"-then the Lord God formed the man out of the dust of the ground and blew into his nostrils the breath of life, and the man became a living being." **Genesis** 2:7

KO_2

THE KOLODJI CORPORATION

Black Swan, LLC

04/19/2021

GENERON

Eliminating Supplemental Natural Gas in Biogas Fired Power Generation

PRESENTED AT

American Institute of Chemical Engineers

Fuels and Petrochemicals Division

2021 Gas Utilization Topical Conference Keynote

Brian Kolodji, PE

President and Owner of Kolodji Corp and Black Swan, LLC

bkolodji@sbcglobal.net

Office: (661) 742-1659- Cell: (713) 907-8742

Website: K-O2.com

and

Marc Straub, Vice President

Generon

Patent Pending Membrane Air Enrichment (MAE) Process for Oxy-Combustion: Chemistry

- Simplified Gas Combustion with Air Feed (Dry at 21% O_2 , 79% N_2)
  - Stoichiometry: $CH_4 + 2\ O_2 + 8\ N_2 >>> CO_2 + 2H_2O + 8\ N_2$
  - Fuel heating value heats 11 moles of combustion product gas, 8 moles being inert N_2
  - Firing temperature reduced by heating inert (nitrogen)

- Membranes Enrich Oxygen from 21% O_2 in Dry Air to ~50% O_2 (~30% Increase)
  - New Combustion Stoichiometry: $CH_4 + 2\ O_2 + 2\ N_2 >>> CO_2 + 2H_2O + 2\ N_2$
  - Fuel heating value heats only 5 moles of combustion product gas, with only 2 being inert N_2
  - 30% O_2 increase in combustion air (to 50% O_2): Over 60% Fuel & 90% NOX Reductions**
  - Biogas Power– under 5% O_2 Increase (25% $O_{2)}$ needed provides over 30% Fuel Savings**

****Inverse Economy of Scale per DOE/GO-102005-2178 (1/2 the savings for only 1/6 scale)**

Energy Tips – Process Heating

Process Heating Tip Sheet #3 • September 2005

Industrial Technologies Program

Oxygen-Enriched Combustion

Figure 2. Energy savings from oxygen injection

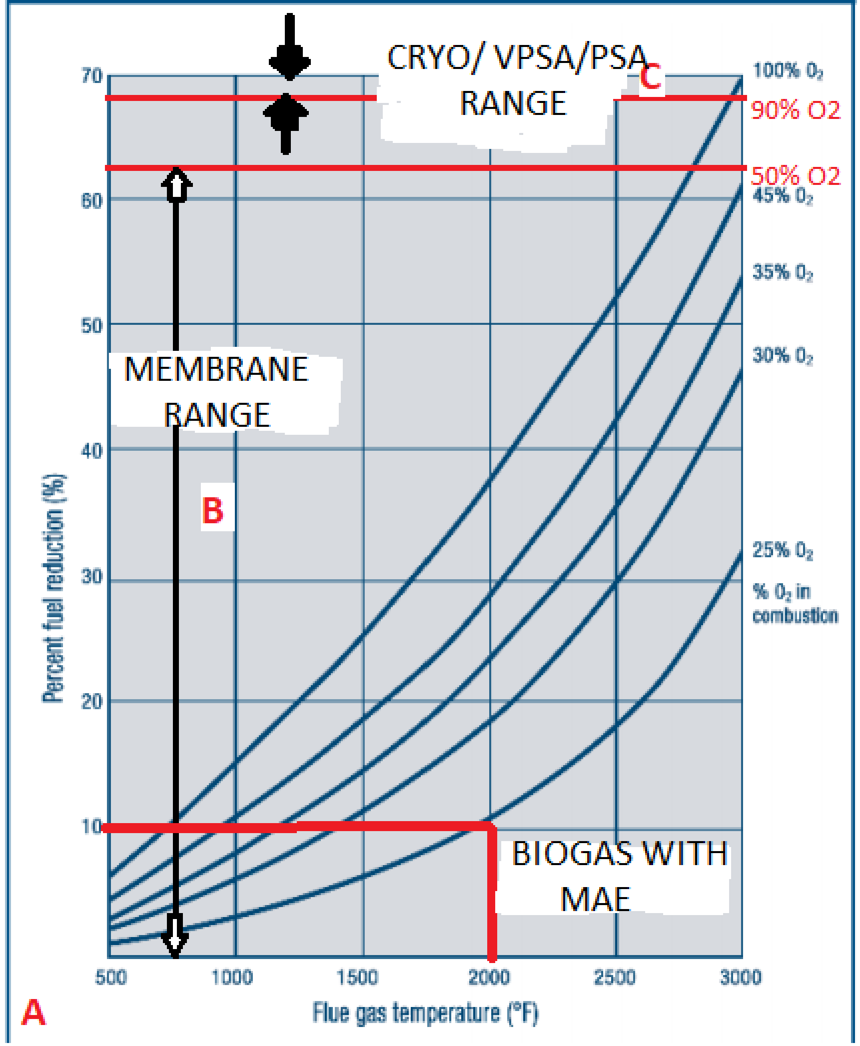


Figure 2 Reference: DOE/GO-102005-2178 September 2005 Process Heating Tip Sheet #3

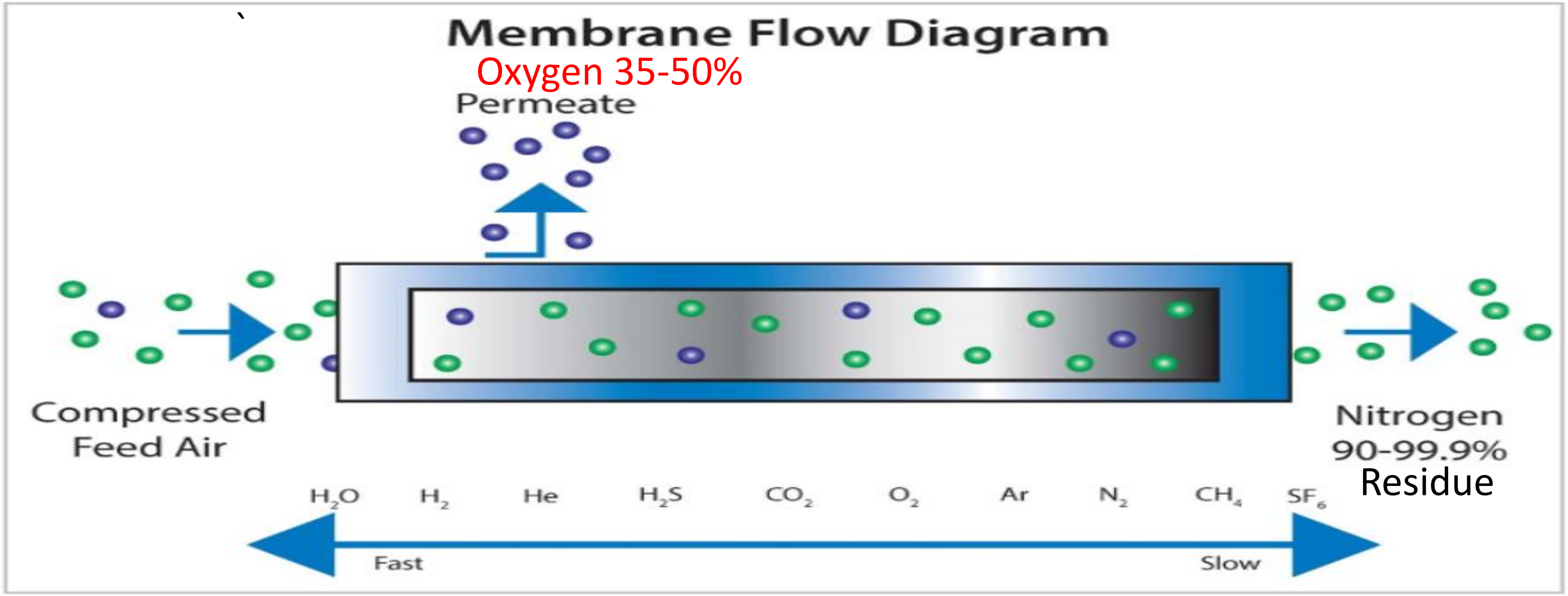
O2 Source	%O2 Purity Dry Concen	%O2 Net Increase	% Fuel Savings
A Air	20.9	0	0
B MAE	21-50	~1-30	30-60
C ASU	90-99+%	70-80	70 Max
Cryo/ VPSA/ PSA (Cryo/V/PSA)			

BLACK · SWAN with MAE/Wig- Advantages

- MAE: Potential of fuel savings of 60% with lowest increase in O_2 (30%)
  - Cryo/V/PSA produces high purity oxygen (~90+% O2, sold @~$300/Ton)
    - Only +10% fuel savings diminish returns further for 50% increased O_2
    - High purity 90% has high firing temp requiring costly retrofit
- MAE/Wig: Lowest capital/operating cost to produce ~50% O_2
  - ~40 to 50% lower energy and manufacture cost; higher performance compared to conventional (~$35-70+/T)** conventional membranes
  - Low to No Cost Fired Unit Retrofit/ "Plug and Play"
- MAE: Performs Direct Air Capture of O2, <u>CO_2- a GHG, and Recoverable H_2O</u>
  - Cryo/V/PSA do not produce recoverable H_2O
  - For V/PSA- CO_2 is not a product; for Cryo, requires high additional cost
  - Dry Flue gas CO_2 Concentration increases over 50% with MAE

**est'd using Membrane Based Oxygen-Enriched Combustion by Lin, Zhou, et al; Ind. Eng. Chem. Res, 2013, 52

INTRODUCING CONVENTIONAL GENERON MEMBRANE AIR OXYGEN GAS SEPARATION TECHNOLOGY



INTRODUCING CONVENTIONAL GENERON MEMBRANE AIR OXYGEN GAS SEPARATION TECHNOLOGY

GENERON®

ABOUT US | PRODUCTS | ENVIRONMENTAL SOLUTIONS | INDUSTRIES SERVED | APPLICATIONS | NEWS & BLOG | CONTACT US

applications of Oxygen purity of 38.5% or less.

