"-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 **(…in the beginning… the awesome power of breath…)**

02/12/2021

KO_2

Black Swan Cycle for Food-Energy-Water Sustainability and Carbon Neutrality

PRESENTED AT

American Institute of Chemical Engineers

Institute for Sustainability

2021 2nd FOOD-ENERGY-WATER NEXUS CONFERENCE

BY

Brian Kolodji, PE

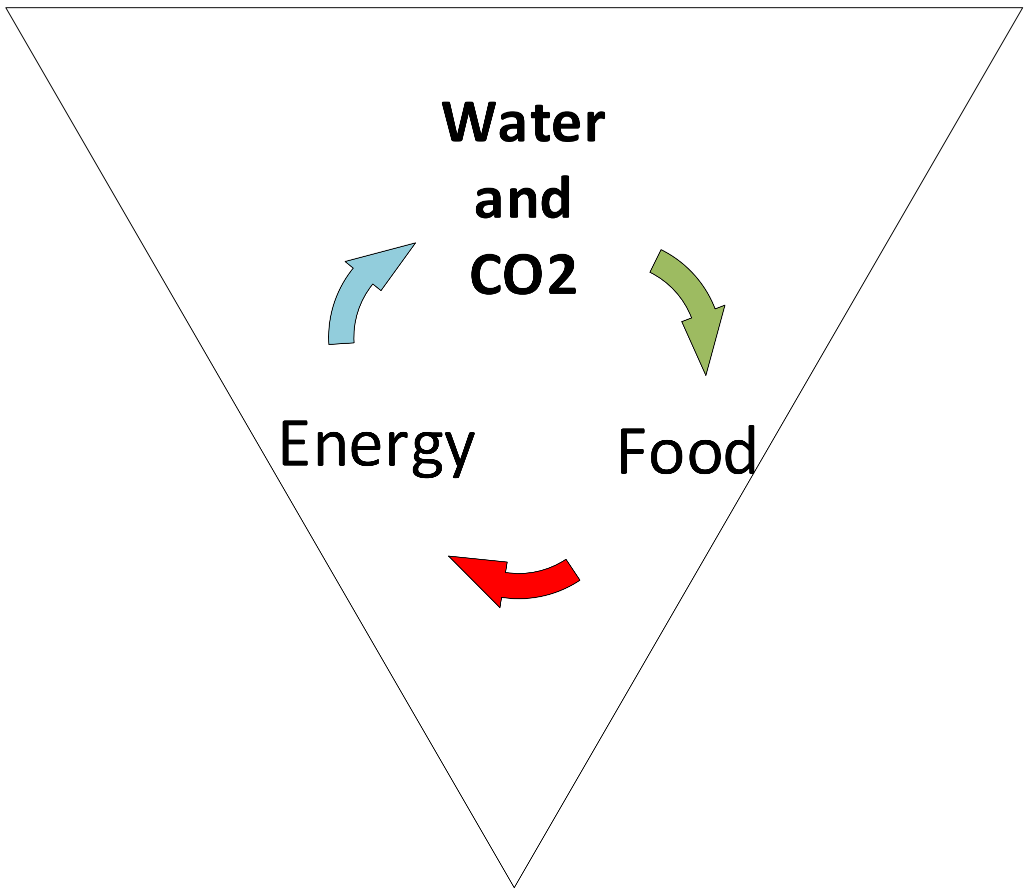
Owner of Kolodji Corp and Black Swan, LLC

bkolodji@sbcglobal.net

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

Website: K-O2.com

Black Swan Cycle



BLACK · SWAN

Energy Carbon Management and Sustainability!

- **Membrane Air Enrichment (MAE) for Fuel/Air Fired Systems**
  - **Directly Captures Carbon Dioxide (CO_2- a GHG) from Air**
  - **Raises CO_2 in Dry Flue Exhaust from under 10 up to 90+%**
  - **Reduces Fuel Consumed/Makes Water/Increases Capacity**

- **Flue Gas Extraction and Bio-Sequestration (FGXB)**
  - **CO2 Used to Make Biomass for Renewable Fuel & Food**
  - **Reduces Agriculture Water Consumption (Highest User)**

Membrane Air Enrichment (MAE): Chemistry

- Simplified Gas Combustion with Air Feed (Dry at 20% O_2 , 80% 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)

- A Membrane Module Provides 50% Oxygen Enrichment of Air (50% O_2, 50% N_2)
  - Low Pressure/ Energy/ Cost Membranes capture oxygen, water, and CO2 directly from air
  - 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
  - Higher firing temperature, Up to 100% increase of Capacity for Industrial Units
  - Eliminates supplemental non-renewable (natural gas) fuel for Biogas Power

Bulk Separation of Nitrogen From CO_2, Oxygen and Water Allows Increased Capacity, Fuel and Water Savings, Higher Concentration of CO2 in Exhaust, and CO_2 Capture/ Use

INTRODUCING CONVENTIONAL MEMBRANE GAS SEPARATION TECHNOLOGY

- CO2 Removal from Field Gas/ Enhanced Oil Recovery (Commercial Scale now at Billions SCFD 40+ Years)
  - Honeywell UOP (Separex®) Using Spiral Wound (Sheet Type) Membrane Elements (see below from MODEC's website) to produce concentrated CO2 for enhanced oil recovery (EOR) and to produce pipeline quality (under 3% CO2) natural gas.
    - Mr. Kolodji led UOP's design and Petrobras/MODEC's commissioning/startup of first of a kind facility below
    - Recovered High Concentration CO2 from Field Gas for use in EOR with 10,000 psig pressure dense phase CO2 reinjection down hole
    - Source: MODEC Website

The *FPSO Cidade de Angra dos Reis MV22* is moored in 2,149m of water in the Lula (formerly Tupi) field, Santos Basin.

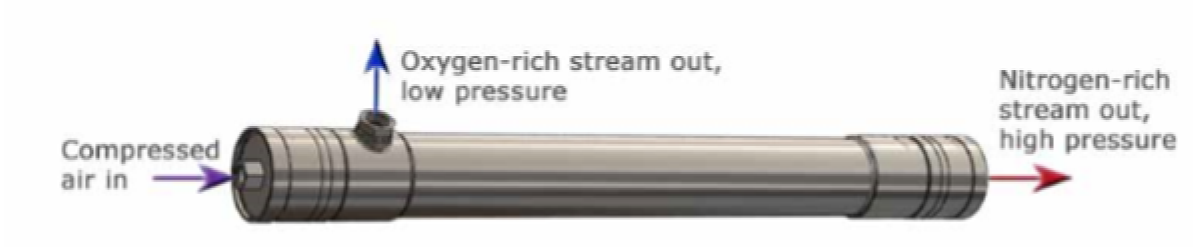
MODEC converted the VLCC "M/V Sunrise IV" into the FPSO. The FPSO is capable of processing up to 100,000 barrels of oil per day and 5 million m³ of gas. The facility is designed for H_2S and CO_2 removal and is capable of reinjecting CO_2 downhole at 550 bar in addition to exporting sales gas to shore. The FPSO will initially gather production from five subsea wells and has the ability to accommodate four additional production wells in the future.

The contract is for a 15 year lease with 5 one-year options. The FPSO is designed to remain on the field for up to 20 years.

Unit Name	: FPSO Cidade de Angra dos Reis MV22		
Field Location	: Lula (formerly Tupi) Field	Storage Capacity	: 1,600,000 bbls
Country	: Brazil	Oil Production	: 100,000 bopd
Water Depth	: 2,149 m	Gas Production	: 150 mmscfd
Mooring Type	: SOFEC Spread Mooring	Water Injection	: 100,000 bwpd

AIR PRODUCTS CONVENTIONAL MEMBRANE AIR OXYGEN ENRICHMENT TECHNOLOGY AND DATA

How membranes work for Oxygen-Enriched Air (OEA)



OEA flow in Nm3/H @ 55°C, 15 barg

	25% O_2 Purity		30% O_2 Purity		35% O_2 Purity		40% O_2 Purity		45% O_2 Purity		50% O_2 Purity	
Model	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
PA1010 N1	0.53	0.44	0.69	0.46	0.94	0.49	1.44	0.51				
PA1020 N1	1.80	1.50	2.34	1.57	3.18	1.63	4.87	1.68				
PA3020 N1	7.88	6.56	10.2	6.84	13.9	7.12	21.3	7.35				
PA3030 N1	13.3	11.1	17.3	11.6	23.5	12.1	36.0	12.5				
PA4030 N1	23.6	19.7	30.6	20.5	41.6	21.4	63.7	22.1				
PA4050 N1	38.8	32.4	50.3	33.8	68.4	35.4	104.7	36.9				
PA6050 N1	97.7	81.6	126.9	85.4	172.2	89.5	263.8	93.7				
PA1010 P3							0.38	0.17	0.54	0.19	0.93	0.20
PA4030 P3							19.3	8.83	27.5	9.34	47.6	9.83
PA4050 P3							31.9	14.7	45.5	15.6	78.7	16.6
PA6050 P3							70.4	32.4	100.5	34.5	173.8	36.6

23.0 SCFM 40% O2 per membrane

58.3 SCFM 40% O2 per membrane

Nm3/H x 37.33 = SCFH

GENERON CONVENTIONAL 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

Simple MAE Process Prototype, Using Unmodified Conventional Air Products Prism™ Membrane

