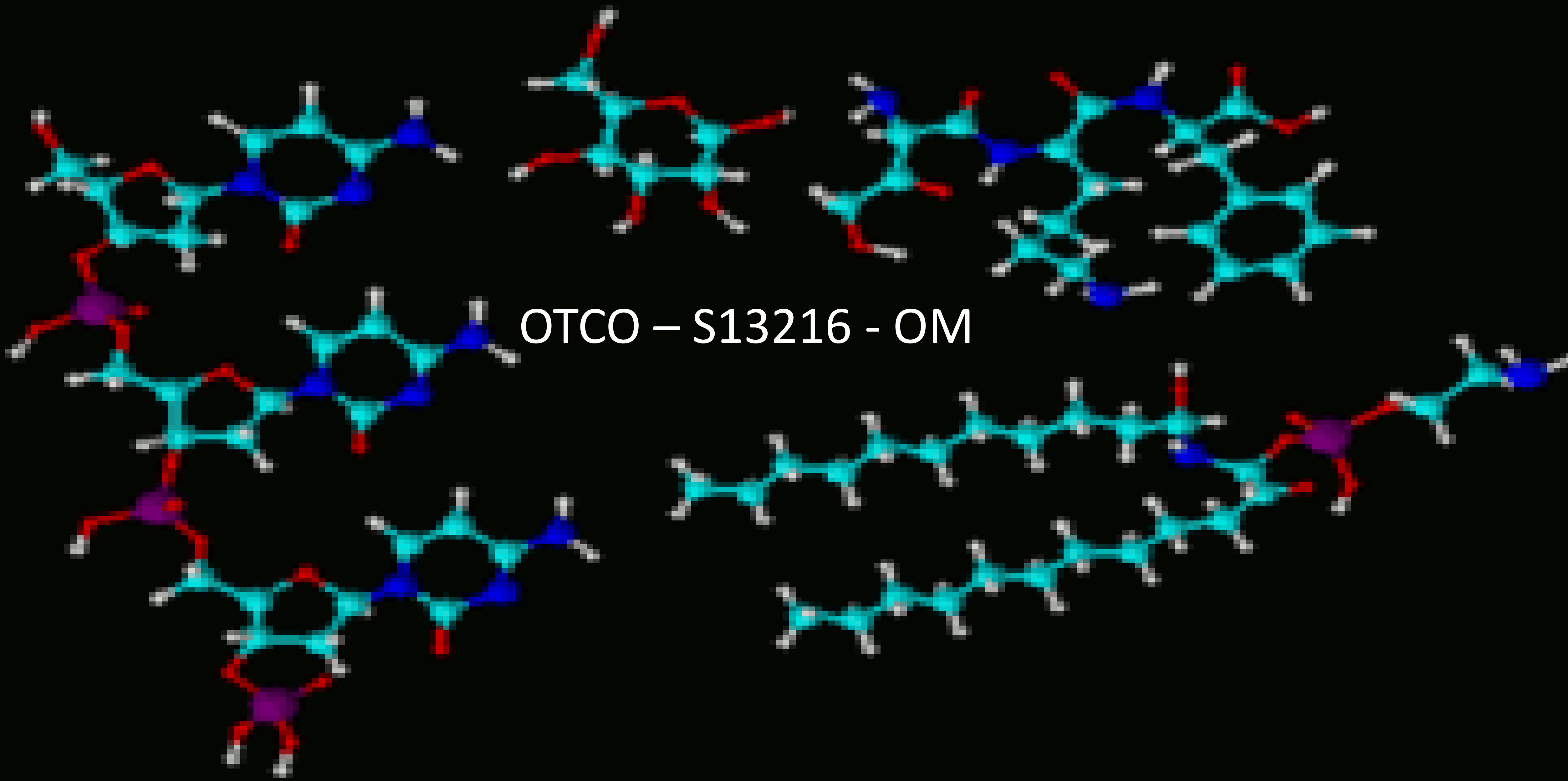
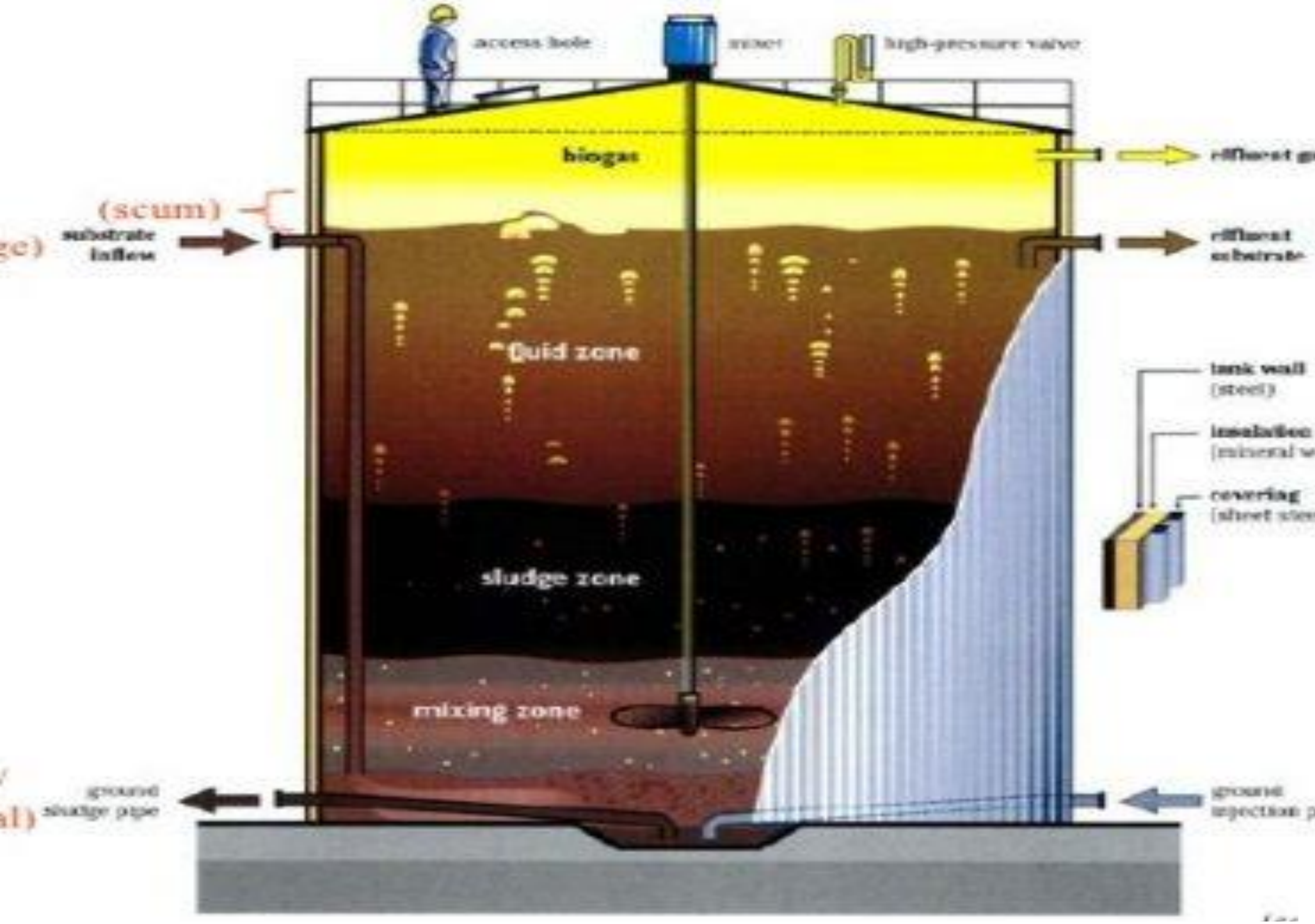
“Anaerobic Digestion Optimization - Tips for the Operator”