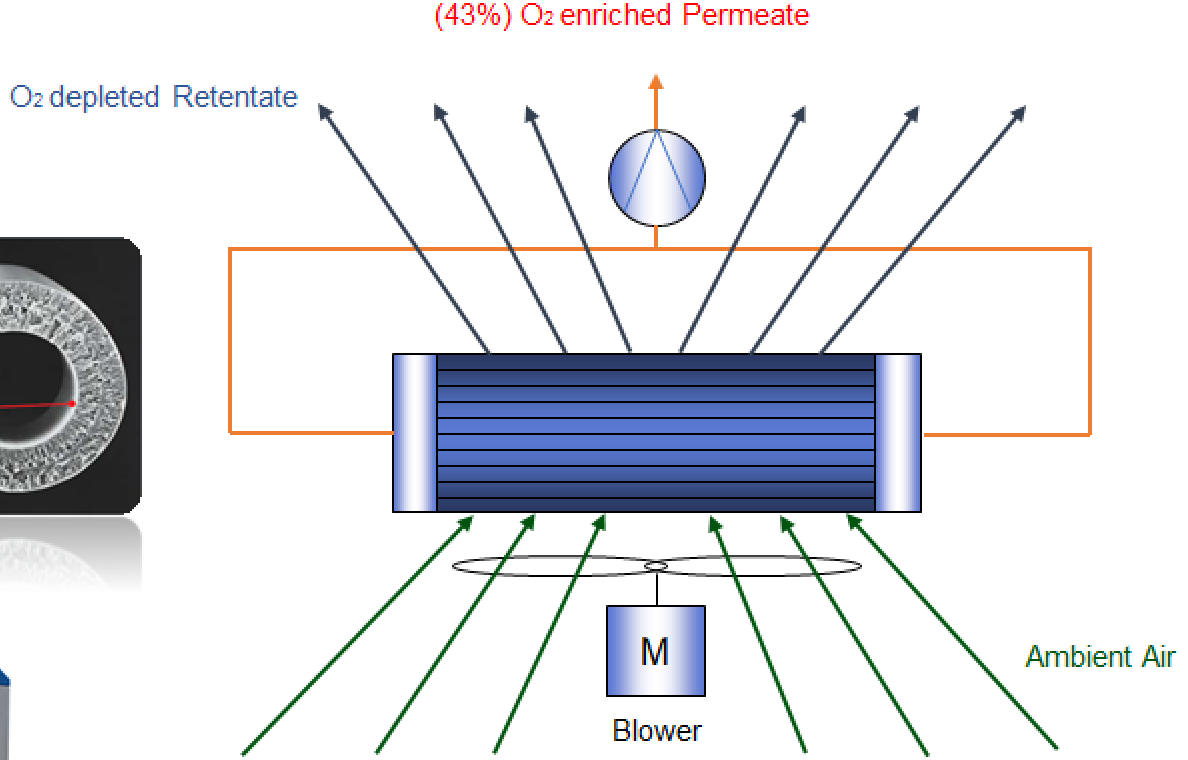
GENERON® Oxygen Membrane Modules				
Application: O_2				
MAWP in PSIG (barg): 203 (14.0), MAWT in °F (°C): 150 (65)				
MODEL	Membrane Casing	O2-Flow Rate @ 38.5% O2-Purity, MAWP, 77°F		View Product PDF
		SCFM	LPM	
210	Aluminum	0.9	23.3	PDF Adobe
330	Aluminum	6.1	156.7	PDF Adobe
4100	Aluminum, 316SS	12.1	313.4	PDF Adobe
6150	Aluminum, 316SS	27.2	706.8	PDF Adobe

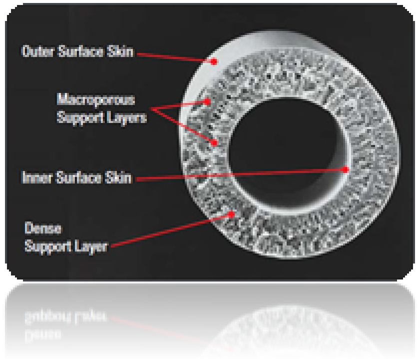
KO$_2$
THE KOLODJI CORPORATION

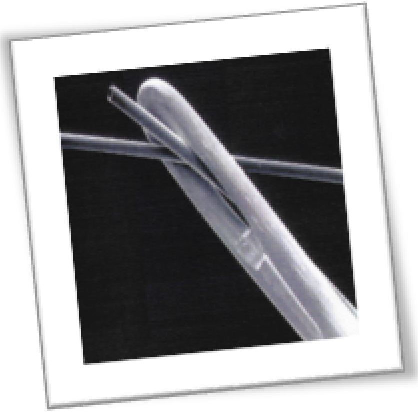
Black Swan, LLC

GENERON

BLACK · SWAN Patent Pending MAE/ Wig Membrane System/ Performance





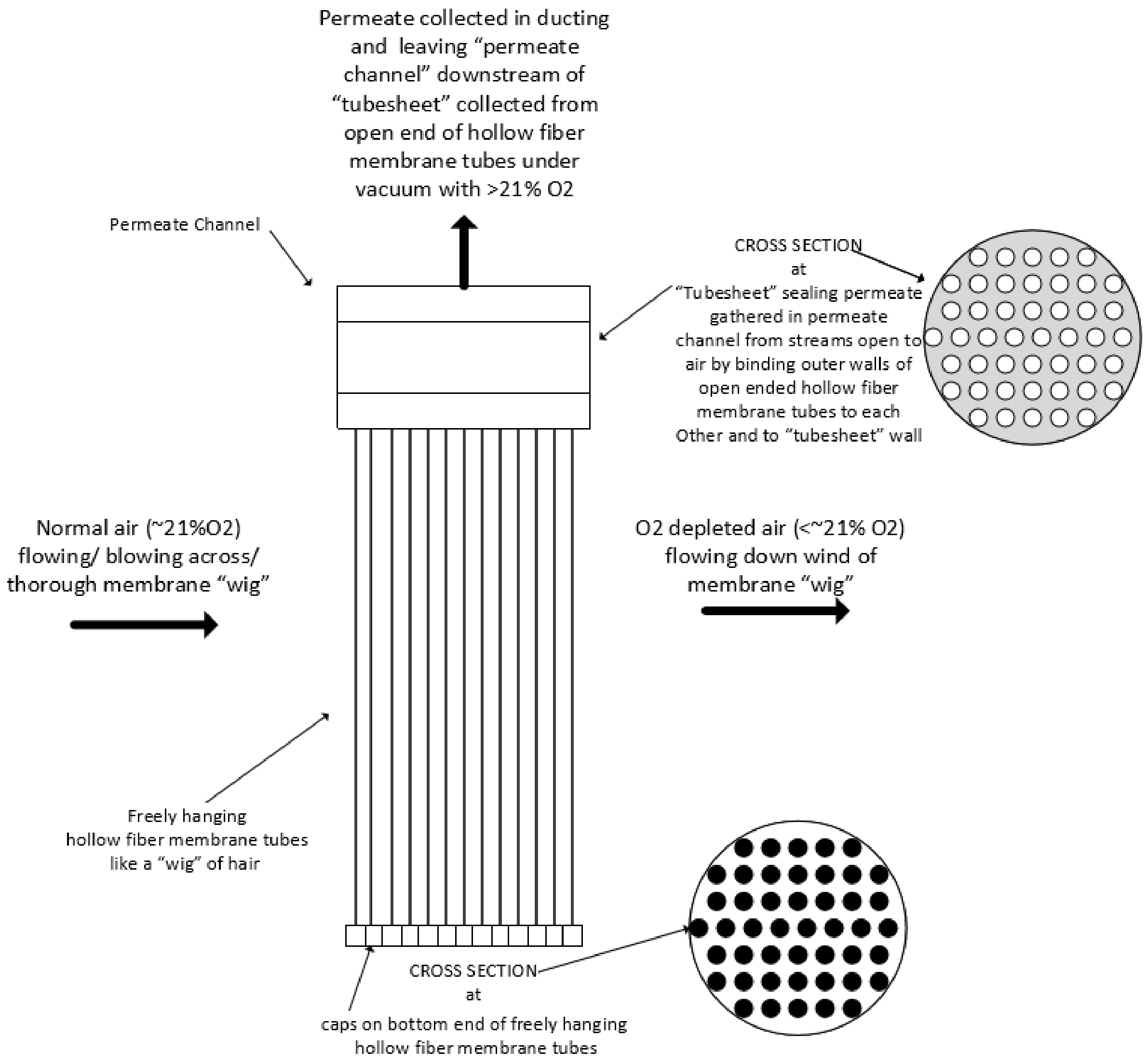


	Air		Retentate			Permeate		
Pressure [psia]	15.7		15.4			3.7		
Component	Mole frac	Mass frac	Mole frac	Mass frac	Recovery	Mole frac	Mass frac	Recovery
O2	0.2100	0.2329	0.1916	0.2130	84.27%	0.4322	0.4651	15.73%
N2	0.7900	0.7671	0.8084	0.7870	94.51%	0.5678	0.5349	5.49%

INTRODUCING BLACK · SWAN WIG Membrane

Very Low Energy/ High Performance/ Lowest Pressure Drop/ Lowest Manufacturing Cost