AIR PRODUCTS CONVENTIONAL MEMBRANE AIR OXYGEN GAS SEPARATION TECHNOLOGY AND DATA

UNDER NEAR **BLACK · SWAN** MAE OPERATING CONDITIONS/ CONFIGURATION

Small Scale Test - 1000scfm

MODEL	*FEED PRESSURE (psig) **	*OPERATING TEMPERATURE (F)*	*PERMEATE (VACUUM) PRESSURE (psig)*	*FEED (scfm)*	*PERMEATE (scfm)*	*NON-PERM (scfm)*	*OEA PURITY (%O2)*	*FEED-NONPERM PRESSURE DROP (psi)*	*AIR / OEA RATIO*	*SEPARATORS REQUIRED*
PA6050N1	2	70	-10.34	1001.0	835.7	165.3	25%	0.36	1.20	839
PA6050N1	2	80	-10.34	1000.6	834.6	166.0	25%	0.45	1.20	699
PA6050N1	2	90	-10.34	1000.4	833.4	167.0	25%	0.56	1.20	587
PA6050N1	2	100	-10.34	1000.5	832.4	168.1	25%	0.68	1.20	497
PA6050N1	2	110	-10.34	1000.7	831.3	169.4	25%	0.83	1.20	424
PA6050N1	2	120	-10.34	999.8	829.1	170.7	25%	1.01	1.21	364
PA6050N1	2	70	-10.34	1000.8	658.3	342.5	30%	0.58	1.52	626
PA6050N1	2	80	-10.34	999.9	651.5	348.4	30%	0.73	1.53	519
PA6050N1	2	90	-10.34	1000.1	644.7	355.4	30%	0.91	1.55	434
PA6050N1	2	100	-10.34	1001.6	637.8	363.8	30%	1.14	1.57	366
PA6050N1	2	110	-10.34	1000.4	628.1	372.3	30%	1.41	1.59	310
PA6050N1	2	120	-10.34	1001.8	618.8	382.9	30%	1.73	1.62	265

* Estimated discharge pressure of a feed blower

Genereon Model 6150 PerformanceConventional Oxygen Membrane Module Simulated Under NEAR BLACK · SWAN MAE Operating Conditions

Module Type and Conditions					
Standard Pressure	14.696	psi	Active Length	2.42	ft
Standard Temperature	25.00	C	Primary Flux Values	50/50 Flux - 6150CP	
Module Type	6150 CP		Isothermal Model	No	
Fiber Type	50/50 Combined Polymer		Permeate Back Pressure	3.70	psia
Number of Fibers	553500		Packing Factor	0.52	
Fiber OD	135	micron	*Project Information (OPTIONAL)*		
Fiber ID	95	micron	Customer Flow		

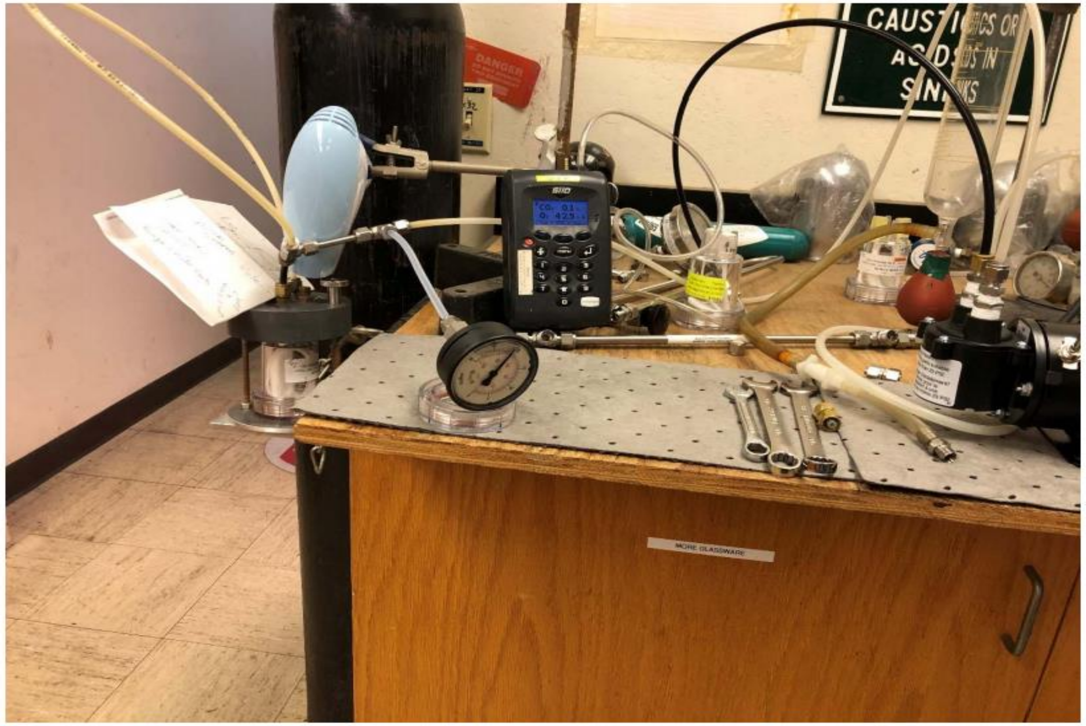
Feed Stream Conditions		
Feed Flow (per module)	430.00	SCFH
Feed Temperature	25.00	C
Feed Pressure (Absolute)	19.20	psia
Wobbe Index	0.0	BTU/ft3
H2:CO Ratio* *(If Applicable)*	N/A	
Component	*Feed Mole Fraction*	
Oxygen	0.2100	
Nitrogen	0.7900	

Model Results: Permeate Stream		
Permeate Flow (per module)	163.67	SCFH
Permeate Temperature	25.00	C
Permeate Pressure (Absolute)	3.70	psia
Permeate Pressure Drop	0.95	psi
Recovery (Permeate/Feed)*	38.06%	
HC Recovery (Permeate/Feed)*	N/A	
Wobbe Index	0.0	BTU/ft3
H2:CO Ratio* *(If Applicable)*	N/A	
Component	*Permeate Mole Fraction*	*Component Recovery**
Oxygen	0.3802	68.90
Nitrogen	0.6198	29.86

BLACK · SWAN Wig™ Membrane Prototype

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.

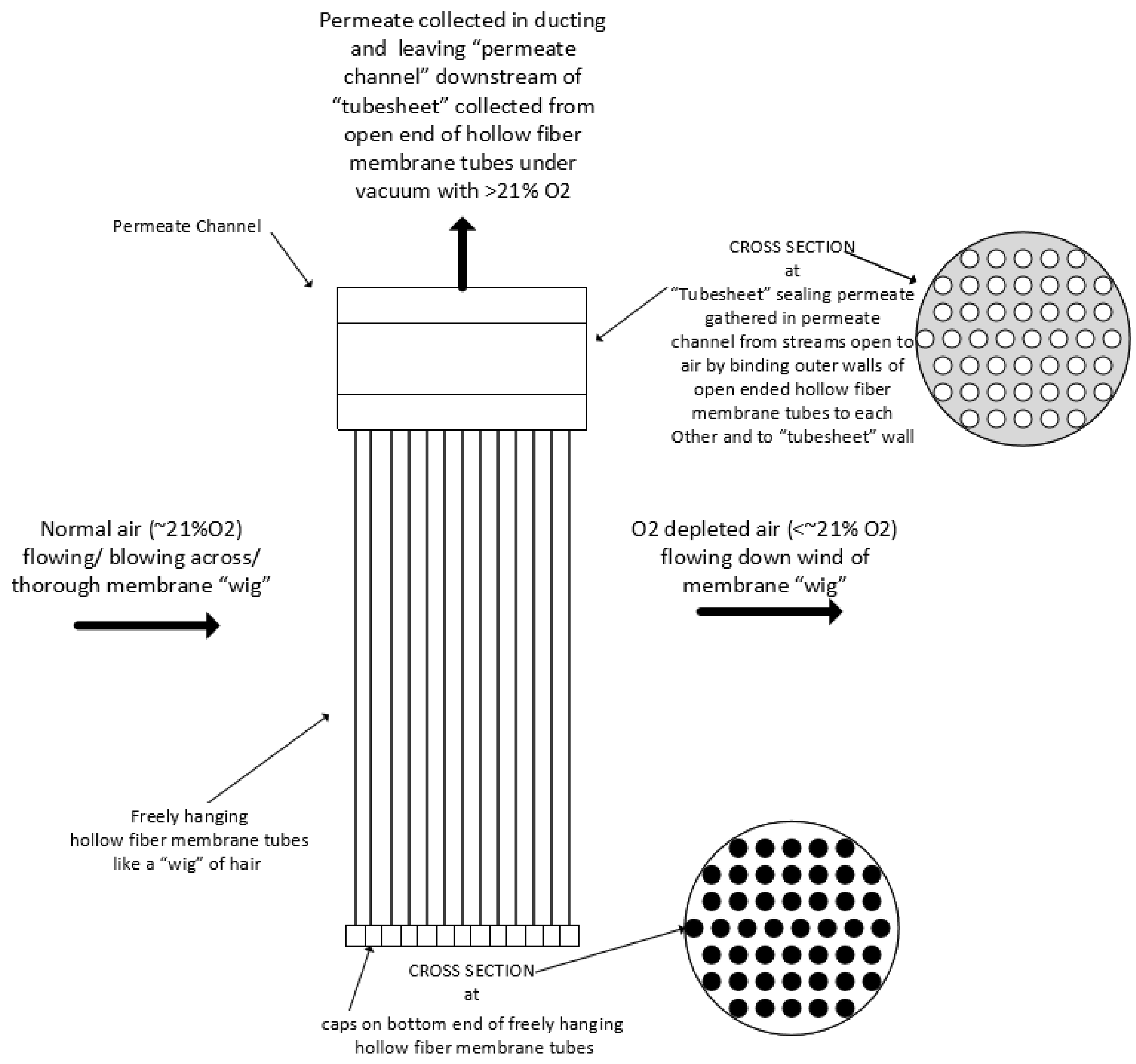


*Photo, instruments and bench/lab measurements courtesy of Mr. Marc Straub, Vice President Membrane Mfrg, Generon

BLACK · SWAN

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

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



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 based on proven science/technology/materials used/commercialized for decades
- MAE Wig lowest membrane operating and capital cost- under 40% of cryogenic technology costs
- MAE Wig higher performance over conventional membranes validated by two major manufacturers

FGXB Chemistry Profits from The Power of Breath!