OTCO – S13216 - OM

Anaerobic Digester : Diagram

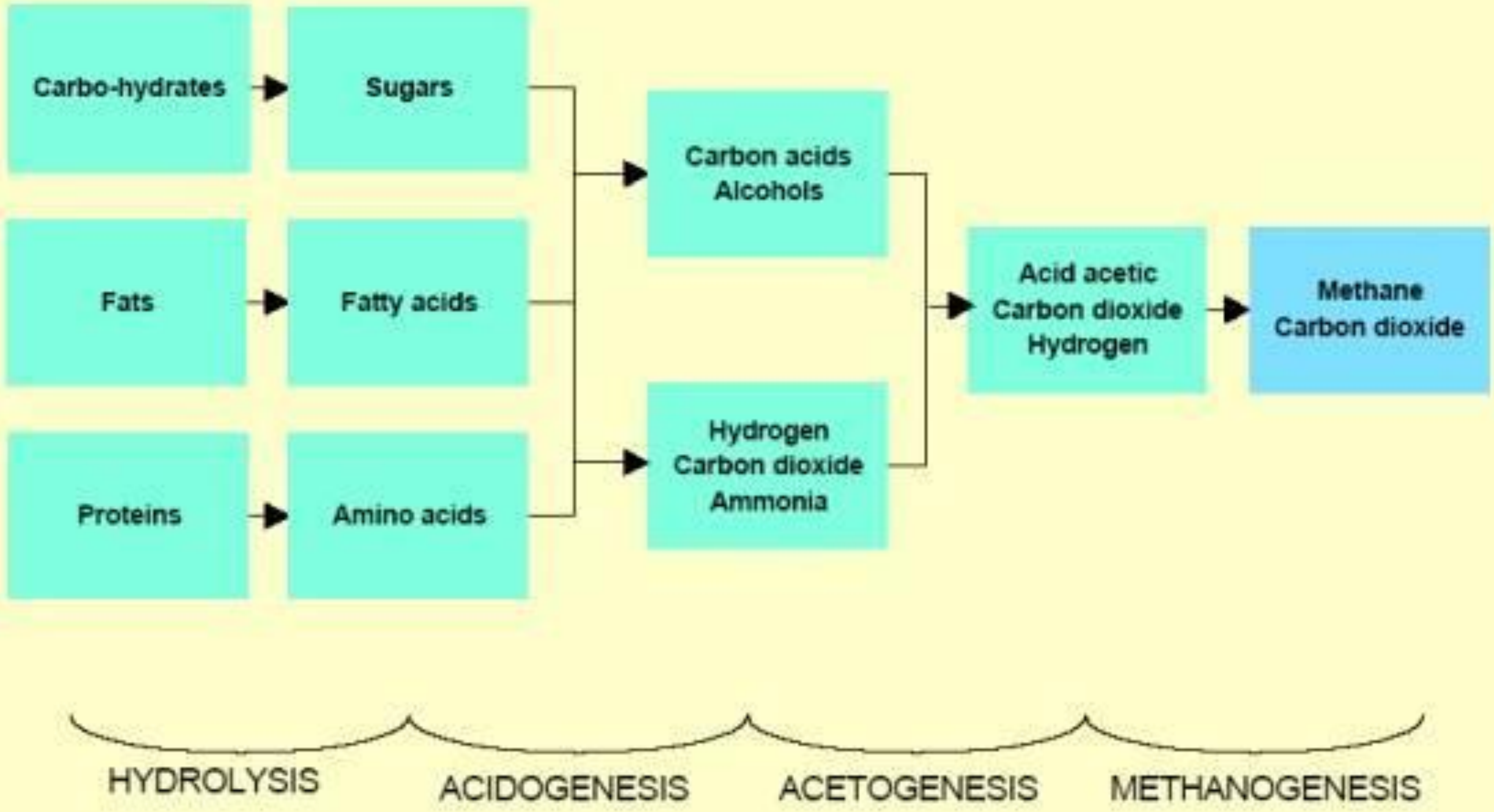


The digestion process is a sludge treatment process that:

Stabilizes sludge, making it suitable for beneficial reuse on cropland as fertilizer and soil conditioner.