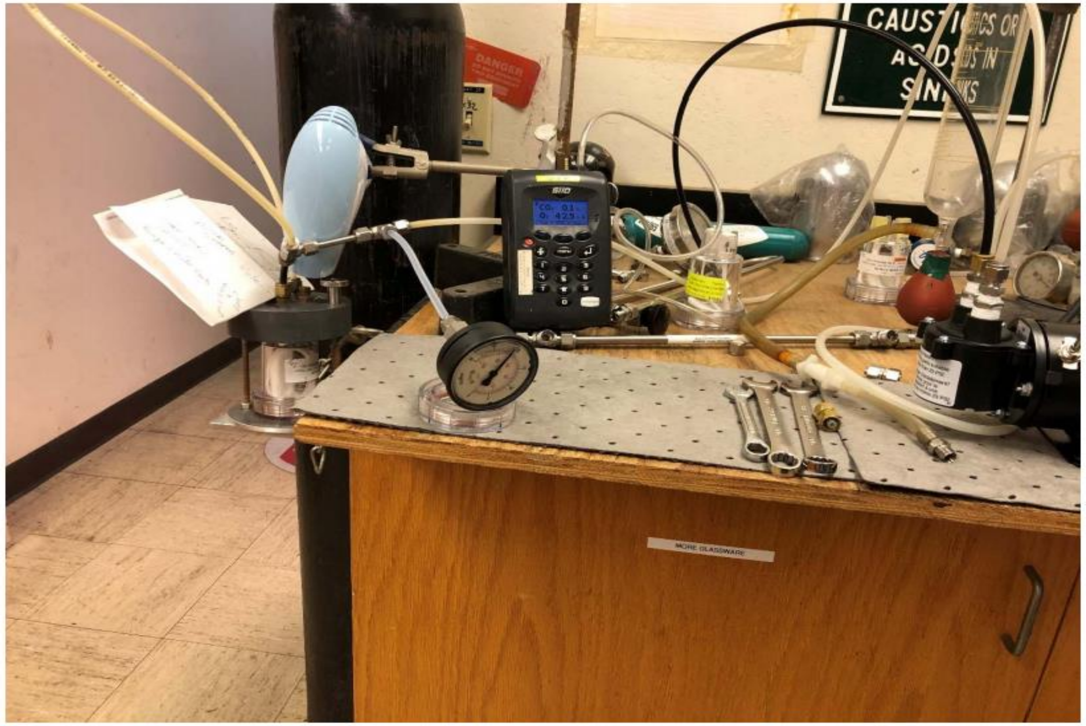
Diagram of Single Tube Sheet Wig™ Membrane Design for MAE™ Process



GENERON BLACK · SWAN Wig™ Lab Scale

Vacuum Testing of PCCP-1 and PCCP-2 Fiber Types (Beaker Unit Evaluation)

Beaker units test devices containing PCCP-1 and PCCP-2 hollow fibers were evaluated for their O2 enrichment capabilities by having ambient air (20C) on the feed side and a vacuum of 4 psia (-22" of Hg) on the bore side of the fibers. The permeate gas was analyzed on the discharge of the vacuum pump used and evaluated for permeate flow and composition (O2 and CO2). In all measurements the ambient air composition was maintained during the test using a hair drier to exchange out the air in the beaker unit shell space. Below is a photo of the test system layout.



*Photo, instruments and bench/lab measurements courtesy of Mr. Marc Straub, Vice President Membrane Mfrg, Generon

GENERON BLACK · SWAN Prototype Dual Tube Sheet Wig™ Membrane Prototype for MAE™ Process

BLACK · SWAN

Introducing Patent-Pending MAE™ Process/ Wig™ Membrane Design Benefits

- MAE/Wig uses decades proven science/materials commercialized by multiple major manufacturers

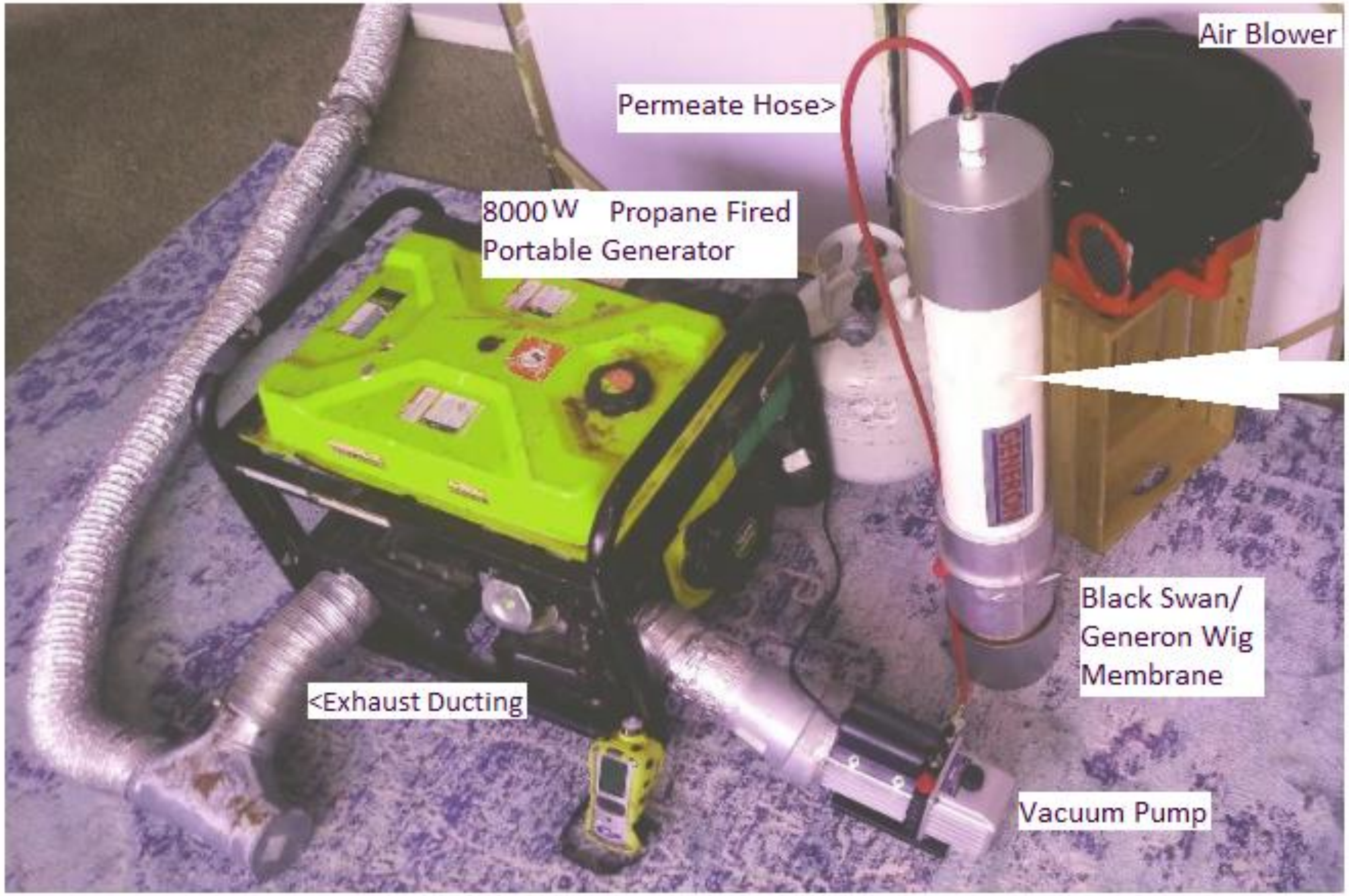
- MAE/Wig lowest membrane operating cost, 60% lower than conventional membranes
  - Conventional membranes feed air at 150 to 250 psig, where as MAE operates at low pressure
  - Permeate is pulled under vacuum at 1/3 lower flow rate

- MAE/Wig higher performance over conventional membranes validated by Generon
  - 10% higher concentration of oxygen or flowrate through membrane
    - Low to no pressure drop on shell-less “residue side”
    - No concentration gradient on shell-less “residue side”
      - Full length of outer hollow fiber tube wall sees same high concentration CO2 instead of gradient concentration