- Fauna: AIR at 400ppm (0.04%) CO_2 is exhaled as BREATH at 40,000ppm (4%) CO_2
  - Respiration "burns" carbohydrates, such as sugar, eg. glucose, $C_6(H_2O)_6$, for life energy
    - $6O_2 + C_6(H_2O)_6$ (stored energy) >> $6CO_2 + 6H_2O$ + Energy (eg. in the form of muscle movement)
  - 21% O_2 level in AIR correspondingly drops 17% in exhaled BREATH due to CO_2 make
    - Humans increase CO_2 concentration in one breath by a factor of 100, making 2 gigatons per year
    - Transport/ Power/ Industry Sectors similarly produce over 40 Gigatons of CO2 per year
    - CO2 production is nescessary for life… Why??? The ultimate sustainability cycle

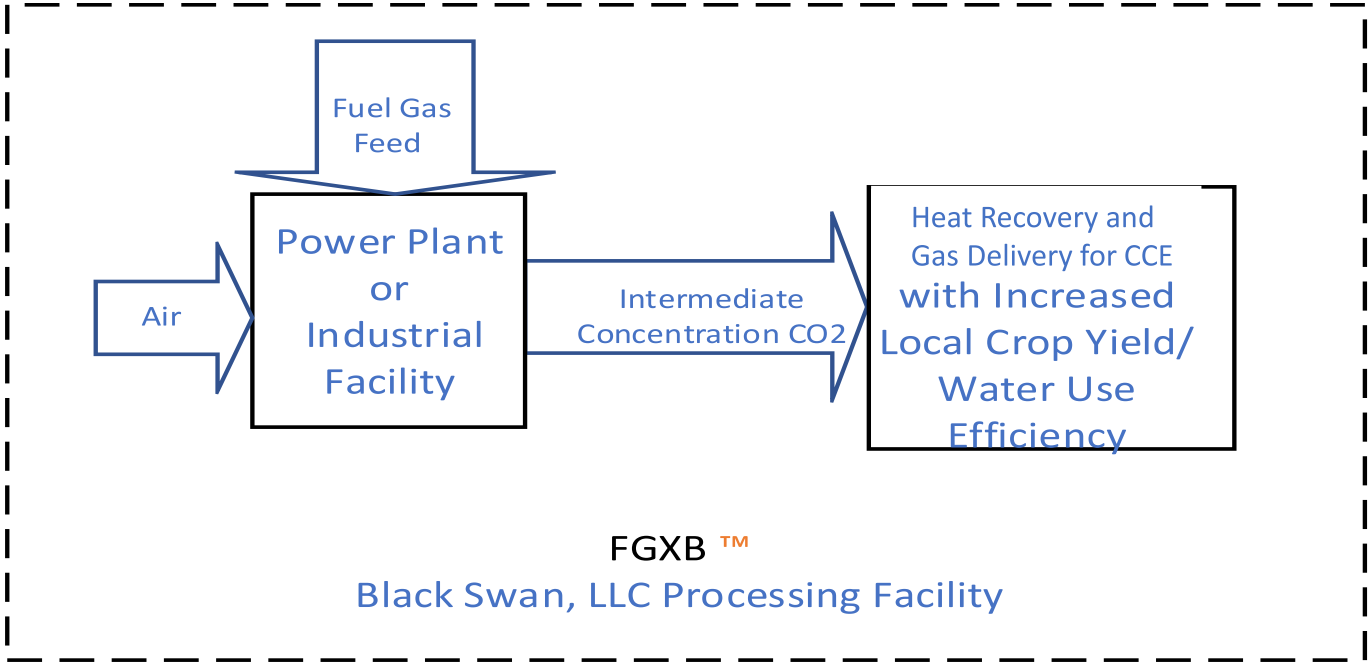
- Flora: CO2 is consumed photosynthetically to make oxygen and cellulose
  - $6CO_2 + 6H_2O$ + sunlight >> $6O_2 + C_6(H2O)_6$ (cellulose, a sugar and building block of plants)
  - Over 95% of plant growth is dependent upon carbon supplied by CO_2
  - **Plant growth rate can up to double if local plant biosphere CO_2 is raised 50%**

Increase agricultural yield and water use efficiency, in world's largest water consumer

BLACK · SWAN

Flue Gas Extraction and Biosequestration

FGXB ™



Profit from CO_2 without concentrating the flue gas, but cooling and dispersing to crops!

CO2 CROP ENRICHMENT (CCE)

(Atmosphere around Crop raised to min 600 ppm CO_2, or 150% that of air!)

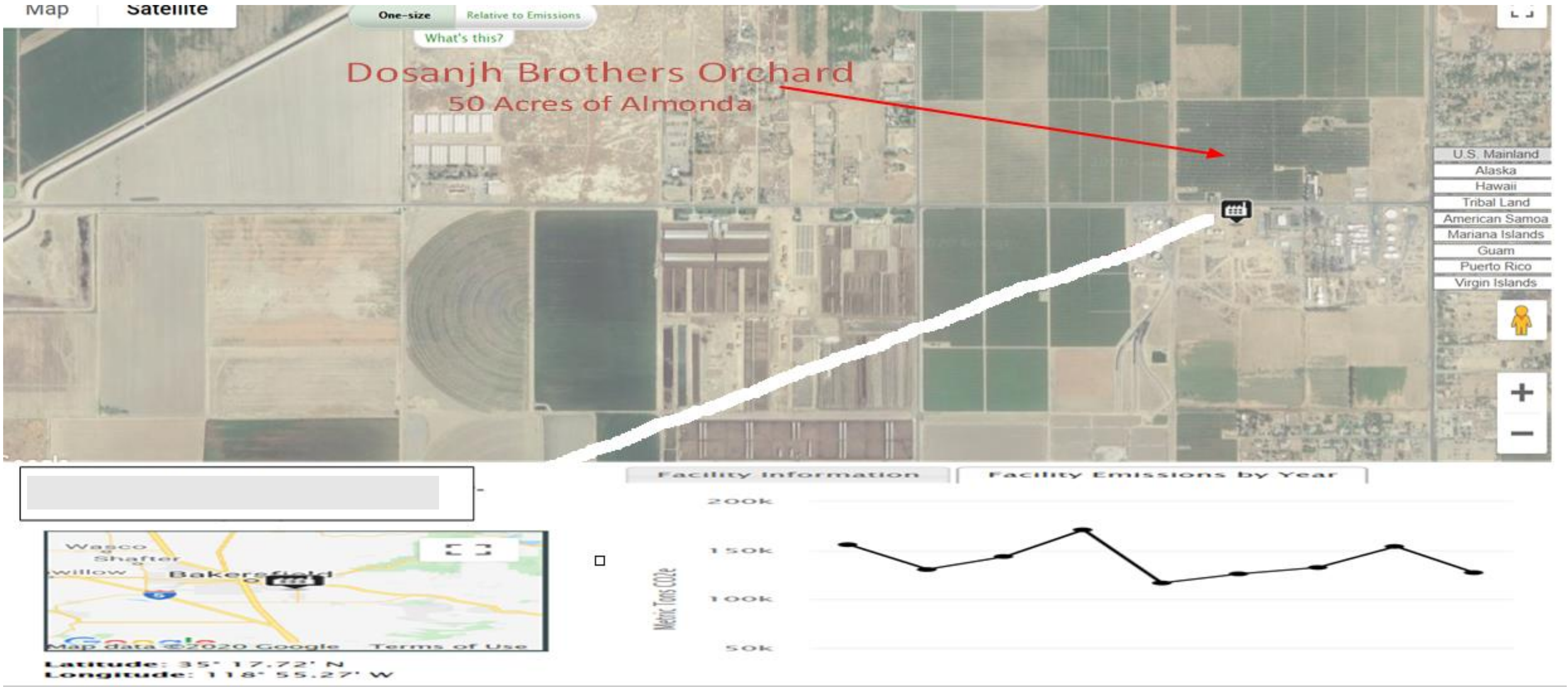
- Used for almost a hundred years throughout the world (especially northern hemisphere) in greenhouses

- Researched/ Proven for past 40 years in open air systems (without greenhouses)
  - Free Air Carbon Enrichment (FACE) Systems by Brookhaven National Laboratory (Dr. George Hendrey/ Keith Lewin)
  - By United States Department of Agriculture (Dr. Bruce Kimball)
  - Commercialized with Black Swan Project Pilot/ Demonstration Facility Funded by California Department of Food and Agriculture

- Proven to Boost Agricultural Yield and Save Water (see literature sources below):

- 1967: Ford & Thorne (Corn +70% yield)
- 1983: Rogers (Corn and Soybean Water Use Efficiency +100%)
- 1984: Havelka (Wheat +35% yield)
- 1985: Acock & Allen (Soybean +40% biomass)
- 1985: Bhattacharya et al (Sweet Potatoes +83% yield)
- 1986: Cure & Acock (Cotton +200% yield)
- 1987/1989: Kimball et al (Cotton +100% yield)
- 1993: Kimball et al (Rice/Soybeans)
- 1994-7: Bindi et al: Grapes (+50 to 70% yield)
- 2007: Kimball et al: Citrus (up to +200% yield)