Reduces volatile material in the sludge by a minimum of 38% to meet VAR (Vector Attraction Reduction)

Produces methane gas that can be converted into multiple forms of energy which can be monetized


Carbo-hydrates
Sugars
Fats
Fatty acids
Proteins
Amino acids
Carbon acids
Alcohols
Hydrogen
Carbon dioxide
Ammonia
Acid acetic
Carbon dioxide
Hydrogen
Methane
Carbon dioxide
HYDROLYSIS
ACIDOGENESIS
ACETOGENESIS
METHANOGENESIS

STEP 1– HYDROLYSIS

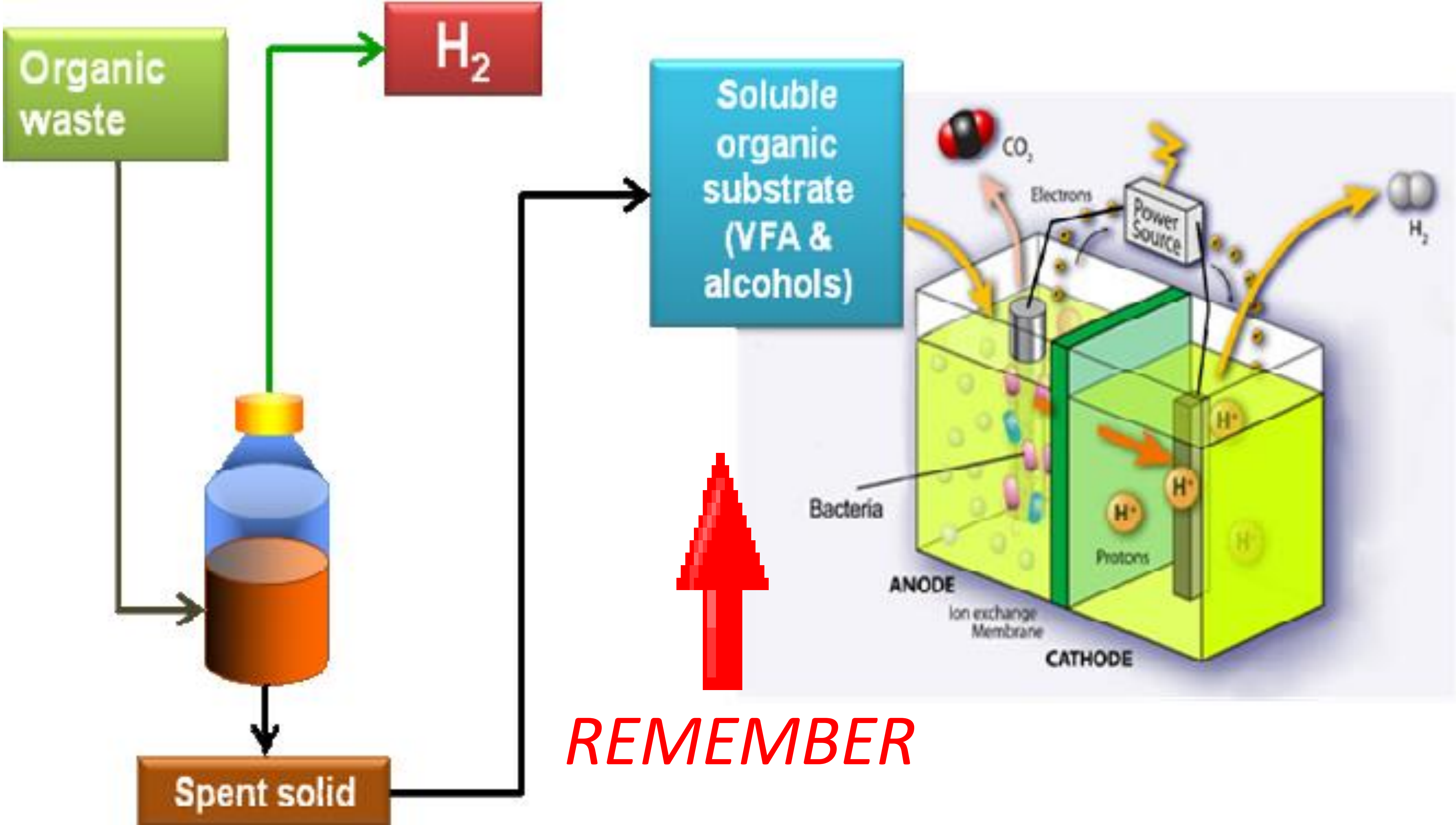
- BACTERIA,FUNGI and PROTISTS PRODUCE ENZYMES THAT
- BREAK DOWN SOLID ORGANICS,PROTEINS, CELLULOSE, LIPIDS, AND LIGNINS INTO SOLUBLE (LIQUID) ORGANIC FATTY ACIDS, ALCOHOL, CARBON DIOXIDE, AND AMMONIA.

Pseudomonas sp

Hartmanella sp.