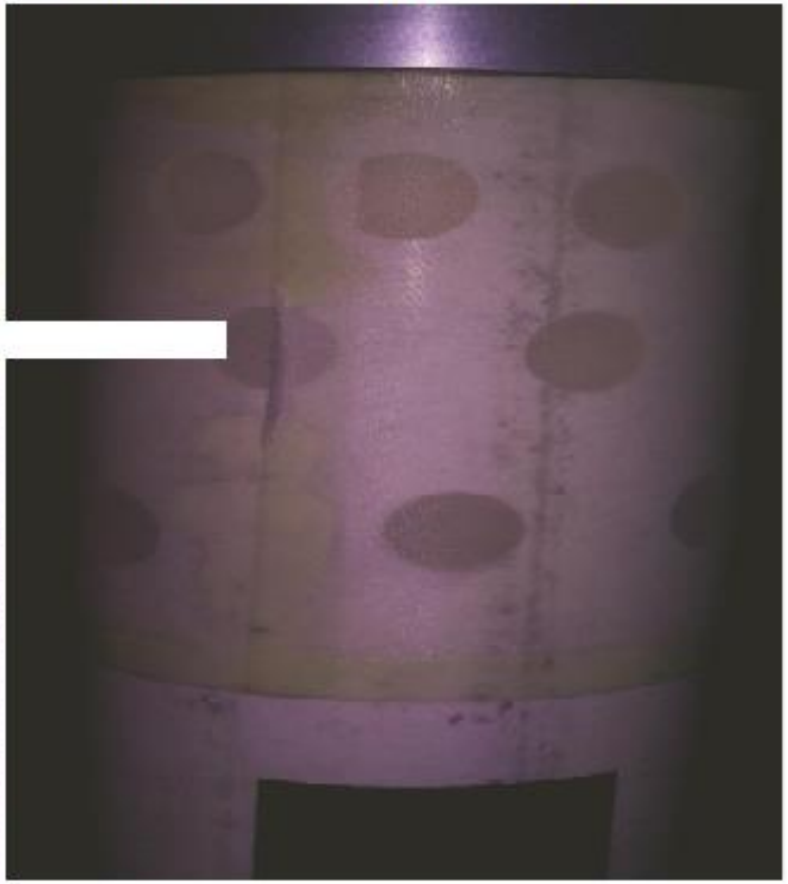
BLACK · SWAN

100 Ton/Year CO2, 12HP, 8 KW

Bench Scale MAE/OxyComb Wig™ Membrane



DETAIL OF AIR INLET PORTS



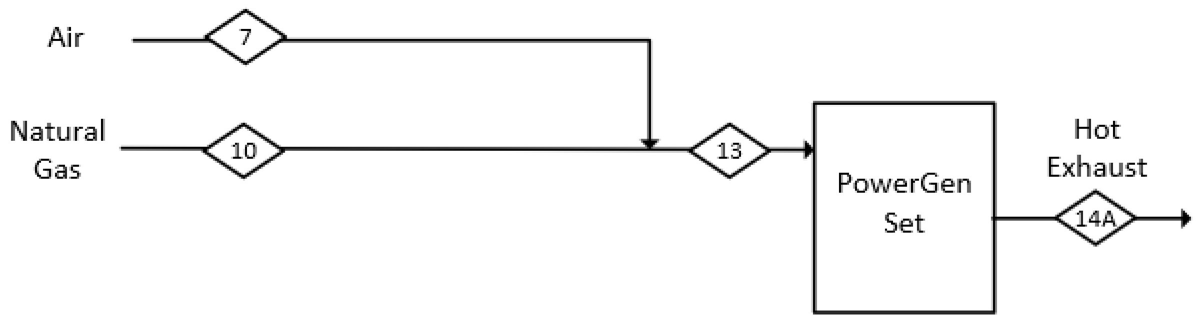
BLACK · SWAN

2,000 Ton/Year CO_2 FGXB/ MAE™ Demonstration Site

400 HP (300KW) Caterpillar® Engine for Well Pump

04/12/2021

Internal Combustion Engine Driven Power Generation Set
Natural Gas Only Case
Simplified Process Flow Diagram



NG Duty Consumed	Heat Duty	-973	kW
HRXN	Heat Duty	-971.08	kW
TRBN-100	Power	-302.06	kW
Eng Ht Loss	Heat Duty	-386.85	kW

NG Duty Consumed	Heat Duty	-3.32e+06	Btu/h
HRXN	Heat Duty	-3.3135e+06	Btu/h
TRBN-100	Power	-405.07	hp
Eng Ht Loss	Heat Duty	-1.32e+06	Btu/h E
Dry Flue Gas	O2(Mole Fraction)	0.50694	% B

04/12/2020

CAT ENGINE BASE CASE

400 HP (300,000 Watt) Nat Gas Only

BASE CASE MODEL VALIDATION

Names	Units	AIR-7	NG- 10	MIX-13	EXH-14A
Temperature	°F	72*	60*	71.75	957.7 D
Pressure	psig	0	5*	0.1	0
Mole Fraction Vapor	%	100	100	100	100
Molecular Weight	lb/lbmol	28.79	17.64	27.77	27.7
Molar Flow	lbmol/h	86.33	8.696	95.02	95.26
Mass Flow	lb/h	2485	153.4	2639	2639
Mass Density	lb/ft^3	0.07417	0.06249	0.07207	0.02676
Vapor Volumetric Flow	CFM	558.4	40.92	610.1	1644
Std Vapor Volumetric Flow	SCFM	546*	A 55*	601	602.5
Std Vapor Volumetric Flow	MMSCFD	0.7862*	0.0792*	0.8654	0.8676
C1(Mole Fraction)	%	0	92.39*	8.455	0
C2H6(Mole Fraction)	%	0	2.5*	0.2288	0
C3(Mole Fraction)	%	0	0.7*	0.06406	0
N2(Mole Fraction)	%	76.83	1.68*	69.95	69.78
O2(Mole Fraction)	%	20.61	0*	18.72	0.4081
H2O(Mole Fraction)	%	1.619	0*	1.47	19.49
Ar(Mole Fraction)	%	0.9012	0*	0.8187	0.8167
CO2(Mole Fraction)	%	0.04034	2.3*	0.2471	9.503
O2(Mass Flow)	ton/yr	2493	0*	2493	54.49
CO2(Mass Flow)	ton/yr	6.712	38.55*	45.27	1745
H2O(Mass Flow)	ton/yr	110.3	0*	110.3	1465
Volumetric Net Ideal Gas Heating Value	Btu/ft^3		C 911.1	83.38	

MATCH OF KEY PROCESS PARAMETERS (A-E)
BR&E PROMAX® MODEL ^ RESULTS (ABOVE) VS.
400HP CATERPILLAR® ENGINE SPEC (TO RIGHT)>

CG137-8

GAS ENGINE TECHNICAL DATA

CATERPILLAR®

ENGINE SPEED (rpm):	1800	RATING STRATEGY:	STANDARD
COMPRESSION RATIO:	8.3	APPLICATION:	GAS COMPRESSION
AFTERCOOLER TYPE:	SCAC	RATING LEVEL:	CONTINUOUS
AFTERCOOLER WATER INLET (°F):	130	FUEL:	NATURAL GAS
JACKET WATER OUTLET (°F):	210	FUEL SYSTEM:	LPG IMPCO
ASPIRATION:	TA		WITH CUSTOMER SUPPLIED AIR FUEL RATIO CONTROL
COOLING SYSTEM:	JW+OC, AC	FUEL PRESSURE RANGE(psig): (See note 1)	1.5-5.0
CONTROL SYSTEM:	ADEM4	FUEL METHANE NUMBER:	85
EXHAUST MANIFOLD:	WC	FUEL LHV (Btu/scf):	C 905
COMBUSTION:	CATALYST SETTING	ALTITUDE CAPABILITY AT 100°F INLET AIR TEMP. (ft):	5000
EXHAUST OXYGEN (% O2):	0.5 B		

RATING		NOTES	LOAD	100%	75%	50%
ENGINE POWER	(WITHOUT FAN)	2	bhp	400	300	200
ENGINE EFFICIENCY	(ISO 3046/1)	3	%	34.2	32.6	29.7
ENGINE EFFICIENCY	(NOMINAL)	3	%	34.2	32.6	29.7
ENGINE DATA						
FUEL CONSUMPTION	(ISO 3046/1)	4	Btu/bhp-hr	7431	7796	8581
FUEL CONSUMPTION	(NOMINAL)	4	Btu/bhp-hr	7431	7796	8581
AIR FLOW (77°F, 14.7 psia)	(WET)	5, 6	ft3/min	531	421	308
AIR FLOW	(WET)	5, 6	lb/hr	2352 A	1865	1366
FUEL FLOW (60ºF, 14.7 psia)			scfm	55	43	32
COMPRESSOR OUT PRESSURE			in Hg(abs)	61.1	59.5	51.4
COMPRESSOR OUT TEMPERATURE			°F	228	215	181
AFTERCOOLER AIR OUT TEMPERATURE			°F	138	138	135
INLET MAN. PRESSURE		7	in Hg(abs)	58.0	46.8	35.0
INLET MAN. TEMPERATURE	(MEASURED IN PLENUM)	8	°F	144	145	146
TIMING		9	°BTDC	31	31	31
EXHAUST TEMPERATURE - ENGINE OUTLET		10	°F	942 D	894	857
EXHAUST GAS FLOW (@engine outlet temp, 14.5 psia)	(WET)	11, 6	ft3/min	1557	1192	849
EXHAUST GAS MASS FLOW	(WET)	11, 6	lb/hr	2502	1983	1453
EMISSIONS DATA - ENGINE OUT						
NOx (as NO2)		12,13	g/bhp-hr	11.65	12.03	12.67
CO		12,14	g/bhp-hr	11.65	12.03	12.67
THC (mol. wt. of 15.84)		12,14	g/bhp-hr	2.40	2.66	2.95
NMHC (mol. wt. of 15.84)		12,14	g/bhp-hr	0.36	0.40	0.44
NMNEHC (VOCs) (mol. wt. of 15.84)		12,14,15	g/bhp-hr	0.24	0.27	0.29
HCHO (Formaldehyde)		12,14	g/bhp-hr	0.06	0.09	0.08
CO2		12,14	g/bhp-hr	452.00 B	478.00	523.00
EXHAUST OXYGEN		12,16	% DRY	0.5	0.5	0.5
LAMBDA		12,16		0.99	1.00	0.99
ENERGY BALANCE DATA						
LHV INPUT		17	Btu/min	49494	38944	28578
HEAT REJECTION TO JACKET WATER (JW)		18,24	Btu/min	16780	14181	11567
HEAT REJECTION TO ATMOSPHERE		19	Btu/min	1980	1558	1143
HEAT REJECTION TO LUBE OIL (OC)		20,24	Btu/min	2266	1915	1562
HEAT REJECTION TO EXHAUST (LHV TO 77°F)	E	21,22	Btu/min	10540	7912	5546
HEAT REJECTION TO EXHAUST (LHV TO 350°F)		21	Btu/min	6910	5017	3422
HEAT REJECTION TO AFTERCOOLER (AC)		23,25	Btu/min	980	668	286