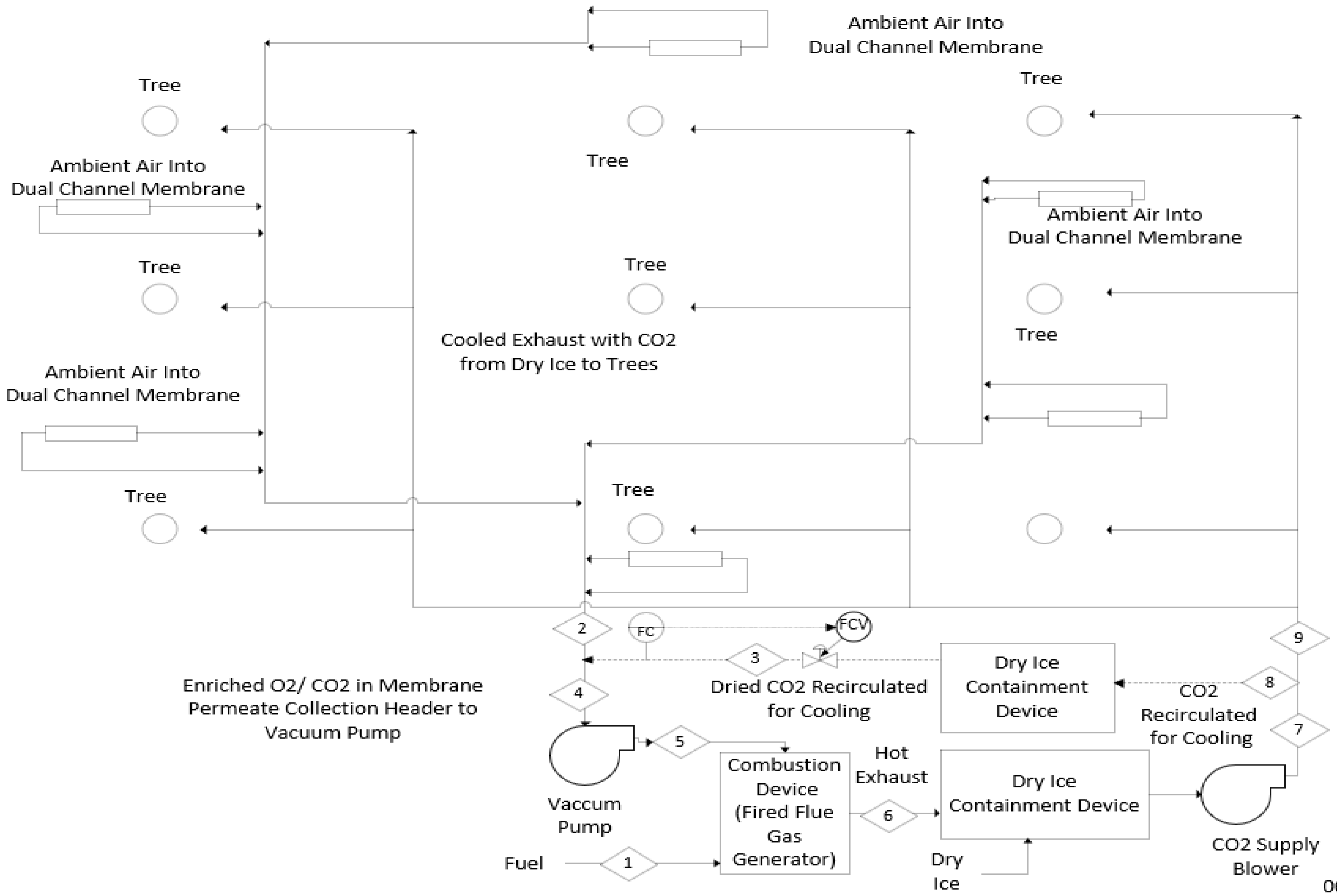
BLACK · SWAN FGXB/MAE Demonstration Site



BLACK · SWAN

MAE/FGXB™ Pilot Scale BIOGAS Facility Site

Membrane Air Enrichment Process Flow Diagram



06/22/2020

Simulated Biogas Material Balance 50 T/Y CO_2 MAE/FGXB™ Pilot

Table 1

Heat and Material Balances for New MAE Process: BASIS 50 Tons/ Year CO2 for 10 almond trees Using Quench

50% O2 Enrich Feed Case- With nescessary Recirculation to protect existing Combustion Device

Benefits: Lower Yet Operating Cost Crop Carbon Enrichment System

40% Increase in Duty of Existing Steam/ Power Generation Device

Stream Numbers	1	2	3	4	5	6	7	9
Process Parameters/ Stream Names	Fuel****	Comb O2	Dry Recirc	Vac Suct	Vac Disch	Flue Gas	Cool FG	Crop Carbon
Absolute Pressure, psia	25	3.8	3.8	3.8	16	15	16	15
Temperature F **	Ambient	Ambient	50	Ambient	200	350	170	60
Gas Standard Volumetric Rate, SCFM	6.32	25.81	9.65	35.46	35.46	41.78	28.95	19.30
Total Molar Flow Rate- LbMole/Hr)	1	4.083	1.52666667	5.609667	5.609667	6.609667	4.579667	3.053
	Mole Balance, lb mols/hr							
Methane (CH4- LbMole/Hr)	1	0	0	0	0	0	0	0
Oxygen (O2- LbMole/Hr)	0	2	0	2	2	0	0	0
Nitrogen (N2- LbMole/Hr)	0	2	1	3	3	3	3	2
Water (H2O- LbMole/Hr)	0	0.08	0	0.08	0.08	2.08	0	0
Carbon Dioxide (CO2- LbMole/Hr)	0	0.003	0.52666667	0.529667	0.529667	1.529667	1.579667	1.053
	Mole Percent							
Methane (CH4- Mole Fraction)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen (O2- Mole Fraction)	0.0	49.0	0.0	35.7	35.7	0.0	0.0	0.0
Nitrogen (N2- Mole Fraction)	0.0	49.0	65.5	53.5	53.5	45.4	65.5	65.5
Water (H2O- Mole Fraction)	0.0	2.0	0.0	1.4	1.4	31.5	0.0	0.0
Carbon Dioxide (CO2- Mole Fraction)	0.0	0.07	34.5	9.4	9.4	23.1	34.5	34.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Mass Balance, Tons/yr ***							
Methane (CH4- Tons/yr)	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen (O2- Tons/yr)	0.0	70.1	0.0	70.1	70.1	0.0	0.0	0.0
Nitrogen (N2- Tons/yr)	0.0	61.3	30.7	92.0	92.0	92.0	92.0	61.3
Water (H2O- Tons/yr)	0.0	1.6	0.0	1.6	1.6	41.0	0.0	0.0
Carbon Dioxide (CO2- Tons/yr)	0.0	0.1	25.4	25.5	25.5	73.7	76.1	50.7
Total , Tons/yr	17.5	133.1	56.0	189.2	189.2	206.7	168.1	112.1

35 % , up from 9% CO2

* Dry Ice CO2 contribution 0.05 lbmols/hr, all water assumed removed in this step.

***Daily Usage only 12 hours/ day, Annual usage is 9 out of 12 months (not winter without leaf.)

**Temperatures estimated only for approximate relative values

****Equivalent to about 10 lbs of fuel per hour in the form of methane or propane or gasoline

BLACK · SWAN

CDFA* Funded Demonstration Site

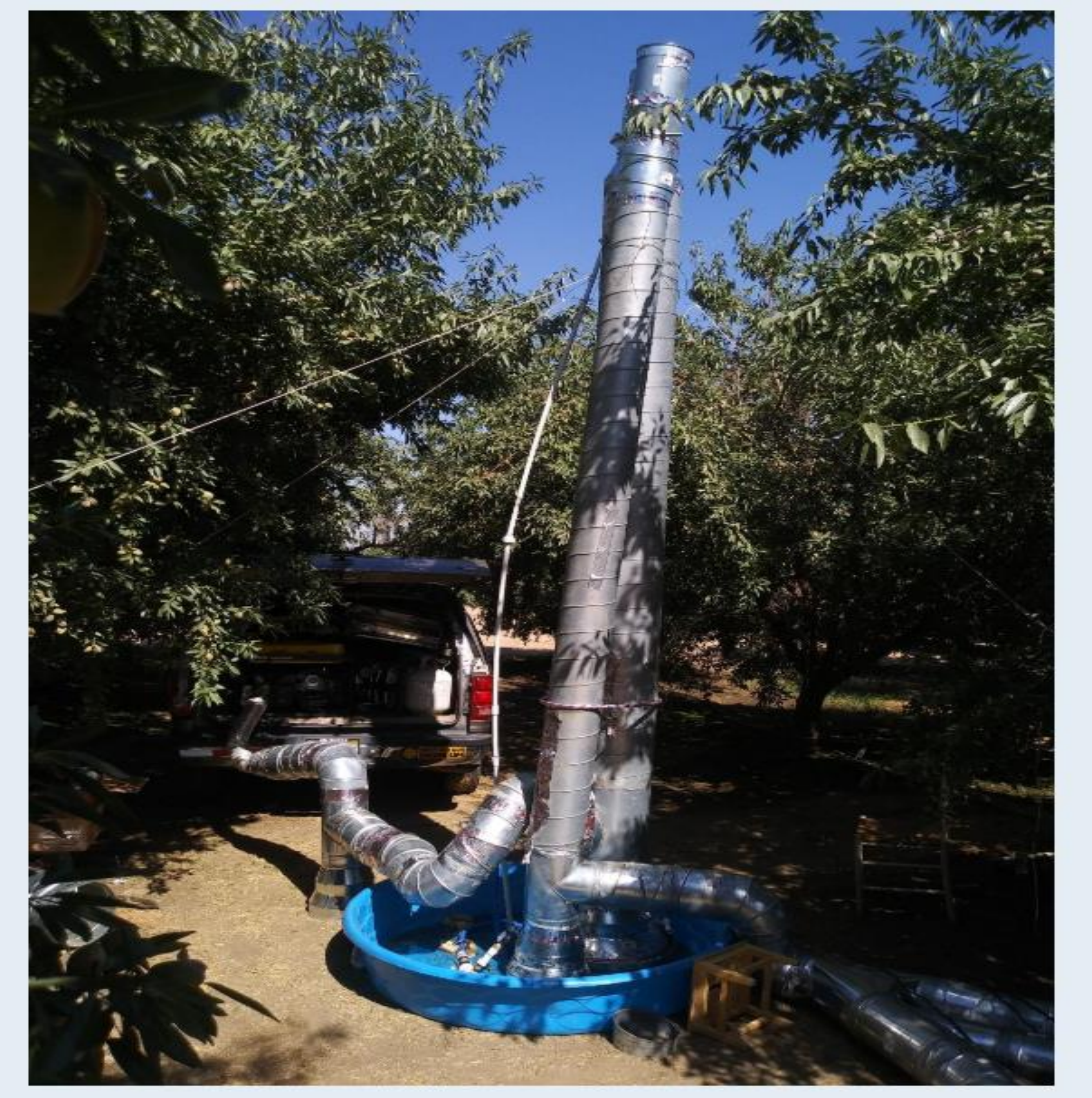
Patented/ Patent Pending FGXB™ / MAE™

- Industry Supply Potential of up to 200,000 T/Y CO2 for 100s of acres of surrounding crops

