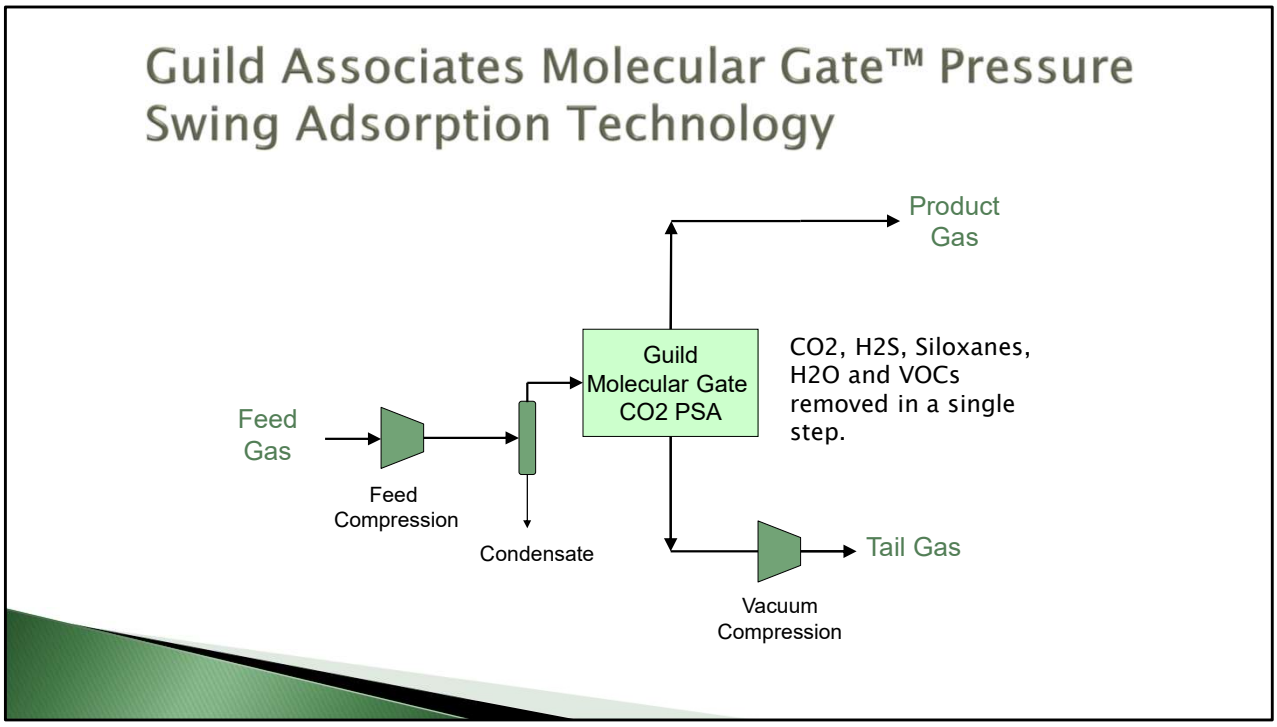
Details of CO2 Molecular Gate PSA's:

Automated Operation – The system has simplified, one-click start ups and shutdowns, with all warm-up and cool-down subroutines run automatically.

No Pre-Treatment – The impurities found in biogas feed stocks, such as H2S, siloxanes, VOC's, and water, can all be tolerated and removed with the system. All of these impurities leave the system during the vacuum step and burned/destroyed in a thermal oxidizer or flare system.

Feed Gas Variations – The PSA's are designed to work within 25%-100% of design flow and the ability to treat gas of varying composition without manual intervention.

Regenerable Media – Patented media has proven to last the life of the plant's service without degradation in performance or capacity. The longest running plant has been in service for 10 years with the same initial charge of media without loss of performance.



Details of the process flow diagram:

Feed Compression – Biogas is fed from the landfill, digester, or feed blower system into a Guild feed compressor. This compresses the gas up to adsorb pressure, 100 PSIG

Condensate – Air cooling is used to drop out free liquids from the compressed biogas into a knockout vessel, removing the majority of the feed moisture.

Molecular Gate CO2 PSA – The biogas is fed into the bottom of an adsorber, which adsorbs all the impurities including CO2 at high pressure. Methane-rich gas leaves the top of the vessel. This product gas is sent to the pipeline or product compression for sales.