STEP 2 - ACIDOGENESIS

- ACID FORMERS SUCH AS LACTOBACCILLUS CONVERT THE PRODUCTS PRODUCED BY STEP 1 INTO LONG-CHAIN AND VOLATILE FATTY ACIDS, ALONG WITH AMMONIA, CARBON DIOXIDE AND HYDROGEN



Organic waste
H2
Spent solid
Soluble organic substrate (VFA & alcohols)
CO2
Electrons
Power Source
H2
Bacteria
ANODE
Ion exchange Membrane
CATHODE
Protons
H+
REMEMBER

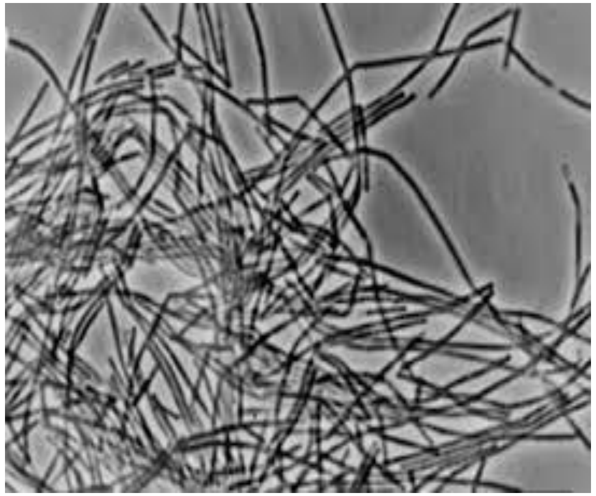
- ACETOBACTER TAKES THE ACIDS AND HYDROGEN AND BREAKS THEM DOWN EVEN FURTHER TO FORM ACETONES (C_3H_6O) AND ACETIC ACID, THE MAIN FOOD FOR OUR NEXT STEP:

STEP 3 - ACETOGENESIS

STEP 4 – METHANOGENESIS

- TWO TYPES OF METHANE FORMING BACTERIA CONVERTS HYDROGEN ACETATE (ACETIC ACID) TO METHANE AND BICARBONATE (CO2 IN SOLUTION) WHILE.

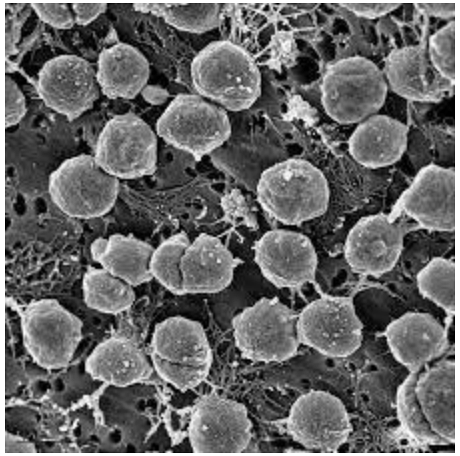
Methanococcus sp.



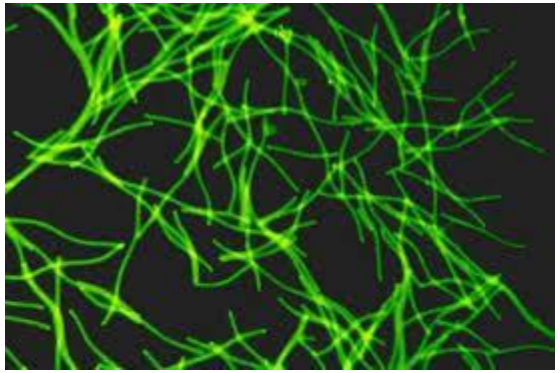
Methanospirillum sp.

METHANOGENESIS

- ANOTHER GROUP OF METHANE FORMERS CONVERTS THE HYDROGEN AND CARBON DIOXIDE TO METHANE.



Methanosarcina sp.



Methanosaeta sp.