  - Demonstration facility scale is 10,000 Tons CO_2 /Year Processing (T/Y)
  - Based on Four other FGXB facilities piloted since 2017 at under 100 T/Y.
  - 5th FGXB Pilot installation (July 2020- 100 T/Y, 9 trees, well under 1 acre)- Cap Cost $2000
  - Demonstration FGXB entails 2000 trees over 20 acres ($50,000 Capital) Target Q1-2021
  - MAE bench scale tests since 2018, MAE Pilot on same site Cap $80,000, target Q2-2021

*California Department of Food and Agriculture (CDFA) State Water and Environmental Efficiency Program (SWEEP) Awarded to Dosanjh Bros for Almond Orchard Crop Carbon Enrichment Project

Quench Column for 10,000 Ton/Year CO_2 FGXB/ MAE™ Demonstration Site



BLACK · SWAN

Patent Pending CO_2 Disperser for 10,000 Ton/Year

FGXB/MAE™ Demonstration Site

BLACK · SWAN

Field Measurement Instruments (Soil Moisture/ Weather Station/ CO2 Meters) for 10,000 Ton/Year

FGXB/MAE™ Demonstration Site

CO2 to Trees with Weather Station (top photo) / Soil Moisture/ CO2 Meters and Data Logger (bottom)

**Photo instruments and field measurements courtesy of Dr. Brian Marsh, Director, University of California, Agriculture and Natural Resources, Cooperative Extension- Kern County

BLACK · SWAN

July 2, 2020 Static Measurements From CO_2 Meters During Commissioning of 50 Ton/Year Pilot

FGXB/MAE™ Demonstration Site

Static measurements
Between 12:45
and 13:00

CO2
ppm

	Height	Tree	Tree	Tree	Tree	Tree	Tree
Between tree rows	5'		400	800			
	7'		900	700	500		
	10'			400	300		
		Tree	Tree	Tree	Tree	Tree	Tree
	3'				700		
	7'			300	1100		
	10'			400	400	300	
		Tree	Tree	Tree	Tree	Tree	Tree
Between trees	10' 700						
In tree row							
		Tree	Tree	Tree	Tree	Tree	Tree
Between tree rows	7'					300	
	10'					300	
		Tree	Tree	Tree	Tree	Tree	Tree

Measurements at vents

ranged from 21000 to 36000+ ppm
Sensor reads to nearest 100

General wind
direction

**Photo instruments and field measurements courtesy of Dr. Brian Marsh, Director, University of California, Agriculture and Natural Resources, Cooperative Extension- Kern County

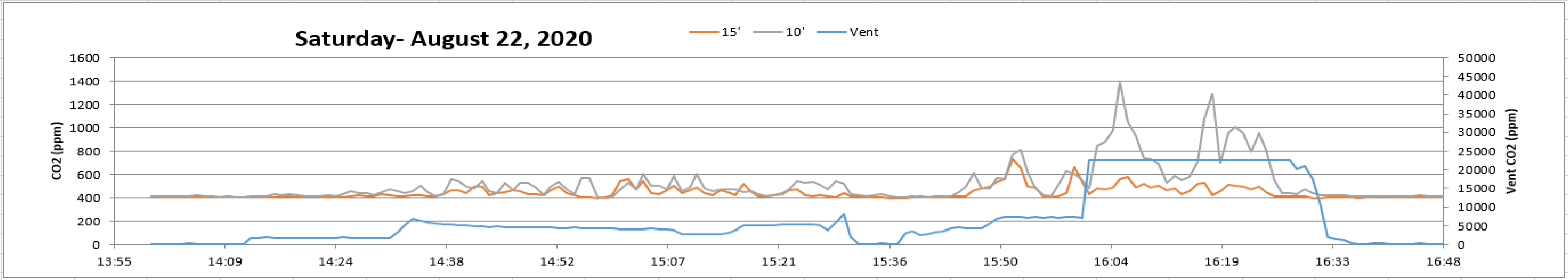
Tree with CO2 enhancement
Tree with continuous CO2 monitoring

North

BLACK · SWAN

August 2020 Field Measurements From CO_2 Meters During Post Commissioning of 100 Ton/Year Pilot

FGXB/MAE™ Demonstration Site



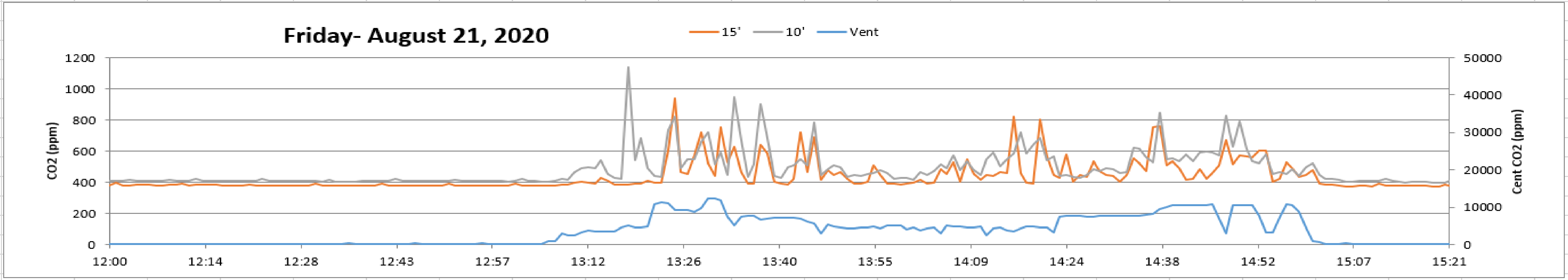


**Photo instruments and field measurements courtesy of Dr. Brian Marsh, Director, University of California, Agriculture and Natural Resources, Cooperative Extension- Kern County

BLACK · SWAN

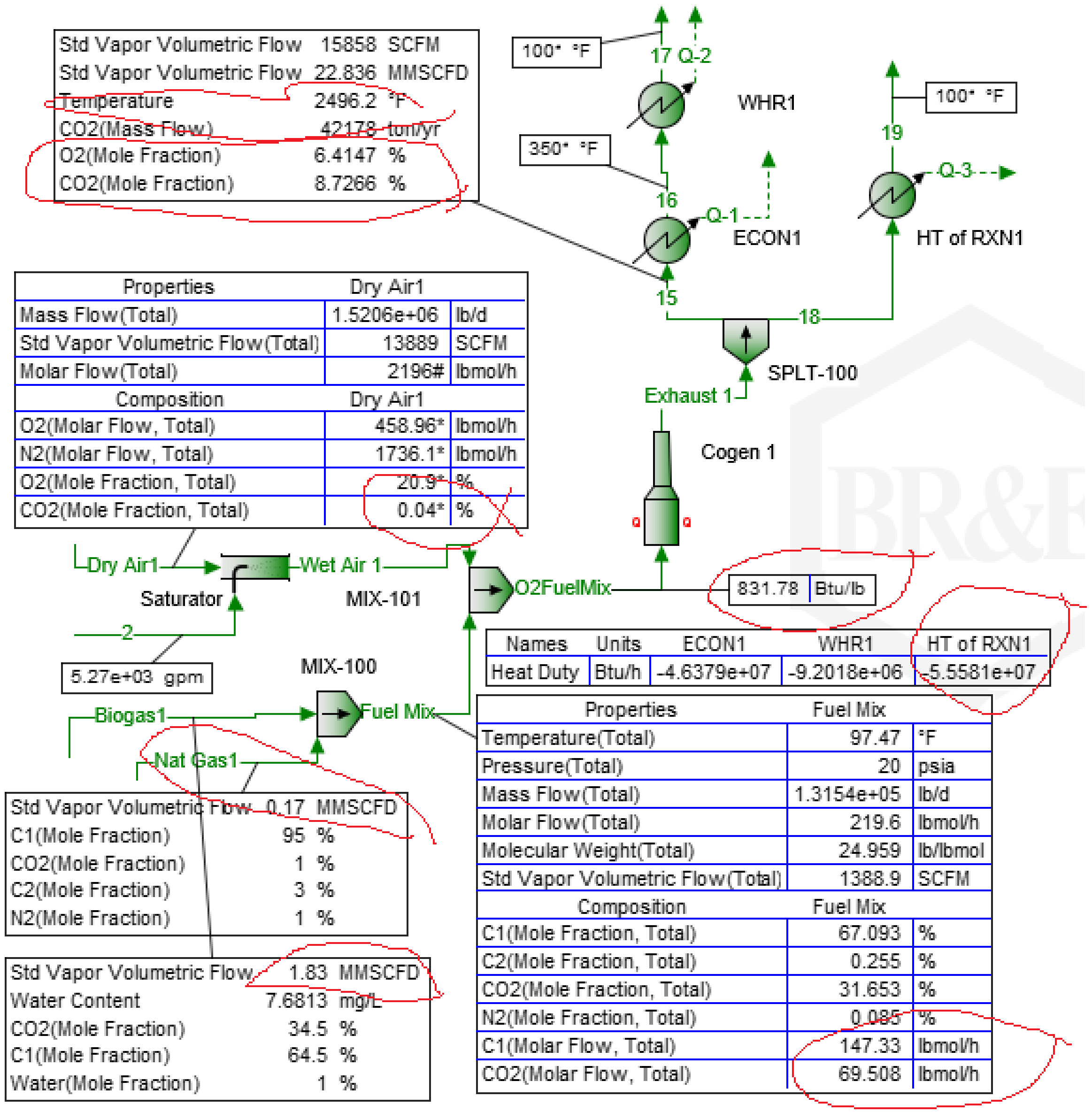
MAE™ 2021 Candidate Commercial Sites

Internal combustion engine driven power plants (1 to 3MW) at California Sanitation Districts