CONDITIONS AND DEFINITIONS

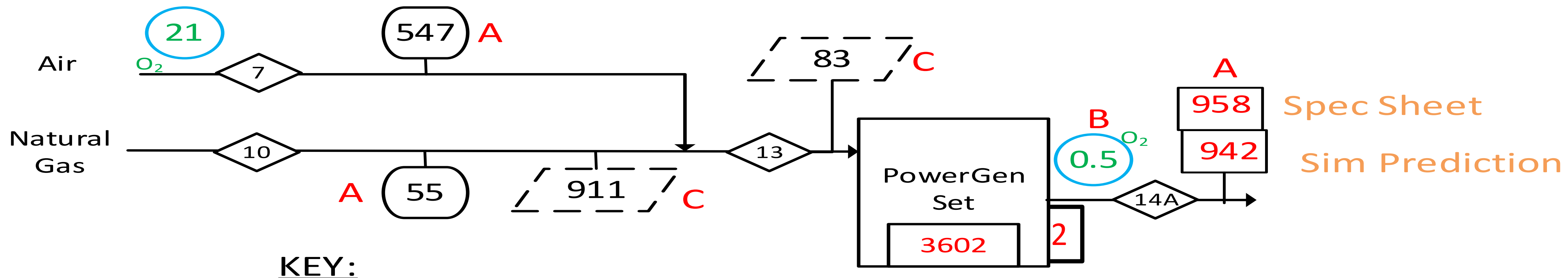
04/17/2021

Internal Combustion Engine Driven Power Gen Set PFD

BASE CASE 0: 400 HP Natural Gas Fired with Air

E=Duty=3.3 MMBTU/HR

400 HP (300KW) Caterpillar ®



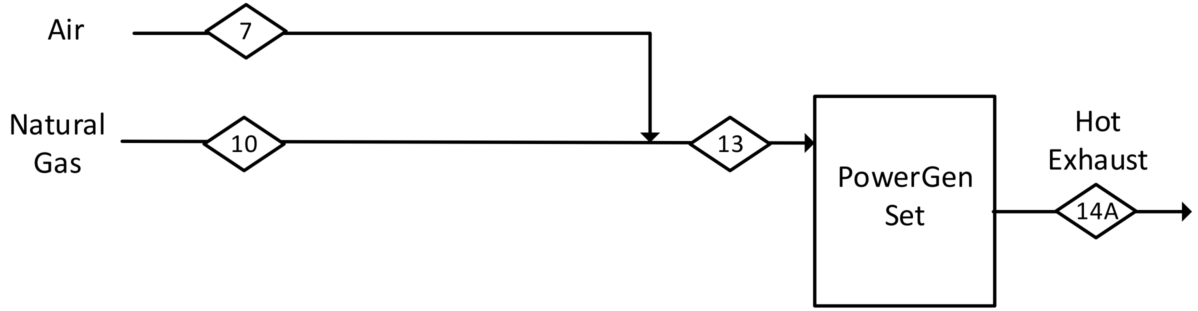
KEY:

- SCFM -Standard Volumetric Flowrate
- # -Stream Number
- % O_2 -Dry Oxygen Volumetric Concentration
- BTU/SCF -Low (Net) Heating Value, dashed lines indicate multiple or previous cases
- F -Temperature Spec Sheet
- F -Temperature Predicted by Simulator

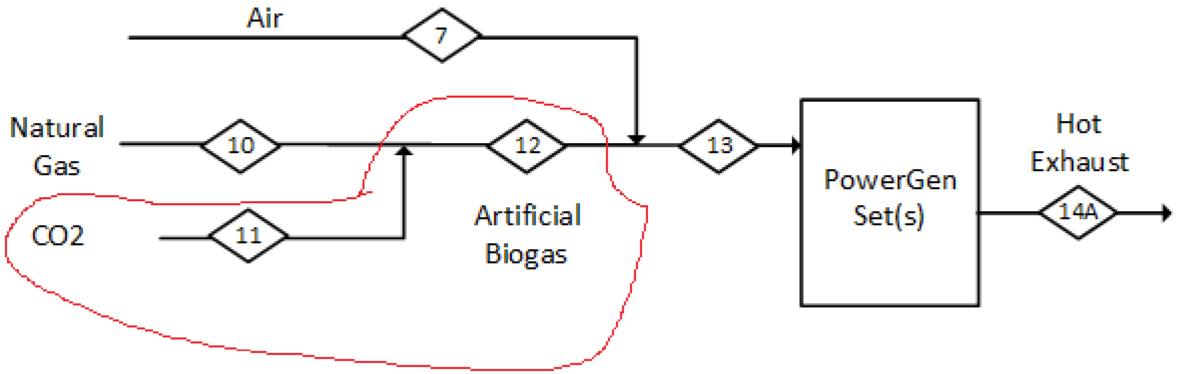
04/12/2021

Internal Combustion Engine Driven Power Generation Set
Simplified Process Flow Diagrams

Natural Gas Only Case 0



"Artificial Biogas" Case 1



04/17/2020

CAT ENGINE CASES 0 and 1

CASE 0 (to Left)

<400 HP (300,000 Watt) Nat Gas with Air

CASE 1 (to Right)

Artificial BioGas Only with Air>

CASE 0

NG Duty Consumed	Heat Duty	-973	kW
HRXN	Heat Duty	-971.08	kW
TRBN-100	Power	-302.06	kW
Eng Ht Loss	Heat Duty	-386.85	kW

NG Duty Consumed	Heat Duty	-3.32e+06	Btu/h
HRXN	Heat Duty	-3.3135e+06	Btu/h
TRBN-100	Power	-405.07	hp
Eng Ht Loss	Heat Duty	-1.32e+06	Btu/h
Dry Flue Gas	O2(Mole Fraction)	0.50694	%

Names	Units	AIR-7	NG- 10	MIX-13	14	EXH-14A
Temperature	°F	72*	60*	71.75	3602	957.7
Pressure	psig	0	5*	0.1	0.1	0
Mole Fraction Vapor	%	100	100	100	100	100
Molecular Weight	lb/lbmol	28.79	17.64	27.77	27.7	27.7
Molar Flow	lbmol/h	86.33	8.696	95.02	95.26	95.26
Mass Flow	lb/h	2485	153.4	2639	2639	2639
Mass Density	lb/ft^3	0.07417	0.06249	0.07207	0.009402	0.02676
Vapor Volumetric Flow	CFM	558.4	40.92	610.1	4677	1644
Std Vapor Volumetric Flow	SCFM	546*	55*	601	602.5	602.5
Std Vapor Volumetric Flow	MMSCFD	0.7862*	0.0792*	0.8654	0.8676	0.8676
C1(Mole Fraction)	%	0	92.39*	8.455	0	0
C2H6(Mole Fraction)	%	0	2.5*	0.2288	0	0
C3(Mole Fraction)	%	0	0.7*	0.06406	0	0
N2(Mole Fraction)	%	76.83	1.68*	69.95	69.78	69.78
O2(Mole Fraction)	%	20.61	0*	18.72	0.4081	0.4081
H2O(Mole Fraction)	%	1.619	0*	1.47	19.49	19.49
Ar(Mole Fraction)	%	0.9012	0*	0.8187	0.8167	0.8167
CO2(Mole Fraction)	%	0.04034	2.3*	0.2471	9.503	9.503
O2(Mass Flow)	ton/yr	2493	0*	2493	54.49	54.49
CO2(Mass Flow)	ton/yr	6.712	38.55*	45.27	1745	1745
H2O(Mass Flow)	ton/yr	110.3	0*	110.3	1465	1465
Volumetric Net Ideal Gas Heating Value	Btu/ft^3		911.1	83.38	2.098e-10	

CASE 1

NG Duty Consumed	Heat Duty	-973	kW
HRXN	Heat Duty	-970.52	kW
TRBN-100	Power	-302.77	kW
Eng Ht Loss	Heat Duty	-386.85	kW

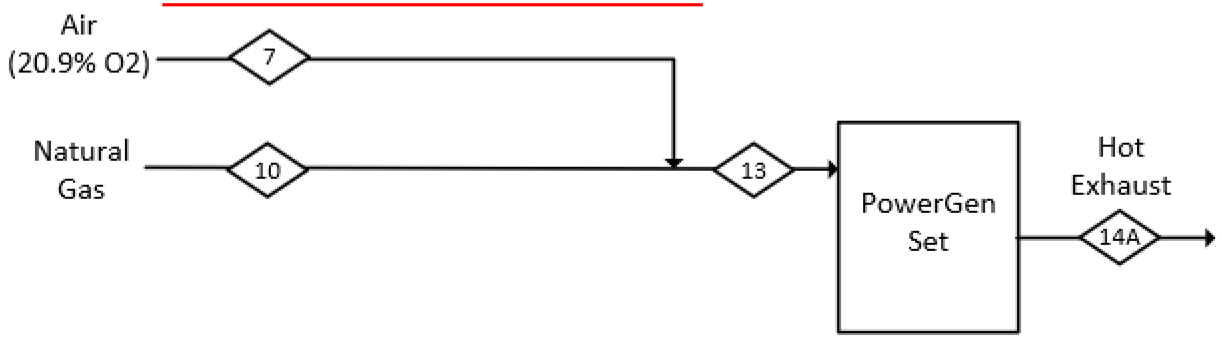
NG Duty Consumed	Heat Duty	-3.32e+06	Btu/h
HRXN	Heat Duty	-3.3115e+06	Btu/h
TRBN-100	Power	-406.02	hp
Eng Ht Loss	Heat Duty	-1.32e+06	Btu/h
Dry Flue Gas	O2(Mole Fraction)	0.47805	%

Names	Units	AIR-7	NG- 10	CO2-11	BG-12	MIX-13	14	EXH-14A
Temperature	°F	72*	60*	70*	63.14	71.54	3390	901.3
Pressure	psig	0	5*	10*	5	0.1	0.1	0
Mole Fraction Vapor	%	100	100	100	100	100	100	100
Molecular Weight	lb/lbmol	28.79	17.64	43.75	26.78	28.52	28.45	28.45
Molar Flow	lbmol/h	86.33	8.696	4.68	13.38	99.7	99.94	99.94
Mass Flow	lb/h	2485	153.4	204.8	358.2	2843	2843	2843
Mass Density	lb/ft^3	0.07417	0.06249	0.1918	0.09438	0.07406	0.01019	0.02862
Vapor Volumetric Flow	CFM	558.4	40.92	17.79	63.25	639.8	4651	1656
Std Vapor Volumetric Flow	SCFM	546*	55*	29.6*	84.6	630.6	632.1	632.1
Std Vapor Volumetric Flow	MMSCFD	0.7862*	0.0792*	0.04262*	0.1218	0.9081	0.9102	0.9102
C1(Mole Fraction)	%	0	92.39*	0*	60.06	8.058	0	0
C2H6(Mole Fraction)	%	0	2.5*	0*	1.625	0.218	0	0
C3(Mole Fraction)	%	0	0.7*	0*	0.4551	0.06105	0	0
N2(Mole Fraction)	%	76.83	1.68*	0*	1.092	66.67	66.51	66.51
O2(Mole Fraction)	%	20.61	0*	0*	0	17.84	0.389	0.389
H2O(Mole Fraction)	%	1.619	0*	0.9901*	0.3464	1.448	18.62	18.62
Ar(Mole Fraction)	%	0.9012	0*	0*	0	0.7803	0.7784	0.7784
CO2(Mole Fraction)	%	0.04034	2.3*	99.01*	36.14	4.883	13.69	13.69
O2(Mass Flow)	ton/yr	2493	0*	0*	0	2493	54.49	54.49
CO2(Mass Flow)	ton/yr	6.712	38.55*	893.2*	931.8	938.5	2638	2638
H2O(Mass Flow)	ton/yr	110.3	0*	3.656*	3.656	113.9	1469	1469
Volumetric Net Ideal Gas Heating Value	Btu/ft^3		911.1	-0	592.3	79.47	-0	