Vacuum Compression – The PSA process produces waste gas by lowering the adsorber vessel pressure to full vacuum, allowing the saturated media to off-gas the impurities in one step. The tail gas leaves the vacuum compression step and moves to a thermal oxidizer or flaring system to be burned/destroyed.

2. RNG Technology Selection

N2 Removal Systems

Parameter	Carbon PSA	Zeolite PSA
Methane Recovery	Typically 96%	Typically 88%
Oxygen Rejection	Mostly removed	Split between product and tail gas
CO2 Rejection	Passed to Product Gas	Rejected with N2
System Sizing	Less sensitive to N2 in feed gas	More sensitive to N2 in feed gas
Media Availability	Commercially Available	Guild Associates Proprietary
Product Gas Pressure	20 PSIG	90 psig
Power Consumption	Higher	Lower
Operational Cost	Higher	Lower
Media Life	Process Dependent	Life of the Equipment

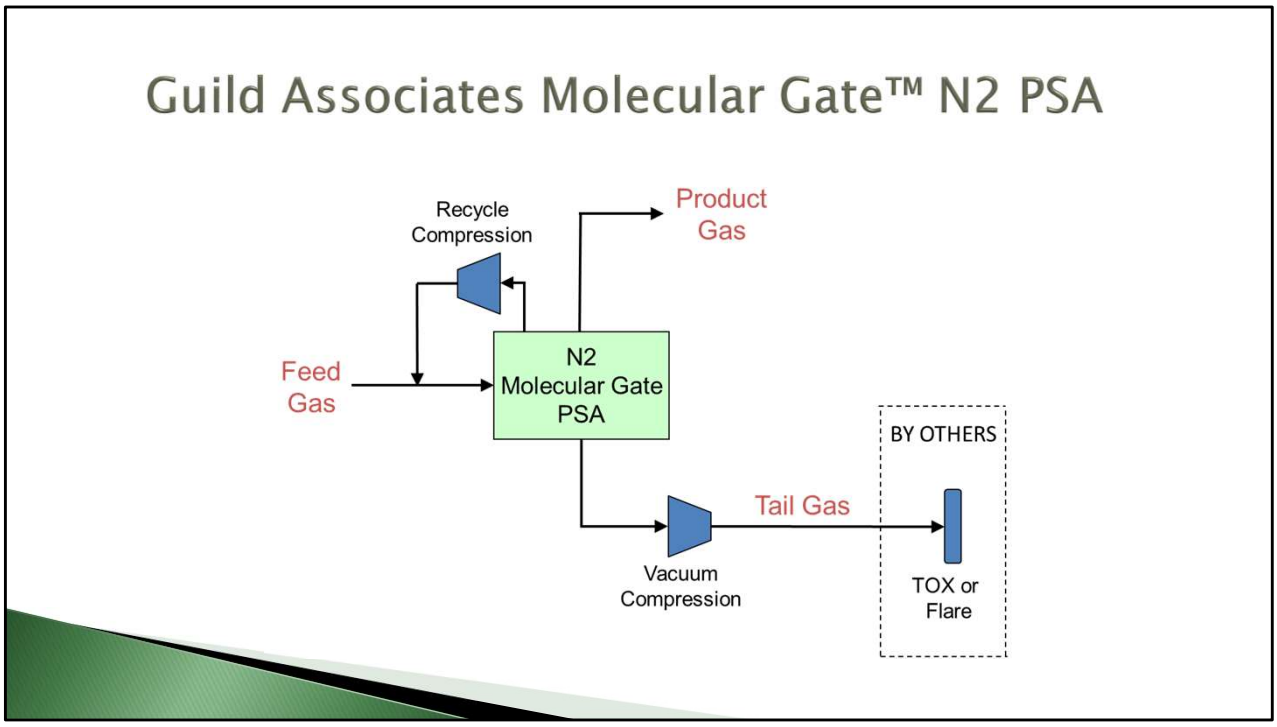
After years of success removing impurities with Guild's Molecular Gate media, the exploration in alternatives became promising for N2 removal.

Guild now has a fully developed PSA system using a carbon-based media to remove N2 and O2.

The largest difference in the process was how carbon adsorbs methane and CO2 versus the N2 and O2. This difference generates a set of pros and cons between the patented zeolite media and the carbon media.

The table here shows where the advantages lie in green.

Guild will assist in making sure your application uses the best technology that suits your needs.