- Fuel: Biogas supplemented with 10% natural gas using 43% O_2 Enrichment
  - Supplemental Natural Gas Savings: 100%
  - Increased Power Generation: 20%
  - Target return on investment of under one year
  - Total Installed Cost Estimates of $300,000 to 500,000

BLACK · SWAN MAE Commercial Site
Normal Operation Case 1 using Biogas and Natural Gas

Case 1
Air with Bio Gas + Natural Gas



Std Vapor Volumetric Flow	15858	SCFM
Std Vapor Volumetric Flow	22.836	MMSCFD
Temperature	2496.2	°F
CO2(Mass Flow)	42178	ton/yr
O2(Mole Fraction)	6.4147	%
CO2(Mole Fraction)	8.7266	%

Properties	Dry Air1	
Mass Flow(Total)	1.5206e+06	lb/d
Std Vapor Volumetric Flow(Total)	13889	SCFM
Molar Flow(Total)	2196#	lbmol/h
Composition	Dry Air1	
O2(Molar Flow, Total)	458.96*	lbmol/h
N2(Molar Flow, Total)	1736.1*	lbmol/h
O2(Mole Fraction, Total)	20.9*	%
CO2(Mole Fraction, Total)	0.04*	%

Names	Units	ECON1	WHR1	HT of RXN1
Heat Duty	Btu/h	-4.6379e+07	-9.2018e+06	-5.5581e+07

Properties	Fuel Mix	
Temperature(Total)	97.47	°F
Pressure(Total)	20	psia
Mass Flow(Total)	1.3154e+05	lb/d
Molar Flow(Total)	219.6	lbmol/h
Molecular Weight(Total)	24.959	lb/lbmol
Std Vapor Volumetric Flow(Total)	1388.9	SCFM
Composition	Fuel Mix	
C1(Mole Fraction, Total)	67.093	%
C2(Mole Fraction, Total)	0.255	%
CO2(Mole Fraction, Total)	31.653	%
N2(Mole Fraction, Total)	0.085	%
C1(Molar Flow, Total)	147.33	lbmol/h
CO2(Molar Flow, Total)	69.508	lbmol/h

Std Vapor Volumetric Flow	0.17	MMSCFD
C1(Mole Fraction)	95	%
CO2(Mole Fraction)	1	%
C2(Mole Fraction)	3	%
N2(Mole Fraction)	1	%

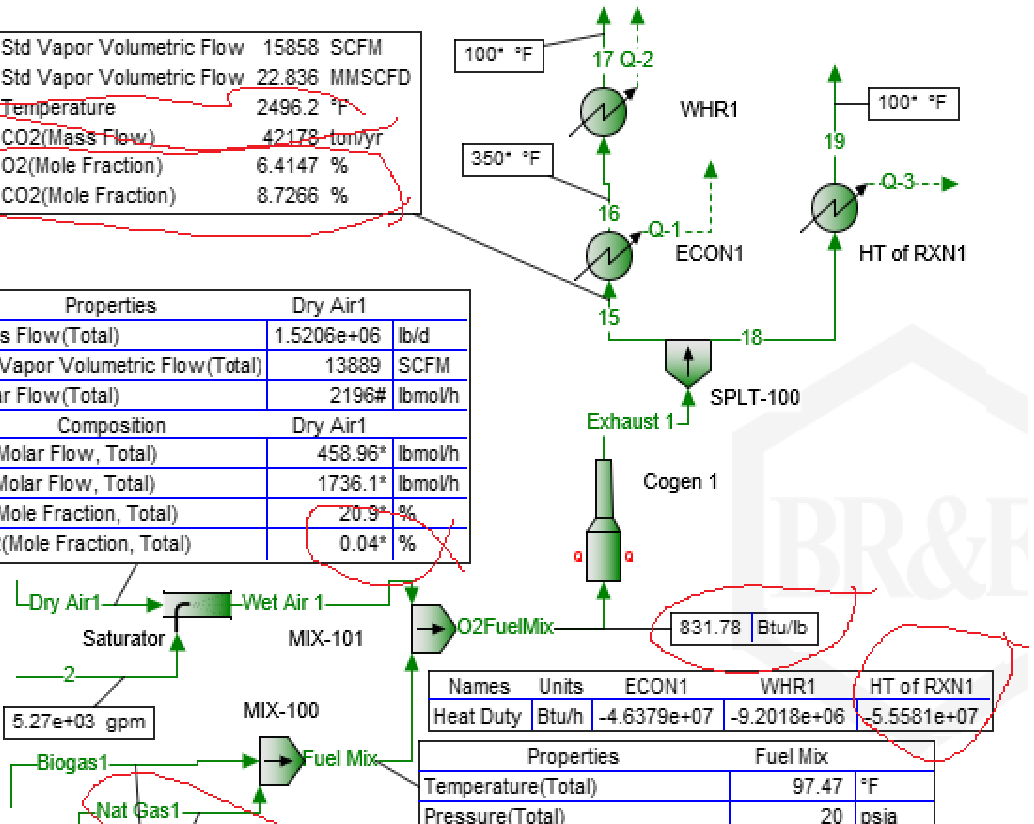
Std Vapor Volumetric Flow	1.83	MMSCFD
Water Content	7.6813	mg/L
CO2(Mole Fraction)	34.5	%
C1(Mole Fraction)	64.5	%
Water(Mole Fraction)	1	%

BLACK · SWAN MAE Commercial Site

Comparison of Normal Op Case 1 vs. Biogas without Natural Gas using Standard Air (Case 0, below note low T/Heat Value)

Case 1

Air with Bio Gas + Natural Gas



Std Vapor Volumetric Flow	15858	SCFM
Std Vapor Volumetric Flow	22.836	MMSCFD
Temperature	2496.2	°F
CO2(Mass Flow)	42178	ton/yr
O2(Mole Fraction)	6.4147	%
CO2(Mole Fraction)	8.7266	%

Properties	Dry Air1	
Mass Flow(Total)	1.5206e+06	lb/d
Std Vapor Volumetric Flow(Total)	13889	SCFM
Molar Flow(Total)	2196#	lbmol/h
Composition	**Dry Air1**	
O2(Molar Flow, Total)	458.96*	lbmol/h
N2(Molar Flow, Total)	1736.1*	lbmol/h
O2(Mole Fraction, Total)	20.9*	%
CO2(Mole Fraction, Total)	0.04*	%

Names	Units	ECON1	WHR1	HT of RXN1
Heat Duty	Btu/h	-4.6379e+07	-9.2018e+06	-5.5581e+07

Nat Gas1:

Std Vapor Volumetric Flow	0.17	MMSCFD
C1(Mole Fraction)	95	%
CO2(Mole Fraction)	1	%
C2(Mole Fraction)	3	%
N2(Mole Fraction)	1	%

Biogas1:

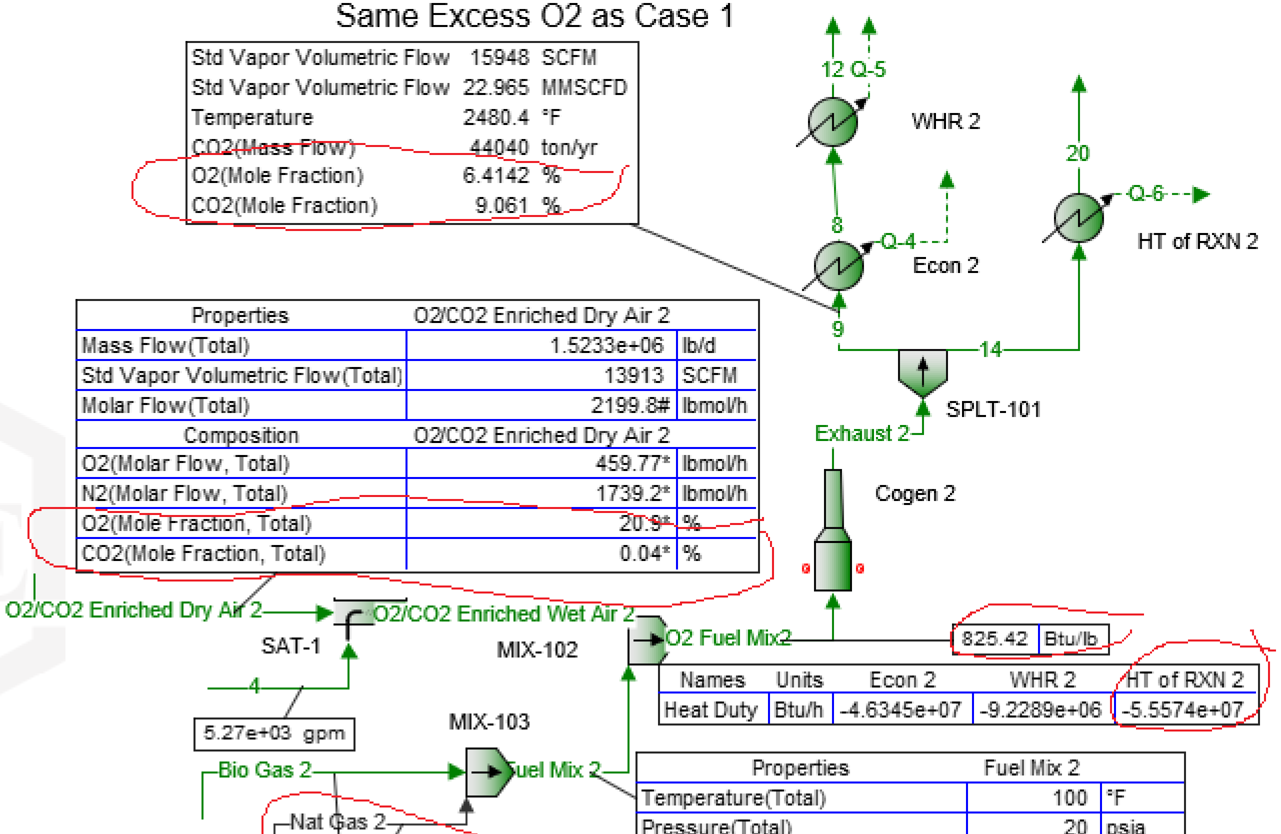
Std Vapor Volumetric Flow	1.83	MMSCFD
Water Content	7.6813	mg/L
CO2(Mole Fraction)	34.5	%
C1(Mole Fraction)	64.5	%
Water(Mole Fraction)	1	%