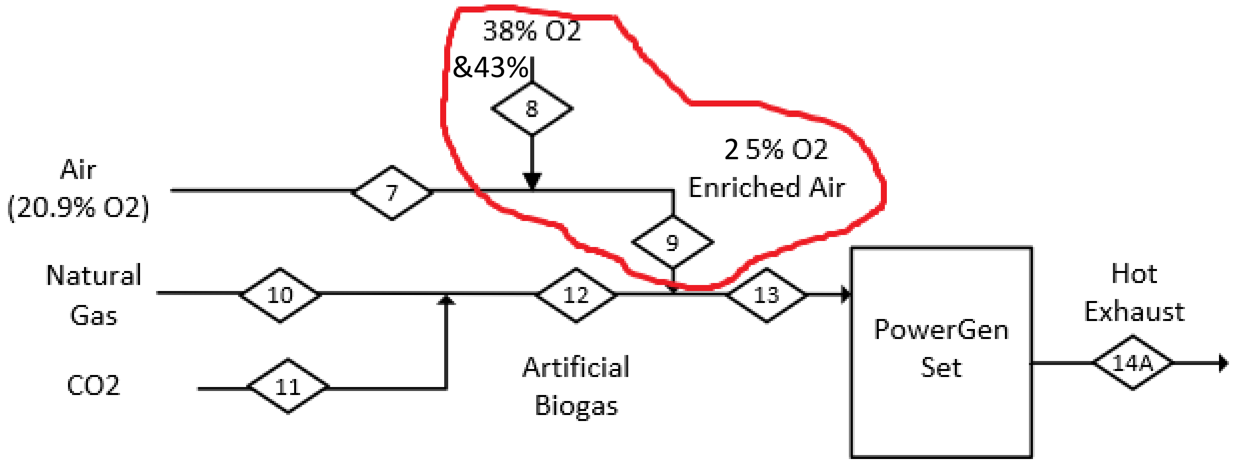
04/12/2021

Internal Combustion Engine Driven Power Generation Set Simplified Process Flow Diagrams

Air Fired Natural Gas Case 0



Conventional Membrane Enriched Oxy-Combustion Biogas Cases 2&3

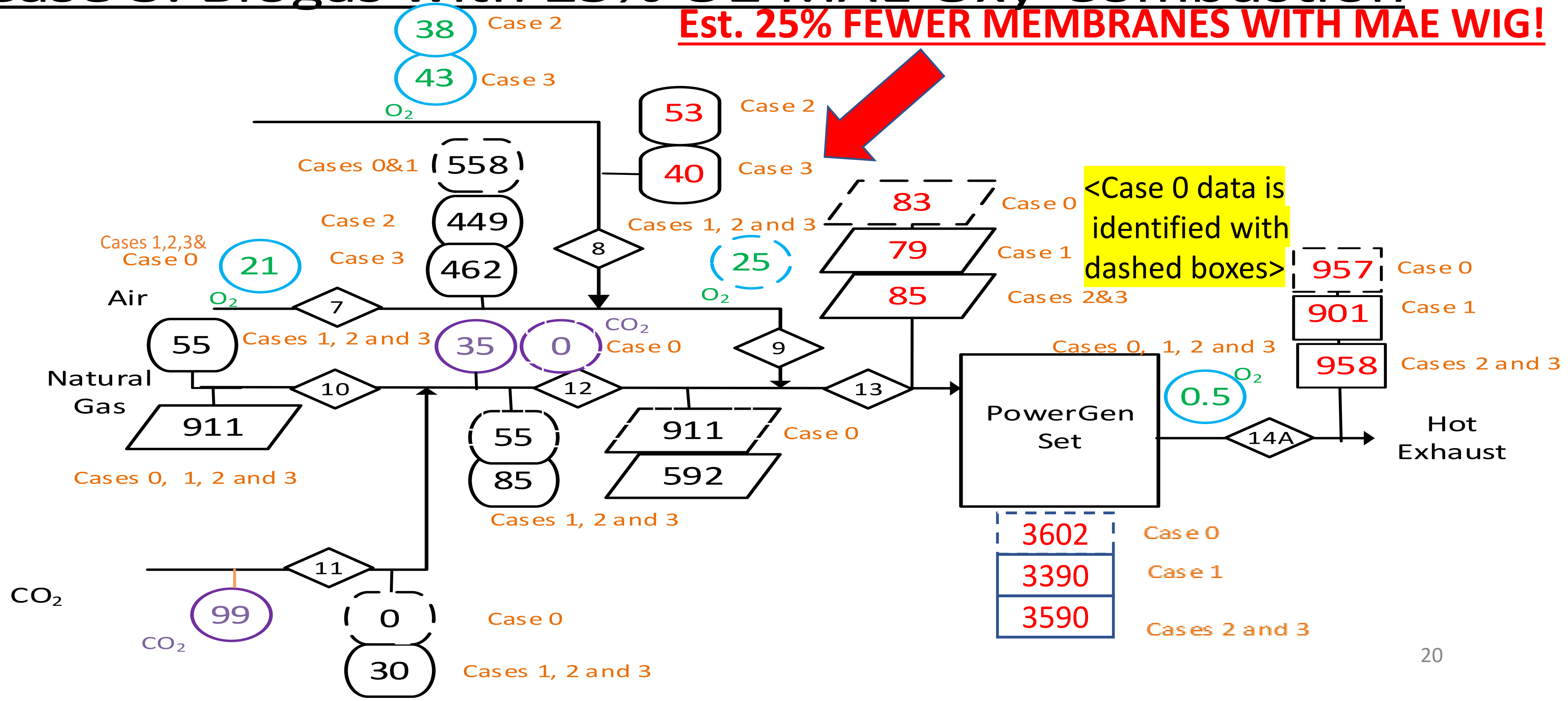


400 HP (300KW) Caterpillar ®

04/12/2021

Internal Combustion Engine Driven Power Generation Set Base Case 0 vs Case 1 vs Case 2 vs Case 3: Biogas with 25% O2 MAE Oxy-Combustion

Est. 25% FEWER MEMBRANES WITH MAE WIG!



KO_2

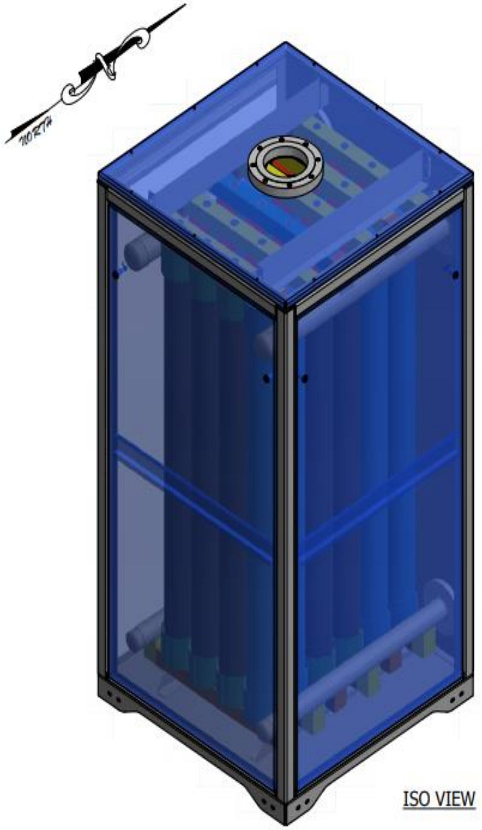
KOLODJI CORPORATION

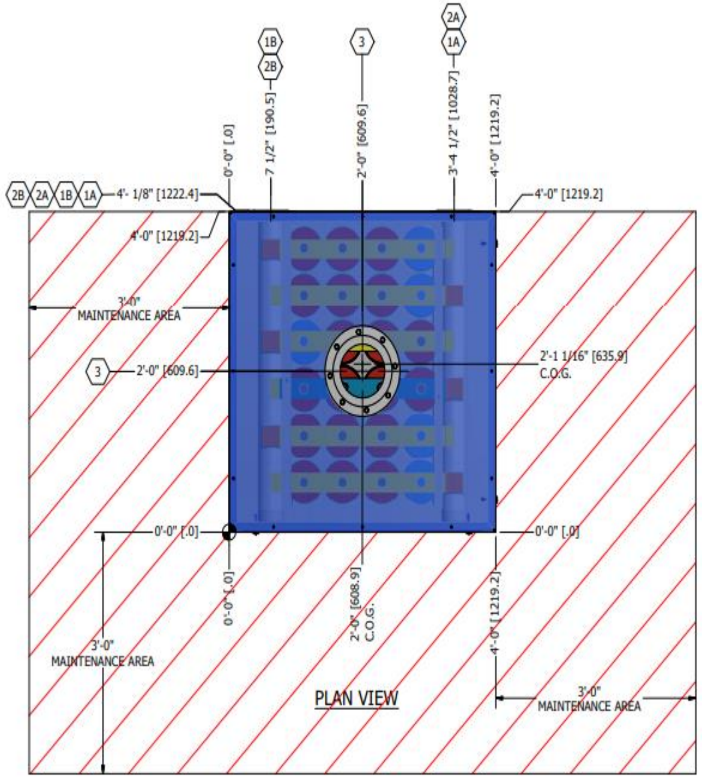
Black Swan, LLC

GENERON

20 Count MAE (43% O_2) Membrane Skid for Pilot and Demonstration Plant

Iso View | **Top View** | **Photo**





BLACK · SWAN

Membrane Air Enrichment (MAE ™)