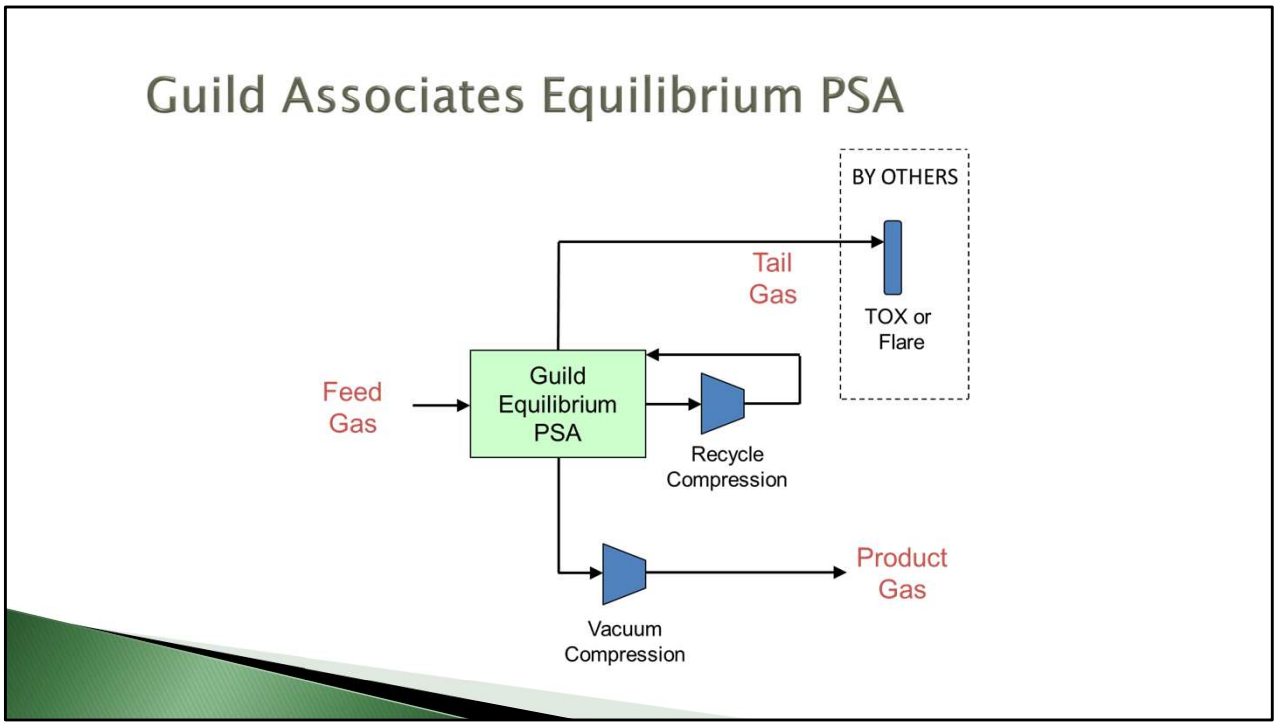


Details of the process flow diagram:

N2 Molecular Gate PSA – The inlet gas is fed into the bottom of an adsorber, which adsorbs all the N2 and remaining CO2 at high pressure. Methane-rich gas leaves the top of the vessel. This product gas is sent to the pipeline or product compression for sales.

Vacuum Compression – The PSA process produces waste gas by lowering the adsorber vessel pressure to full vacuum, allowing the saturated media to off-gas the impurities. The tail gas leaves the vacuum compression step and moves to a thermal oxidizer or flaring system to be burned/destroyed. This gas can sometimes be used as a fuel source for boilers or power generation.

Recycle Compression – The N2 Molecular Gate PSA utilizes a small recycle step to improve the recovery of methane. This gas is pulled off the adsorbers at low, atmospheric pressures and repressurized to feed pressure.



Details of the process flow diagram:

Guild Equilibrium PSA – The inlet gas is fed into the bottom of an adsorber bed. The methane and CO2 is adsorbed at high pressure. The N2 and O2 then leave the top of the adsorber. This waste gas is metered out of the system using buffer volume and a flow control valve, to which it flows to a thermal oxidizer or flaring system to be burned/destroyed.

Vacuum Compression – The Equilibrium PSA process produces product gas by lowering the adsorber vessel pressure to full vacuum, allowing the saturated media to off-gas the methane. The product gas leaves the vacuum compression step and moves to a pipeline or product compression for sales.

Recycle Compression – The Equilibrium PSA has an internal recycle loop that increases methane recovery and the utilization of the media.