Properties	Fuel Mix	
Temperature(Total)	97.47	°F
Pressure(Total)	20	psia
Mass Flow(Total)	1.3154e+05	lb/d
Molar Flow(Total)	219.6	lbmol/h
Molecular Weight(Total)	24.959	lb/lbmol
Std Vapor Volumetric Flow(Total)	1388.9	SCFM
Composition	**Fuel Mix**	
C1(Mole Fraction, Total)	67.093	%
C2(Mole Fraction, Total)	0.255	%
CO2(Mole Fraction, Total)	31.653	%
N2(Mole Fraction, Total)	0.085	%
C1(Molar Flow, Total)	147.33	lbmol/h
CO2(Molar Flow, Total)	69.508	lbmol/h

Case 0

Air with Bio Gas Only (no Natural Gas)

Same Excess O2 as Case 1



Std Vapor Volumetric Flow	15948	SCFM
Std Vapor Volumetric Flow	22.965	MMSCFD
Temperature	2480.4	°F
CO2(Mass Flow)	44040	ton/yr
O2(Mole Fraction)	6.4142	%
CO2(Mole Fraction)	9.061	%

Properties	O2/CO2 Enriched Dry Air 2	
Mass Flow(Total)	1.5233e+06	lb/d
Std Vapor Volumetric Flow(Total)	13913	SCFM
Molar Flow(Total)	2199.8#	lbmol/h
Composition	**O2/CO2 Enriched Dry Air 2**	
O2(Molar Flow, Total)	459.77*	lbmol/h
N2(Molar Flow, Total)	1739.2*	lbmol/h
O2(Mole Fraction, Total)	20.9*	%
CO2(Mole Fraction, Total)	0.04*	%

Names	Units	Econ 2	WHR 2	HT of RXN 2
Heat Duty	Btu/h	-4.6345e+07	-9.2289e+06	-5.5574e+07

Nat Gas 2:

Std Vapor Volumetric Flow	0	MMSCFD
C1(Mole Fraction)	95	%
CO2(Mole Fraction)	1	%
C2(Mole Fraction)	3	%
N2(Mole Fraction)	1	%

Bio Gas 2:

Std Vapor Volumetric Flow	2.094	MMSCFD
Water Content	7.6813	mg/L
CO2(Mole Fraction)	34.5	%
C1(Mole Fraction)	64.5	%
Water(Mole Fraction)	1	%

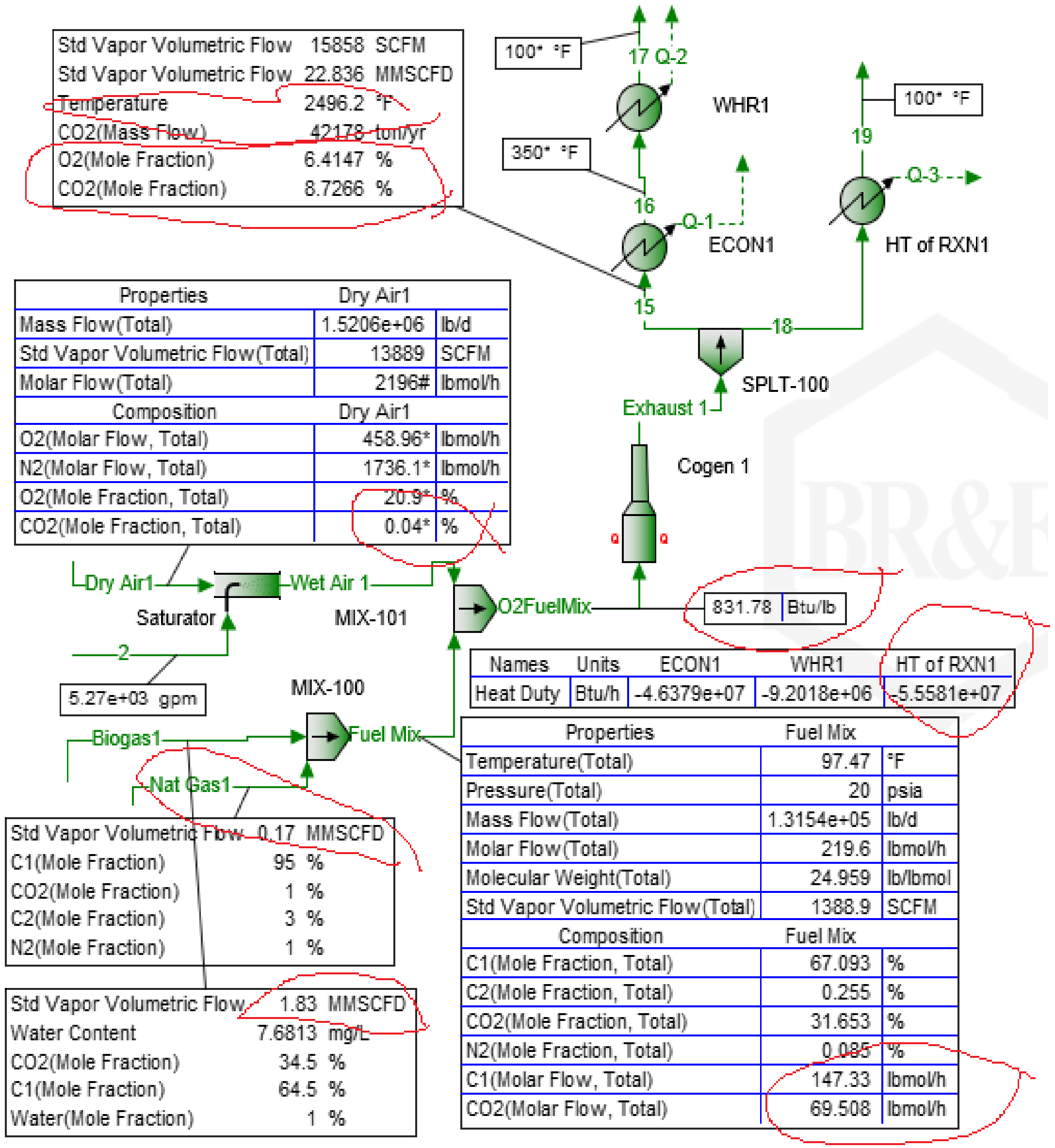
Properties	Fuel Mix 2	
Temperature(Total)	100	°F
Pressure(Total)	20	psia
Mass Flow(Total)	1.4187e+05	lb/d
Molar Flow(Total)	229.92	lbmol/h
Molecular Weight(Total)	25.711	lb/lbmol
Std Vapor Volumetric Flow(Total)	1454.2	SCFM
Composition	**Fuel Mix 2**	
C1(Mole Fraction, Total)	64.5	%
C2(Mole Fraction, Total)	0	%
CO2(Mole Fraction, Total)	34.5	%
N2(Mole Fraction, Total)	0	%
C1(Molar Flow, Total)	148.3	lbmol/h
CO2(Molar Flow, Total)	79.322	lbmol/h

BLACK · SWAN MAE Commercial Site

Comparison of Normal Op Case 1 vs. Biogas without Natural Gas using O2 Enriched Air (Case 2, below note higher T/Heat Value)

Case 1

Air with Bio Gas + Natural Gas



Std Vapor Volumetric Flow	15858	SCFM
Std Vapor Volumetric Flow	22.836	MMSCFD
Temperature	2496.2	°F
CO_2(Mass Flow)	42178	ton/yr
O_2(Mole Fraction)	6.4147	%
CO_2(Mole Fraction)	8.7266	%

Properties	Dry Air1	
Mass Flow(Total)	1.5206e+06	lb/d
Std Vapor Volumetric Flow(Total)	13889	SCFM
Molar Flow(Total)	2196#	lbmol/h
Composition	**Dry Air1**	
O_2(Molar Flow, Total)	458.96*	lbmol/h
N_2(Molar Flow, Total)	1736.1*	lbmol/h
O_2(Mole Fraction, Total)	20.9*	%
CO_2(Mole Fraction, Total)	0.04*	%

Names	Units	ECON1	WHR1	HT of RXN1
Heat Duty	Btu/h	-4.6379e+07	-9.2018e+06	-5.5581e+07

Properties	Fuel Mix	
Temperature(Total)	97.47	°F
Pressure(Total)	20	psia
Mass Flow(Total)	1.3154e+05	lb/d
Molar Flow(Total)	219.6	lbmol/h
Molecular Weight(Total)	24.959	lb/lbmol
Std Vapor Volumetric Flow(Total)	1388.9	SCFM
Composition	**Fuel Mix**	
C1(Mole Fraction, Total)	67.093	%
C2(Mole Fraction, Total)	0.255	%
CO_2(Mole Fraction, Total)	31.653	%
N_2(Mole Fraction, Total)	0.085	%
C1(Molar Flow, Total)	147.33	lbmol/h
CO_2(Molar Flow, Total)	69.508	lbmol/h