Anaerobic Digestion Process

Carbohydrates, Fats, Proteins

↓ *Hydrolysis*

Sugar, Fatty Acids, Amino Acids

↓ *Acidogenesis*

Volatile Fatty Acids

↓ *Acetogenesis*

Acetic Acid, Hydrogen, Carbon Dioxide

↓ *Methanogenesis*

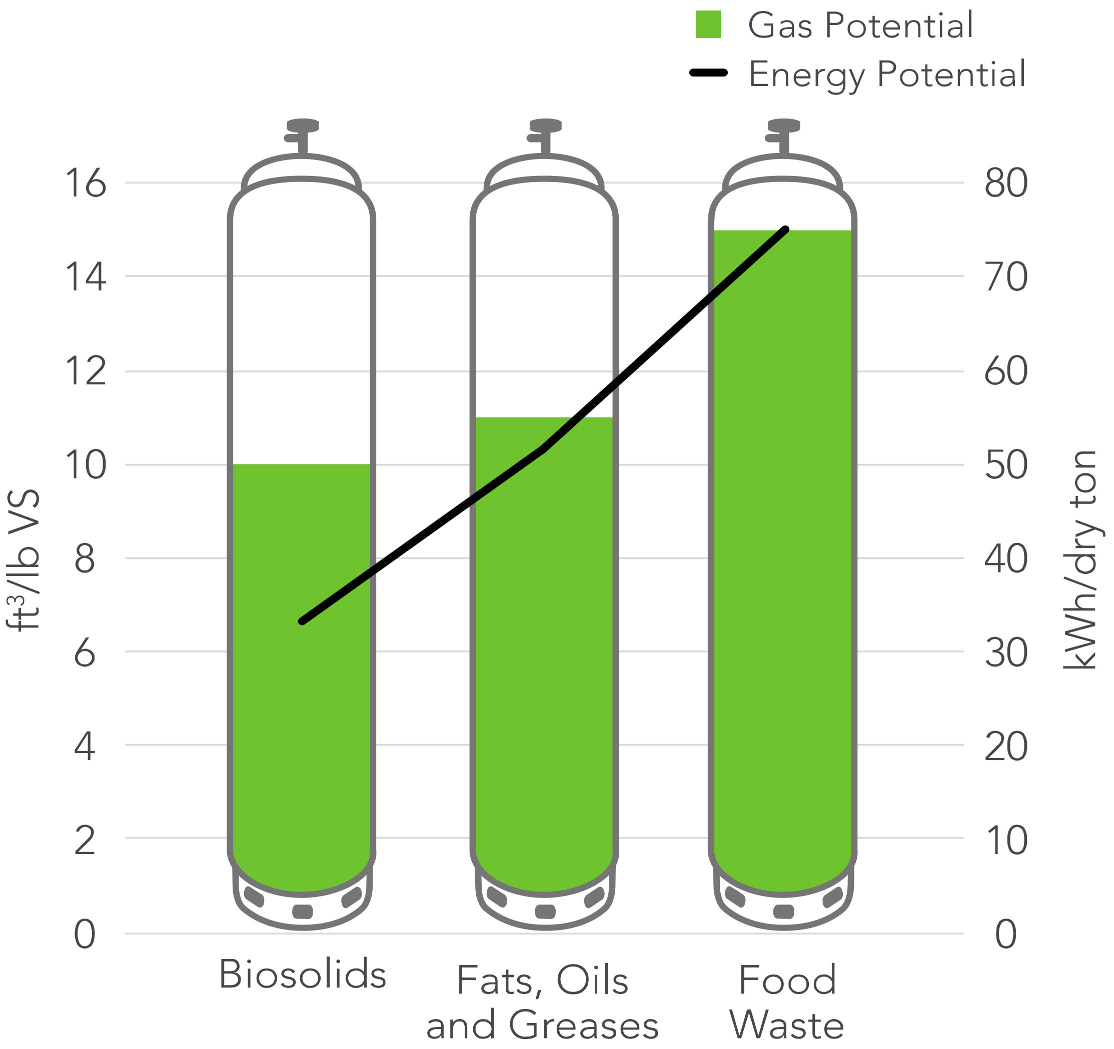
Methane, Carbon Dioxide

The performance of anaerobic digestion in destroying volatile (organic) matter to methane and carbon dioxide depends on:

- Sludge Type
- Digestion Time & Loading
- Digestion Temperature
- Mixing

Comparison of Biosolids, FOG and Food Waste

- The energy potential per dry ton of material is significantly higher for food waste and FOG compared to biosolids.
- High strength material, such as food waste and FOG can increase the energy production of an on-site digester to an output that can offset a greater portion of the WWTP's demand.
- The higher volatile solids rate indicates that a greater portion of the solid fraction of the material is available to be broken down during anaerobic digestion.
- The high gas potential illustrates that, on a per pound of volatile solids basis, more gas can be produced from these feedstock.



* The chart assumes an electric generator efficiency of 38%.

Our bodies are not **100%** efficient at converting food energy into mechanical output. But at **about 25% efficiency**, we're surprisingly good considering that most cars are **around 20%**, and that an Iowa cornfield is only about 1.5% efficient at converting incoming sunlight into chemical storage.

Where does the other 75% Go???

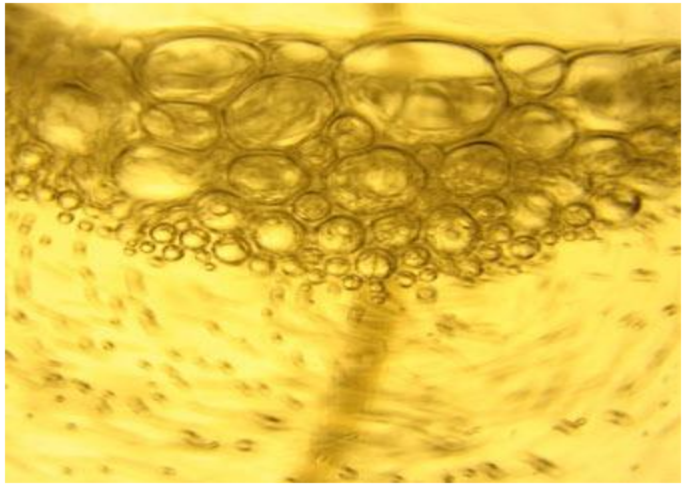
Americans use 5.7 billion gallons per day from toilet flushes.

REMEMBER THEY CAN'T

FL_ _ H

WITHOUT

US



HOW TO FIND POUNDS VOLATILE SOLIDS

GALLONS OF SLUDGE x 8.34 x %TS x % Volatile Solids =

POUNDS VOLATILE SOLIDS

HOW TO FIND
PERCENT VOLATILE DESTRUCTION TO MEET 38% Vector Attraction Reduction (VAR)

$$\frac{\text{PERCENT VOLATILE (IN)} - \text{PERCENT VOLATILE (OUT)}}{\text{PERCENT (IN)} - [\text{PERCENT (IN)} \times \text{PERCENT (OUT)}]} \times 100\% =$$

Percent Volatile Solids Reduction

PROCESS CONTROL

Chemical Effects

VA / ALK. RATIO:

TYPICAL: 0.20

Increase above 0.3 – 0.4 Indicates Process Upset

STRESS RATIO CONTINUED

- Increases above 0.3 to 0.4 indicate an upset and the necessity for corrective action. When the ratio exceeds 0.8. pH depression and inhibition of gas production occurs – the process is failing.