3. RNG Delivery Specification (CA Rule 30/21)

- Pipeline Specification can be Difficult to Meet/Qualify
- Gas acceptance protocol can drive process inefficiencies
- Few Laboratories Capable of Testing to Specification Requirements
- Testing can be Expensive

The last aspect to RNG projects circles back to the topic of California Rule 21 and Rule 30.

The technologies efficiencies are reduced when pipeline specifications are overly tight, with strict acceptance protocols and long acceptance tests.

Finding reputable test labs capable of measuring Rule 21 and Rule 30 can be restrictive and expensive.

The more realistic the specifications are, the more probable the system can meet the demand.

Guild Case Study

Featured Projects: Billings Landfill
Billings, Montana – Commissioned 2010

Dual CO2 N2 PSA

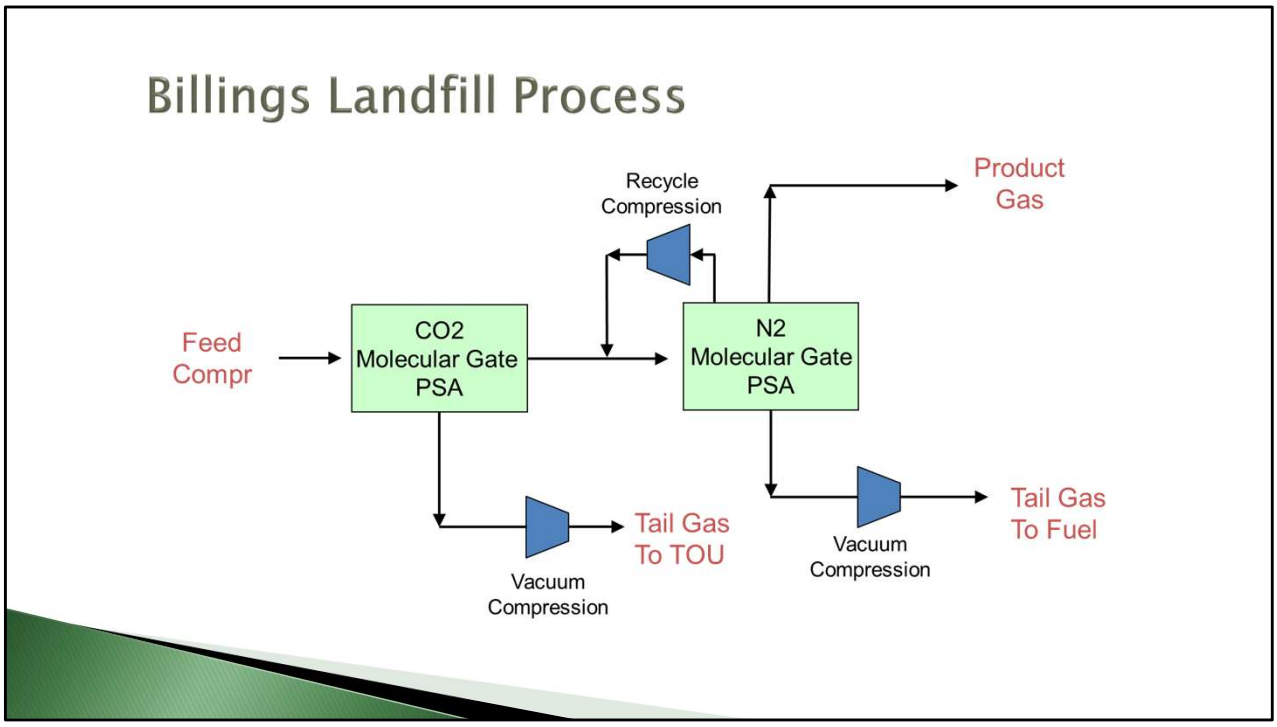
- 2400 SCFM Feed
- 90% Methane Recovery
- 98% uptime

Guild Scope:

- CO2 PSA Skid
- N2 PSA Skid
- Recycle Compr.
- Vacuum Compr.

The feed conditions for this plant are:

Flow:	2400 scfm
CH4%:	50%
N2%:	5.85%
CO2%:	43.5%
O2%:	0.5%
H2O%:	0.15%
Pressure:	110 PSIG
Temperature:	158°F



Similar to previous process flow diagrams, this system incorporated a Molecular Gate CO2 PSA in series with a Molecular Gate N2 PSA.

The product of the CO2 PSA fed the N2 PSA. The CO2 PSA tail gas goes to a thermal oxidizer, while the N2 PSA waste goes to fuel on-site equipment.