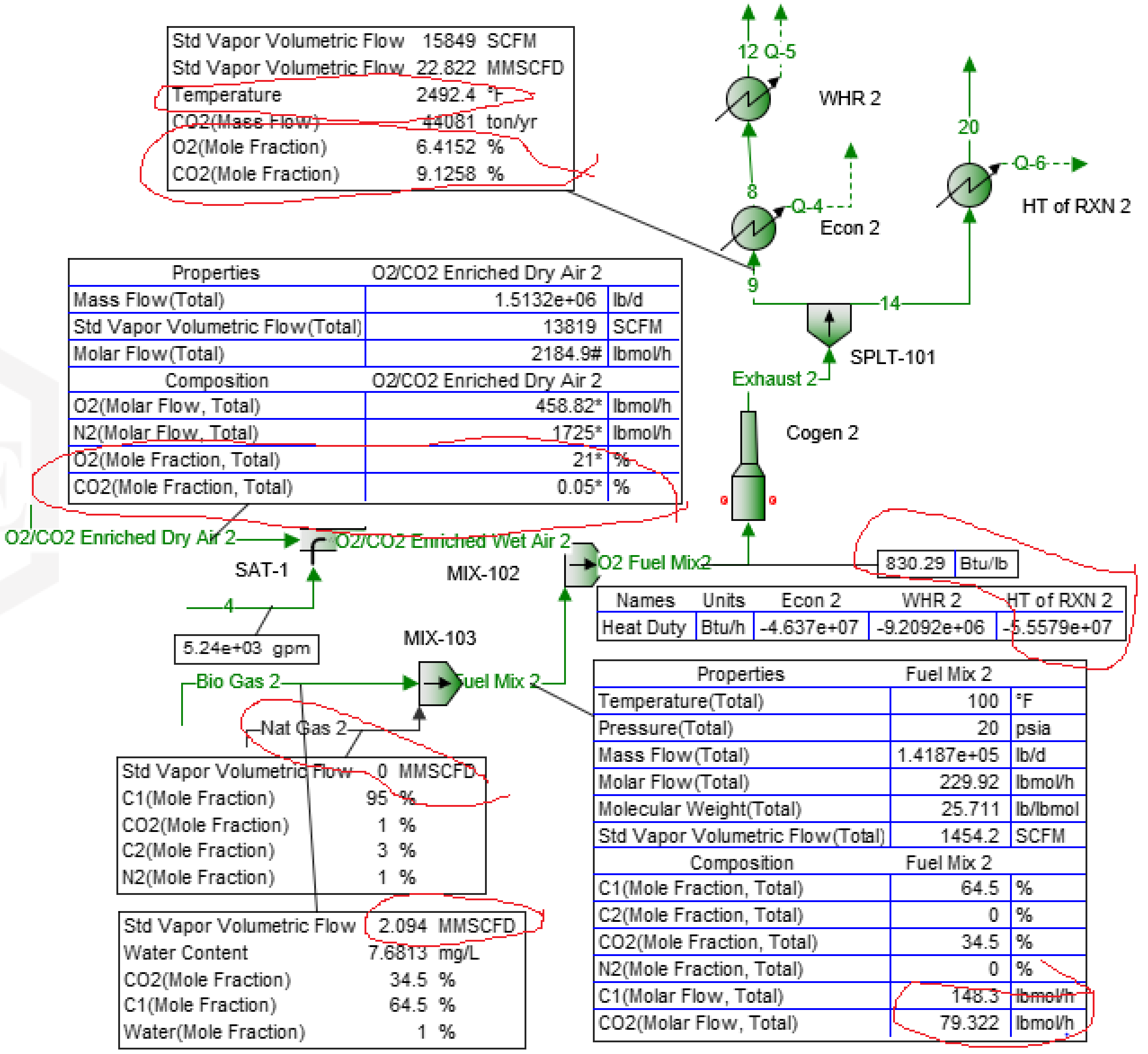
Std Vapor Volumetric Flow	0.17	MMSCFD
C1(Mole Fraction)	95	%
CO_2(Mole Fraction)	1	%
C2(Mole Fraction)	3	%
N_2(Mole Fraction)	1	%

Std Vapor Volumetric Flow	1.83	MMSCFD
Water Content	7.6813	mg/L
CO_2(Mole Fraction)	34.5	%
C1(Mole Fraction)	64.5	%
Water(Mole Fraction)	1	%

Case 2

O2 Enriched Air with Bio Gas Only

Same Duty/ Excess O2 as Case 1



Std Vapor Volumetric Flow	15849	SCFM
Std Vapor Volumetric Flow	22.822	MMSCFD
Temperature	2492.4	°F
CO_2(Mass Flow)	44081	ton/yr
O_2(Mole Fraction)	6.4152	%
CO_2(Mole Fraction)	9.1258	%

Properties	O2/CO2 Enriched Dry Air 2	
Mass Flow(Total)	1.5132e+06	lb/d
Std Vapor Volumetric Flow(Total)	13819	SCFM
Molar Flow(Total)	2184.9#	lbmol/h
Composition	**O2/CO2 Enriched Dry Air 2**	
O_2(Molar Flow, Total)	458.82*	lbmol/h
N_2(Molar Flow, Total)	1725*	lbmol/h
O_2(Mole Fraction, Total)	21*	%
CO_2(Mole Fraction, Total)	0.05*	%

Names	Units	Econ 2	WHR 2	HT of RXN 2
Heat Duty	Btu/h	-4.637e+07	-9.2092e+06	-5.5579e+07

Properties	Fuel Mix 2	
Temperature(Total)	100	°F
Pressure(Total)	20	psia
Mass Flow(Total)	1.4187e+05	lb/d
Molar Flow(Total)	229.92	lbmol/h
Molecular Weight(Total)	25.711	lb/lbmol
Std Vapor Volumetric Flow(Total)	1454.2	SCFM
Composition	**Fuel Mix 2**	
C1(Mole Fraction, Total)	64.5	%
C2(Mole Fraction, Total)	0	%
CO_2(Mole Fraction, Total)	34.5	%
N_2(Mole Fraction, Total)	0	%
C1(Molar Flow, Total)	148.3	lbmol/h
CO_2(Molar Flow, Total)	79.322	lbmol/h

Std Vapor Volumetric Flow	0	MMSCFD
C1(Mole Fraction)	95	%
CO_2(Mole Fraction)	1	%
C2(Mole Fraction)	3	%
N_2(Mole Fraction)	1	%

Std Vapor Volumetric Flow	2.094	MMSCFD
Water Content	7.6813	mg/L
CO_2(Mole Fraction)	34.5	%
C1(Mole Fraction)	64.5	%
Water(Mole Fraction)	1	%

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

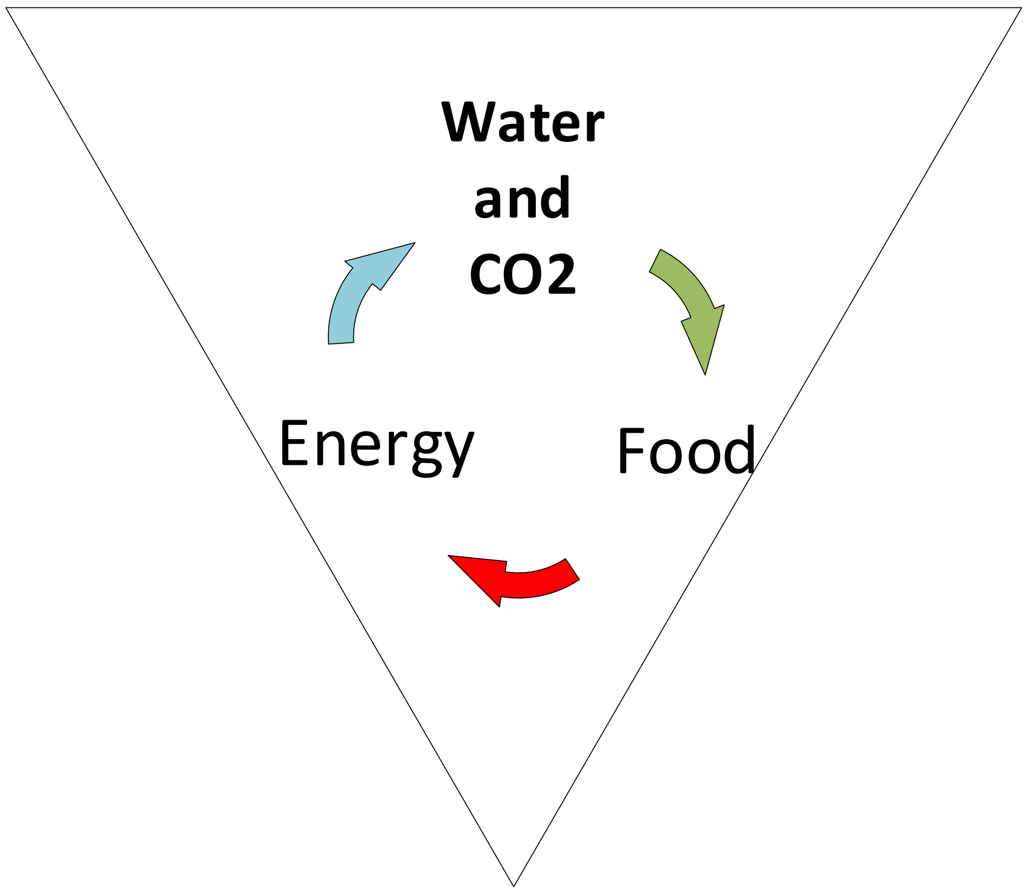
- Achieve Carbon Neutrality in CA by 2025!

- 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



02/12/2021

KO_2

Black Swan Cycle for Food-Energy-Water Sustainability and Carbon Neutrality

PRESENTED AT

American Institute of Chemical Engineers

Institute for Sustainability

2021 2nd FOOD-ENERGY-WATER NEXUS CONFERENCE

BY

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

”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.”