Estimated Conventional vs. MAE Cat Performance Comparison

- Basis: 400HP (300KW or 1MMBTU/H), 53 scfm, 38% O_2 combustion air

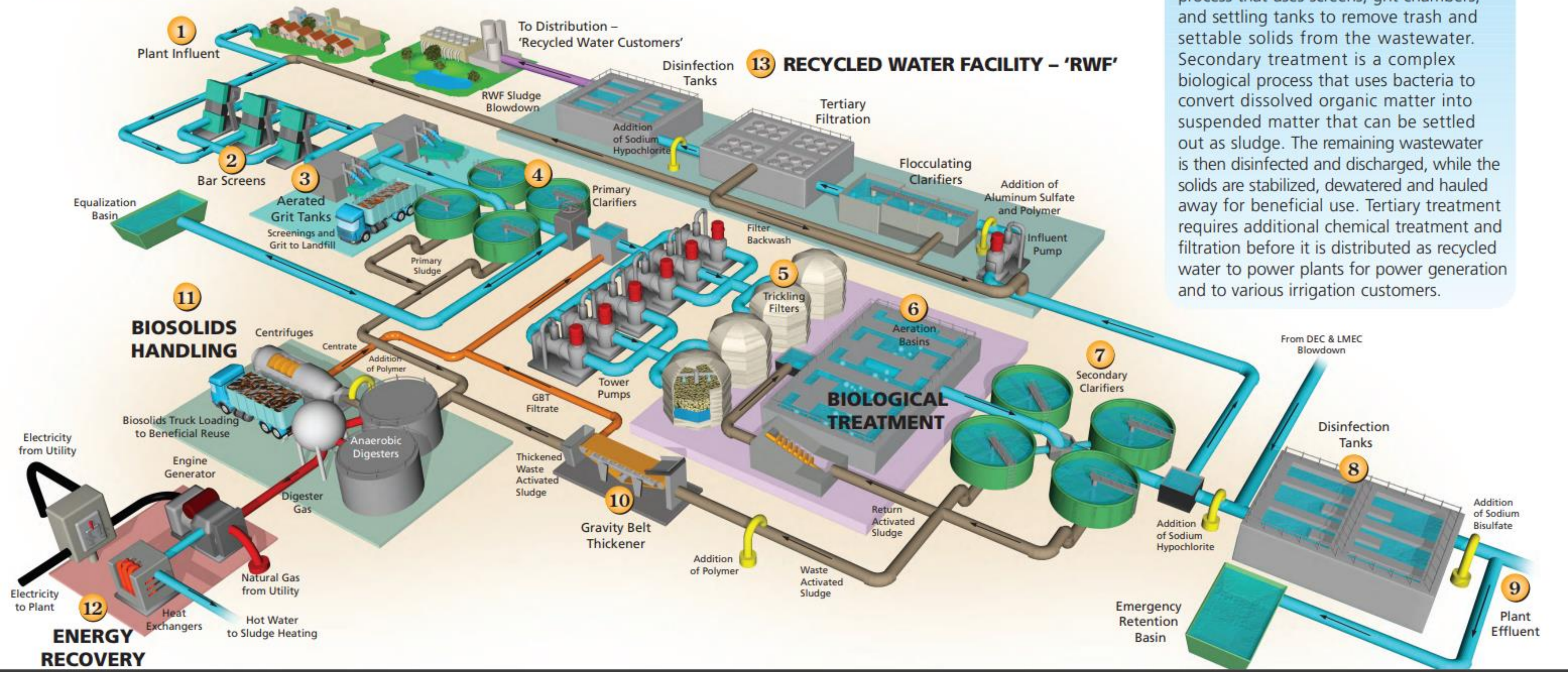
- Conventional 6150 Membrane System (38% O_2):
  - @203 psig Feed Air Requires 4 membranes
  - @2 psig Feed Air Requires 20 membranes

- Lower Cost MAE Wig™ Membrane Produces 43% O_2 Under Vac:
  - Passive (No Air Compression) needing under 15 membranes
  - Based on Prototype/ Bench Scale Tests

Transforming Wastewater to Resources

THE PROCESS

Delta Diablo treats wastewater from Antioch, Bay Point, and Pittsburg using primary, secondary and tertiary treatment. Primary treatment is a simple mechanical process that uses screens, grit chambers, and settling tanks to remove trash and settable solids from the wastewater. Secondary treatment is a complex biological process that uses bacteria to convert dissolved organic matter into suspended matter that can be settled out as sludge. The remaining wastewater is then disinfected and discharged, while the solids are stabilized, dewatered and hauled away for beneficial use. Tertiary treatment requires additional chemical treatment and filtration before it is distributed as recycled water to power plants for power generation and to various irrigation customers.

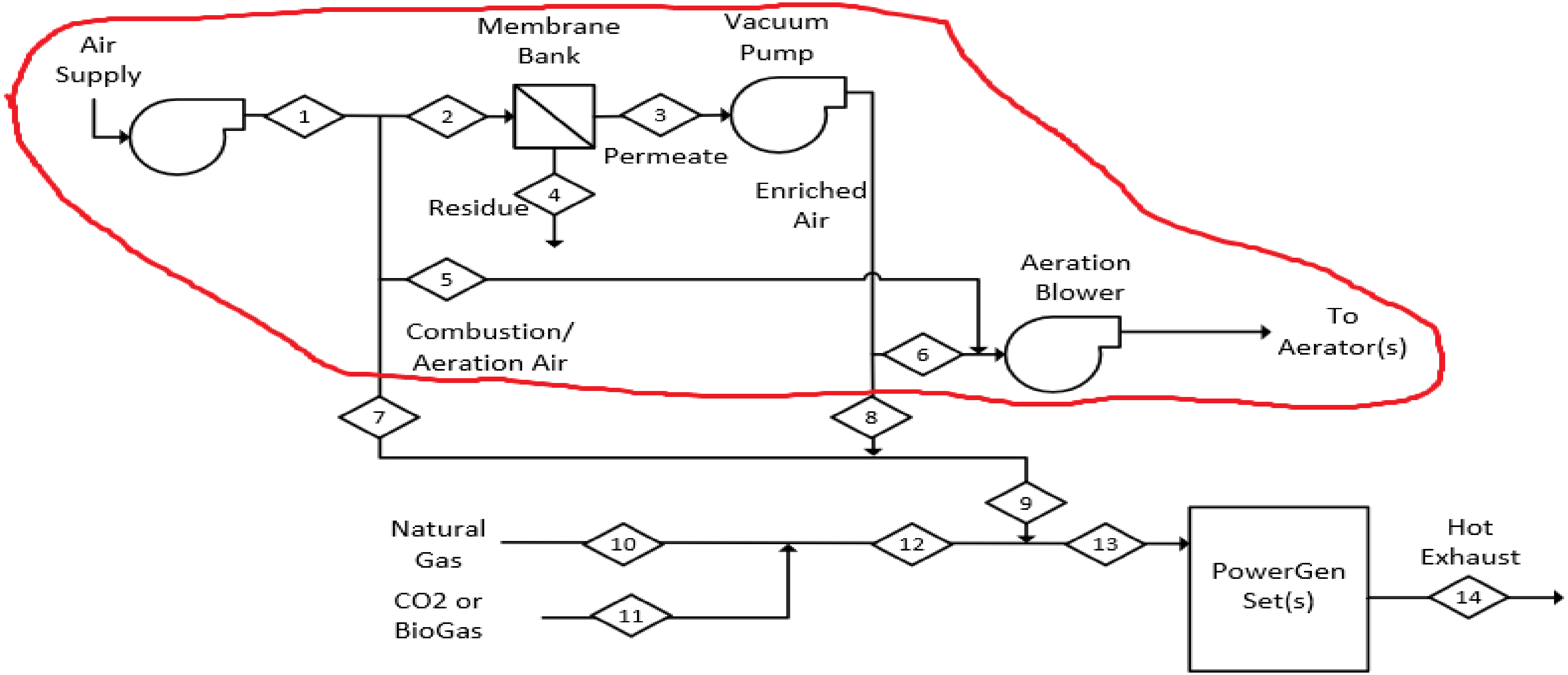


04/16/2021

Membrane Air Enrichment (MAE) 30TPD Aeration/ 1MW Biogas Oxy-comb

Delta Diablo

Simplified Process Flow Diagram



1100 HP (800KW) Delta Diablo
BG/NG/Air Base Case 0

03/02/2021

19.3 MGD Delta Diablo Base Case
Comb/Aer Air/Enr: O2- 38/74/- TPD
0.8MW, 220BG /22NG/ 183 KWH/MGD

MAE Fd Blow	Power	0	kW
Vac Pump	Power	0	kW
B4910	Power	0	kW
B4920	Power	143.15	kW
B4930	Power	0	kW
TRBN-100	Power	-801.84	kW
Increased BG Duty Made	Heat Duty	-0	kW
NG Duty Consumed	Heat Duty	-351.69	kW
HRXN	Heat Duty	-2534.2	kW
Cmb Blow	Power	1.355	kW
Eng Ht Loss	Heat Duty	-2.08e+06	Btu/h