Summary Of Rule 30 And 21 Requirements And Results

	Trigger level, ppmv	Lower Action Level, ppmv	Upper Action Level, ppmv		Guild Testing Feed, ppmv	Guild Testing CO_2 PSA Effulent, ppmv	Guild Testing N_2 PSA Effulent, ppmv
Chemical, Carcinogenic							
Arsenic	0.006	0.06	0.15		ND, <0.006	ND, <0.006	ND, <0.006
p-Dicholorobenzene	0.95	9.5	24		0.275	ND, <0.001	ND, <0.001
Ethylbenezene	6.0	60	150		81	ND, <0.001	ND, <0.001
n-Nitroso-di-n-propylamine	0.006	0.06	0.15		BDL, 1 ppm	BDL, 1 ppm	BDL, 1 ppm
Vinyl Chloride	0.33	3.3	8.3		1	0.2250	0.0090
Chemical, Non-Carcinogenic							
Antimony	0.12	1.2	6.1		ND, <0.0026	ND, <0.0026	ND, <0.0026
Copper	0.02	0.23	1.2		ND, <0.0031	ND, <0.0031	ND, <0.0031
Hydrogen Sulfide	22	216	1080		86.5	ND, <0.011	ND, <0.011
Lead	0.009	0.09	0.44		ND, <0.0012	ND, <0.0012	ND, <0.0012
Mercaptans	12	120	610		2.219	ND, <0.011	ND, <0.011
Methacrolein	0.37	3.7	18		Not Found	Not Found	Not Found
Toluene	240	2400	120000		18.5	ND, <0.001	0.002
	Trigger level, [C]	**Lower Action Level, [C]**	**Upper Action Level, [C]**		**Guild Testing Feed**	**Guild Testing CO_2 PSA Effulent**	**Guild Testing N_2 PSA Effulent**
Chemical, Pipeline Intefrity							
Ammonia	0.001 vol%	TBD	TBD		BDL, 1 ppm	BDL, 1 ppm	BDL, 1 ppm
Biologicals - Acid producing bacteria (APB)	4x10^4/SCF	TBD	TBD		1.68E+04	1.35E+03	BDL
Biologicals - Iron-oxidizing Bacteria (IOB)	4x10^4/SCF	TBD	TBD		Not Detected	Not Detected	Not Detected
Biologicals - Sulfate-reducing Bacteria (SRB)	4x10^4/SCF	TBD	TBD		Not Detected	Not Detected	Not Detected
Hydrogen	0.1 vol%	TBD	TBD		BDL	BDL	BDL
Mecury	0.08 mg/m^3	TBD	TBD		BDL	BDL	BDL
Siloxanes	0.01 mg Si/m^3	0.1 mg Si/m^3	TBD		7.7 mg Si/m^3	<0.016 mg Si/m^3 per species	<0.016 mg Si/m^3 per species

From the lab results, all of the measured components read below the trigger limits specified in Rule 21 and Rule 30 after the CO2 PSA.

Also note that the majority of the species were below the detectable limits of the laboratory.

Once the gas processed through the N2 PSA, the product stream met all requirements for Rule 21 and Rule 30.

Siloxane Testing

Constituent	Feed	After CO2 PSA	After N2 PSA
	Si µg/m³	Si µg/m³	Si µg/m³
Trimethylsilanol	3650	BDL	BDL
Hexamethyldisiloxane (L2)	1700	BDL	BDL
Hexamethylcyclotrisiloxane (D3)	225	BDL	BDL
Octamethyltrisiloxane (L3)	93	BDL	BDL
Octamethylcyclotetrasiloxane (D4)	1800	BDL	BDL
Decamethyltetrasiloxane (L4)	BDL	BDL	BDL
Decamethylcyclopentasiloxane (D5)	205	BDL	BDL
Dodecamethylpentasiloxane (L5)	BDL	BDL	BDL
Dodecamethylcyclohexasiloxane (D6)	BDL	BDL	BDL
Total Silicon	7700	BDL	BDL

Trigger Level: 10 Si µg/m³ Lower Action Level: 100 Si µg/m³

This slide further details the various species of siloxanes measured at the Billings plant. After processing through the Guild PSA's, the system removed all species to below detectable limits.

Thanks for viewing my presentation!

Please reach out to myself or Tyler Russell at 614-652-6526 (trussell@guildassociates.com) so we can help you engineer your next system!