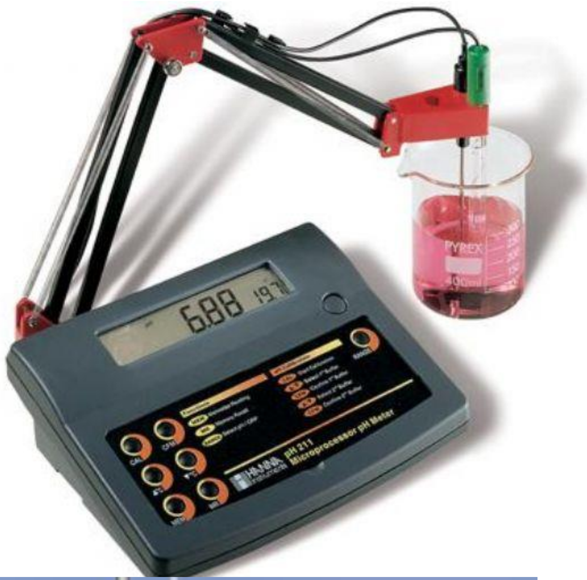
- Normal operation should yield a stress ratio of 0.2 or less. If the digester is high rate and/or being excessively loaded, the stress ratio may be higher. A continued increase in the stress ratio indicates that conditions are getting worse and corrective action should be taken.

STRESS RATIO PROCEDURE

1. Take 50 ml of digester liquor sample and place in a beaker.

2. Place beaker on magnetic spinner and add magnetic stir bar. Adjust to slow speed.

STRESS RATIO PROCEDURE



3. Immerse electrode of previously calibrated pH meter into sample.

4. Titrate sample to pH 3.5 with 0.10N H_2SO_4 (2.8 grams1000 ml)

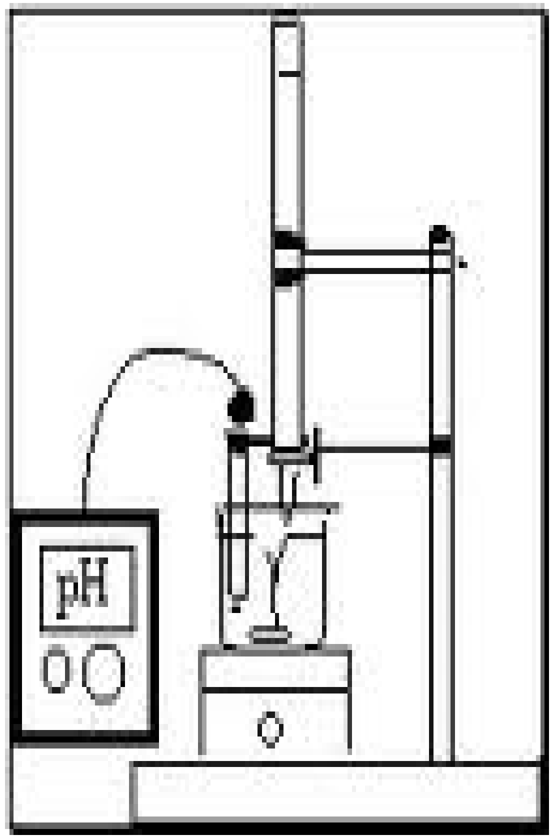
RECORD VOLUME IN MILLILITERS AS READING "A"

STRESS RATIO PROCEDURE

5. Cover sample beaker with a watch glass and bring to boiling for 1 – 2 minutes.

Cool to room temperature and rinse watch glass into beaker with distilled H_2O.

STRESS RATIO PROCEDURE



6. Using 0.05N NaOH (2 grams/L)

   Bring pH to exactly 4.0.

   Record volume as reading "B"

7. Continue adding 0.05N NaOH until pH is 5.1.

   Record volume as reading "C"

STRESS RATIO CALCULATIONS

- Total Alkalinity (TA), as mg/L $CaCO_3$ = A x 100

- Volatile Acids (VA), as mg/L acetic = (C –B) x 100

- Bicarbonate Alkalinity (BA), as mg/L $CaCO_3$

USE 1.0 FACTOR IF VA < 180 ; USE 1.5 FACTOR IF VA > 180

BA = TA – (1.0 or 1.5 x VA)

***Note*: The 1.0 or 1.5 factor in the equation is needed to convert the volatile acid units from mg/L as Acetic Acid to mg/L as C_aCO_3, the equivalent Alkalinity unit.**

- Print Volatile Acids&Alkalinity.tif (10 pages)