Stream Numbers>>		1	2	3	4	5	6	7	8	9	10	11	12	13	14	14A	15
Names	Units	Tot Air	Memb Fd	Res	Perm	Cl Air	Cl5EnrAer	CmbAir	CmbEnr	O2FdMx9	Nat Gas	Biogas	Fuel Fd	Gen Fd	Comb Gas	Exhaust	To Stack
Temperature	°F	50.9		70*	70*	50.9		50.9	100	50.9	80*	70*	70.9	53.5	1.98e+03	1e+03	300*
Pressure	psig	0	2*	0*	-10.9*	0	0.1*	0	0.1	0	20*	10*	10	0.1	0.1	0	0
Mole Fraction Vapor	%	100			100			100		100	100	100	100	100	100	100	100
Molecular Weight	lb/lbmol	28.9	28.9		29.4	28.9	29.4	28.9	29.4	28.9	17.6	25.7	25	28.6	28.6	28.6	28.6
Molar Flow	lbmol/h	1.46e+03	0	0	0	0	0	538	0	538	3.48	34.8	38.3	576	576	576	576
Mass Flow	lb/h	4.22e+04	0	0	0	0	0	1.55e+04	0	1.55e+04	61.4	894	956	1.65e+04	1.65e+04	1.65e+04	1.65e+04
Mass Density	lb/ft^3	0.0775			0.0197			0.0775		0.0775	0.106	0.112	0.109	0.0769	0.0161	0.0268	0.0516
Vapor Volumetric Flow	CFM	9.07e+03	0	0	0	0	0	3.34e+03	0	3.34e+03	9.63	133	146	3.57e+03	1.7e+04	1.02e+04	5.32e+03
Std Vapor Volumetric Flow	SCFM	9.24e+03	0	0	0*	0*	0	3.4e+03*	0*	3.4e+03	22*	220*	242	3.64e+03	3.64e+03	3.64e+03	3.64e+03
C1(Mole Fraction)	%	0	0		0*	0	0	0	0	0	92.4*	64.5*	67	4.45	0	0	0
C2H6(Mole Fraction)	%	0	0		0*	0	0	0	0	0	2.5*	0*	0.227	0.0151	0	0	0
C3(Mole Fraction)	%	0	0		0*	0	0	0	0	0	0.7*	0*	0.0636	0.00423	0	0	0
N2(Mole Fraction)	%	77.5	77.5		60.9*	77.5	60.9	77.5	60.9	77.5	1.68*	0*	0.153	72.4	72.3	72.3	72.3
O2(Mole Fraction)	%	20.8	20.8		38*	20.8	38	20.8	38	20.8	0*	0*	0	19.4	10.4	10.4	10.4
H2O(Mole Fraction)	%	0.763	0.763		1*	0.763	1	0.763	1	0.763	0*	1*	0.909	0.772	9.76	9.76	9.76
CO2(Mole Fraction)	%	0.0407	0.0407		0.1*	0.0407	0.1	0.0407	0.1	0.0407	2.3*	34.5*	31.6	2.14	6.64	6.64	6.64
Ar(Mole Fraction)	%	0.909	0.909		0*	0.909	0	0.909	0	0.909	0*	0*	0	0.849	0.848	0.848	0.848
O2(Mass Flow)	ton/yr	4.25e+04	0	0	0	0	0	1.57e+04	0	1.57e+04	0*	0*	0	1.57e+04	8.4e+03	8.4e+03	8.4e+03
CO2(Mass Flow)	ton/yr	115	0	0	0	0	0	42.2	0	42.2	15.4*	2.31e+03*	2.33e+03	2.37e+03	7.38e+03	7.38e+03	7.38e+03
H2O(Mass Flow)	ton/yr	879	0	0	0	0	0	324	0	324	0*	27.4*	27.4	351	4.43e+03	4.43e+03	4.43e+03
O2(Mass Flow)	ton/d	117	0	0	0	0	0	42.9	0	42.9	0*	0*	0	42.9	23	23	23
Volumetric Net Ideal Gas Heating Value	Btu/ft^3										911	587	616	40.9	-0		

Names	Units	MAE Fd Blow	Vac Pump	B4910	B4920	HRXN	Eng Ht Loss	Increased BG Duty Made	NG Duty Consumed
Power	hp	0	0	0	191.97	-3398.4	-817.47	-0	-471.62
Power	W	0	0	0	1.4315e+05	-2.5342e+06	-6.0959e+05	-0	-3.5169e+05
Power	Btu/h	0	0	0	4.8845e+05	-8.6471e+06	-2.08e+06	-0	-1.2e+06

BLACK · SWAN

MAE™ 2021 Candidate California Sanitation District Sites

Increaseing aeration basin and power generation capacity with Membrane Air Enrichment

- Orange County Sanitation District (20+MW) and Delta Diablo (~1MW)
  - Supplemental Natural Gas Savings: 100%, meaning no natural gas required!
  - Estimated Increased Power Generation Capacity: 20%

- Potential Aeration Operating Cost Savings
  - 50 to 80% Power / Operating Cost Savings
  - Max 30% Potential Increased Aeration Basin Capacity

- Target return on investment of under two years
  - Estimated Total Installed Cost Estimates of $3,000,000 to 5,000,000
  - California Energy Commission Grants Pending

BLACK · SWAN

MAE/FGXB™ 2022 Candidate Commercial Sites

Natural gas fired 10 to 60 Million BTU/Hour Industrial Scale Boilers Bordered by Orchards

- Both candidate sites using 43% O_2 Enrichment:
  - Winery with 40,000 TPY CO_2 with 100 Acres of Citrus on adjacent plot
  - County Facility with 40,000 TPY CO_2 from Boilers with 500 acres crops
  - Manufacturer with 80,000 TPY CO_2 from Boilers with 1000 acres of crops
  - Refinery Cogen with up to 200,000 TPY CO_2 with 1000 acres crops

    - Natural Gas Savings Target: 40%
    - 100% added profit from crop carbon enrichment in neighbor orchards
    - Target return on investment of under two years
    - Total Installed Cost Estimates of $2,000,000 to 4,000,000

BLACK · SWAN

Membrane Air Enrichment (MAE ™)

Estimated Conventional vs. MAE Boiler Performance Comparison

- Basis: 15MMBTU/Hr Boiler, 1211 scfm, 38% O_2 combustion air

- Conventional 6150 Membrane System (38% O_2):
  - 203 psig Feed Air Requires 45 membranes
  - 4.5 psig Feed Air Requires 449 membranes

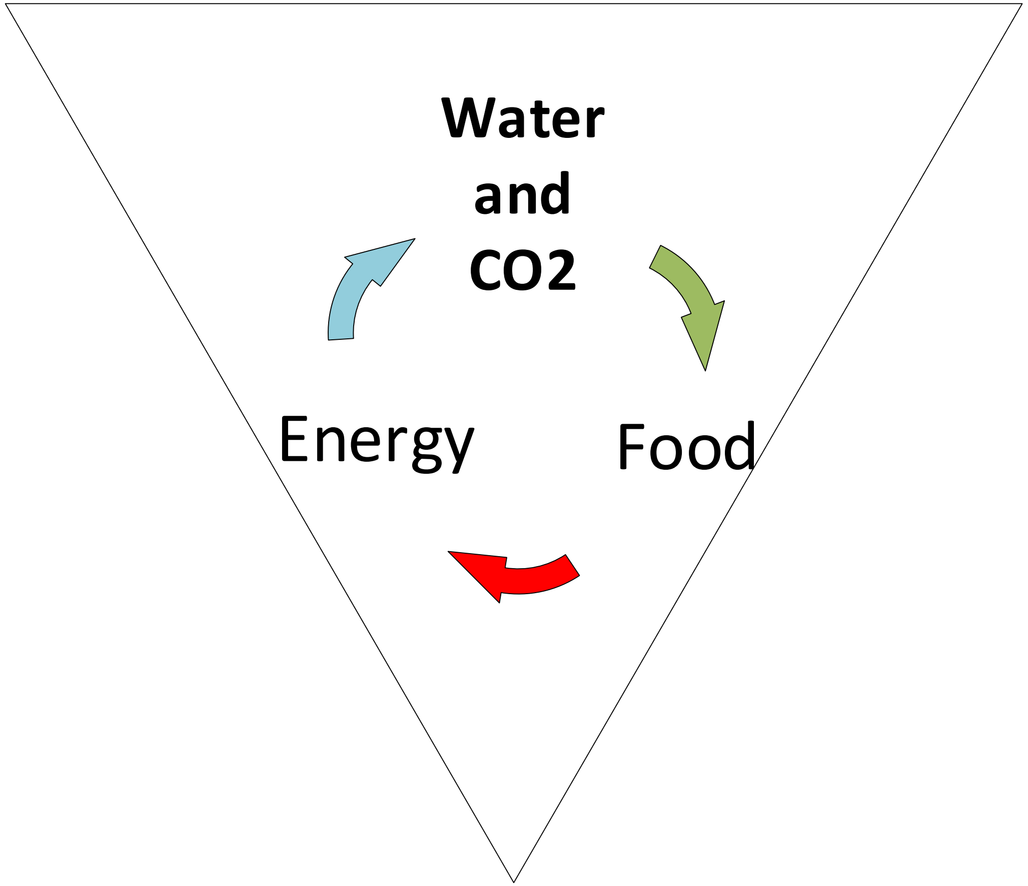
- Lower Cost MAE Wig™ Membrane Produces 43% O_2 Under Vac:
  - Passive (No Air Compression) needing under 300 membranes
  - Based on Prototype/ Bench Scale Tests

BLACK · SWAN

- Achieve Carbon Neutrality in CA by 2025!
- Achieve US Carbon Deceleration at -0.04 GT/Yr^2 by 2030!
- Achieve Carbon Neutrality around the World by 2035.

How? Profitably making Fuel, Water, and Sugar with…!

BLACK · SWAN Cycle



KO_2

THE KOLODJI CORPORATION

Black Swan, LLC

04/19/2021

GENERON

Eliminating Supplemental Natural Gas in Biogas Fired Power Generation

PRESENTED AT

American Institute of Chemical Engineers

Fuels and Petrochemicals Division

2021 Gas Utilization Topical Conference Keynote

Brian Kolodji, PE

Owner of Kolodji Corp and Black Swan, LLC

bkolodji@sbcglobal.net

Office: (661) 742-1659- Cell: (713) 907-8742

Website: K-O2.com

and

Marc Straub, Vice President

Generon

”Jesus said to them, again, “Peace be with you. As the Father has sent me, so I send you.”

And when He had said this, he breathed on them and said to them, “Receive the Holy Spirit.”