STRESS RATIO CALCULATION

Example : A = 30 ml

B = 12 ml

C = 15 ml

$$\text{STRESS RATIO} = \frac{300}{2{,}550}$$

= 0.11

TA = A x 100 = 30 x 100 = 3,000 mg/L as $CaCO_3$

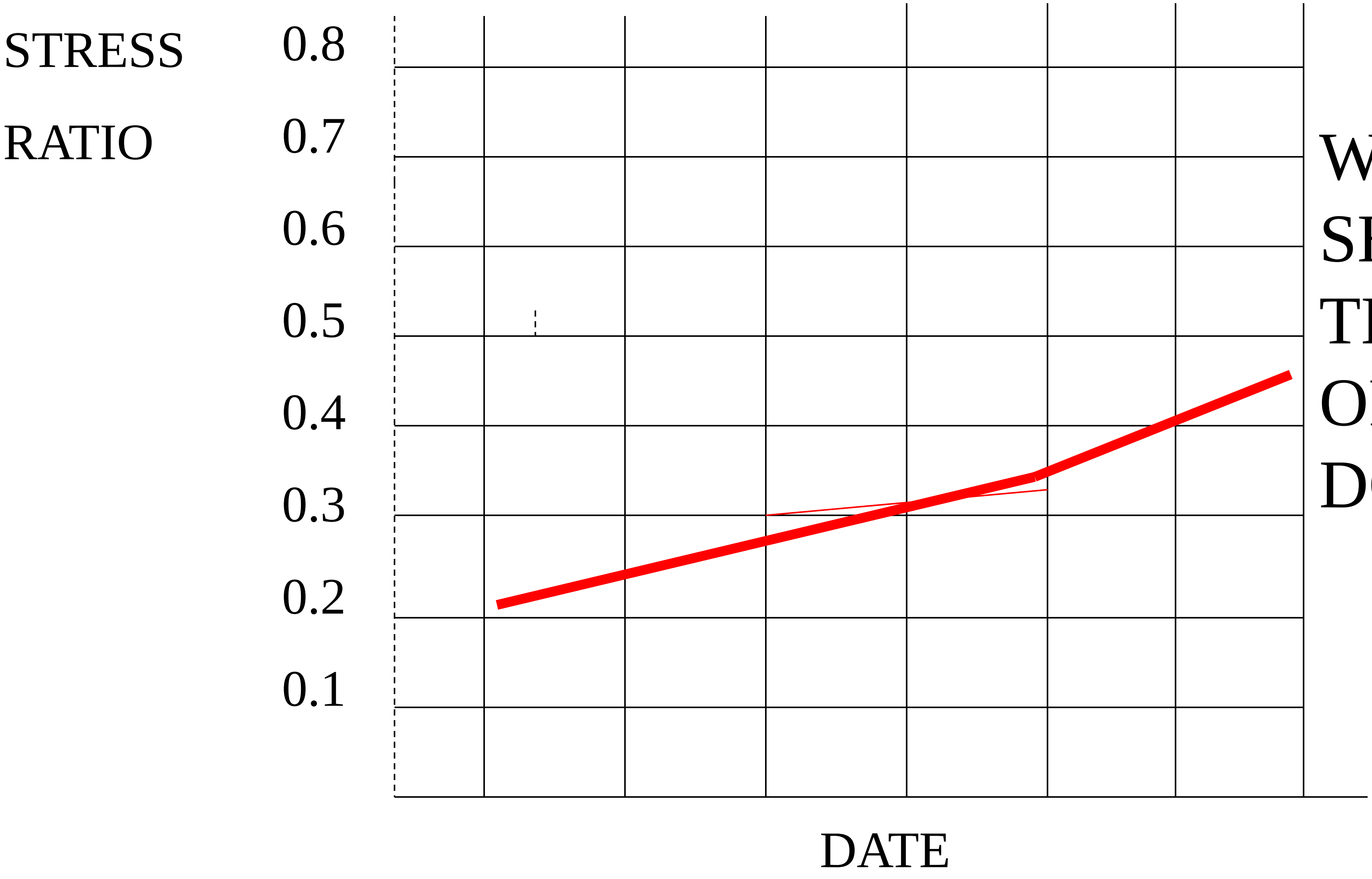
VA = (C – B) x 100 = (15 – 12) x 100 = 300 mg/L as Acetic Acid

BA = TA – (1.5 x VA) = 3,000 – (1.5 x 300)

= 3,000 – 450

= 2,550 mg/L $CaCO_3$

STRESS RATIO CHART



WHAT SHOULD THE OPERATOR DO?

$Mg(OH)_2$

Magnesium Hydroxide

Why?

Because MgOH- has a pH range to 9.0, this will not affect the acid formers and the magnesium is a nutrient for the methane formers. Followed by supplementing with Bicarbonate.

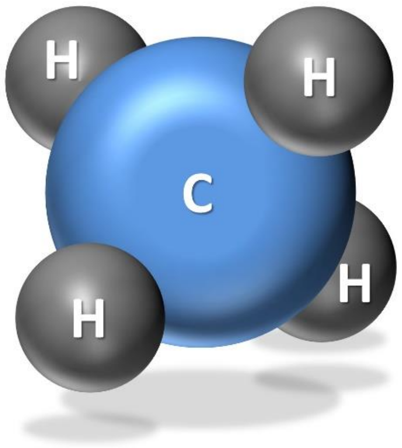
Nutritional Requirements

Nutrient	Pounds per 1,000 pounds COD
Nitrogen (N)	120
Phosphorous (P)	20
Iron (Fe)	0.2
Cobalt (Co)	.1
Nickel (Ni)	0.01

Digester Biogas

Characteristics to Test

- Carbon dioxide
- Methane
- Nitrogen
- Oxygen
- Hydrogen Sulfide
- Ammonia
- Moisture Content



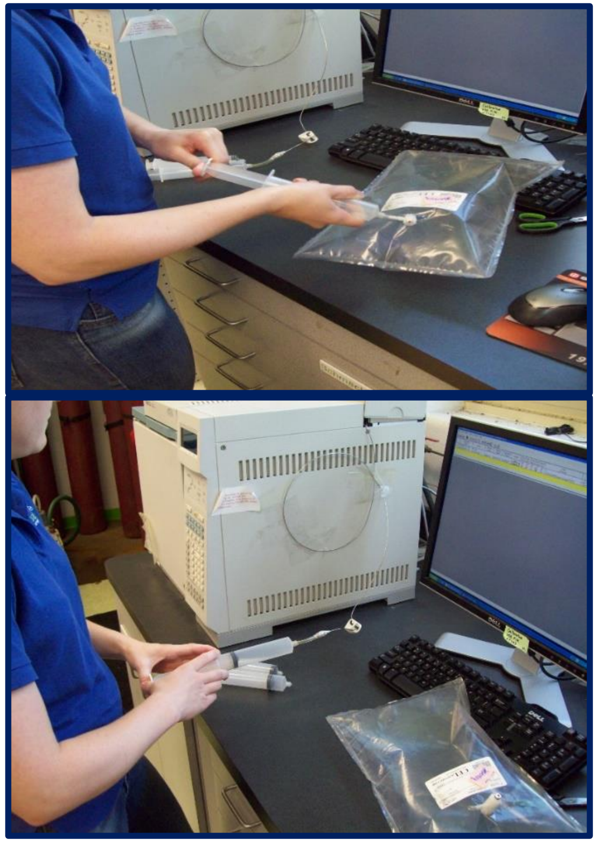
Measuring the make-up of biogas can indicate how well the digester is converting biomass to methane, and provide parameters for treatment necessary before biogas utilization

Biogas Collection

Digester gas sampling line

Pulling biogas sample

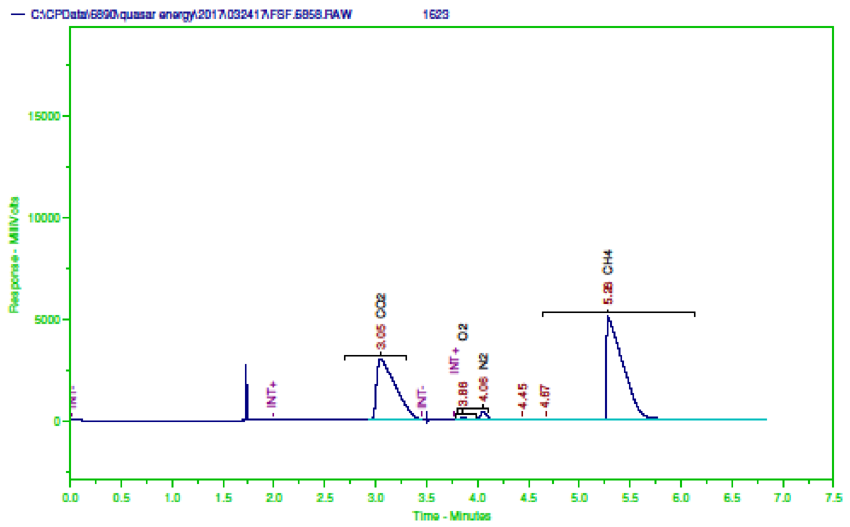
Biogas Analysis



SAMPLE GAS READING
FROM GAS CHROMATOGRAPH

Gas can be tested onsite using a gas chromatograph or sent via tedlar bag (shown above) or cannister to outside lab

Chrom Perfect Chromatogram Report



Sample Name = 1623

Instrument = HP6890
Heading 1 =
Heading 2 =

Raw File Name = C:\CPData\6890\quasar energy\2017\032417\FSF.6858.RAW Date Taken (end) = 3/24/2017 11:09:16 AM
Method File Name = C:\CPData\6890\Methods\Biogas6890-XG-2017.MET Method Version = 12
Calibration File Name = C:\CPData\6890\Methods\Biogas6890_XG-2017.CAL Calibration Version = 31

Peak #	Ret. Time	Name	Amount	Amt %	Area	Area %	Type	Width
1	3.05	CO_2	44.35	26.716	38072400	39.278	BB	0.21
2	3.86	O_2	0.89	0.534	491992	0.508	BV	0.06
3	4.06	N_2	2.99	1.798	1770549	1.827	VV	0.07
4	4.45		0.00	0.000	36389	0.038	VB	0.12
5	4.67		0.00	0.000	60333	0.062	BV	0.12
6	5.28	CH_4	117.79	70.952	56498830	58.288	VB	0.17

Total Area = 9.693049E+07 Total Height = 8527739 Total Amount = 166.0124

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Biogas Analysis

SAMPLE GAS ANALYSIS
FROM OUTSIDE LAB

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS
Page 1 of 1

Client: City of Sandusky OH
Client Sample ID: 1SS00082
Client Project ID: Digester Gas

ALS Project ID: P1502288
ALS Sample ID: P1502288-001

Test Code: ASTM D3588-98
Analyst: Mike Conejo/Nalini Lall
Sample Type: 1.0 L Silonite Summa Canister
Test Notes:
Container ID: 1SS00082

Date Collected: 6/2/15
Date Received: 6/8/15

Initial Pressure (psig): 0.42 Final Pressure (psig): 6.59

Canister Dilution Factor: 1.41

Components	Result Volume %	Result Weight %	Data Qualifier
Hydrogen	< 0.01	< 0.01	
Oxygen + Argon	< 0.01	< 0.01	
Nitrogen	0.49	0.52	
Carbon Monoxide	< 0.01	< 0.01	
Methane	63.42	38.84	
Carbon Dioxide	36.08	60.62	
Hydrogen Sulfide	< 0.01	< 0.01	
C2 as Ethane	< 0.01	< 0.01	
C3 as Propane	< 0.01	< 0.01	
C4 as n-Butane	< 0.01	< 0.01	
C5 as n-Pentane	< 0.01	< 0.01	
C6 as n-Hexane	< 0.01	< 0.01	
> C6 as n-Hexane	< 0.01	< 0.01	
TOTALS	99.99	99.99	

Components	Mole %	Weight %
Carbon	23.34	45.63
Hydrogen	59.51	9.76
Oxygen + Argon	16.93	44.08
Nitrogen	0.23	0.52
Sulfur	< 0.10	< 0.10

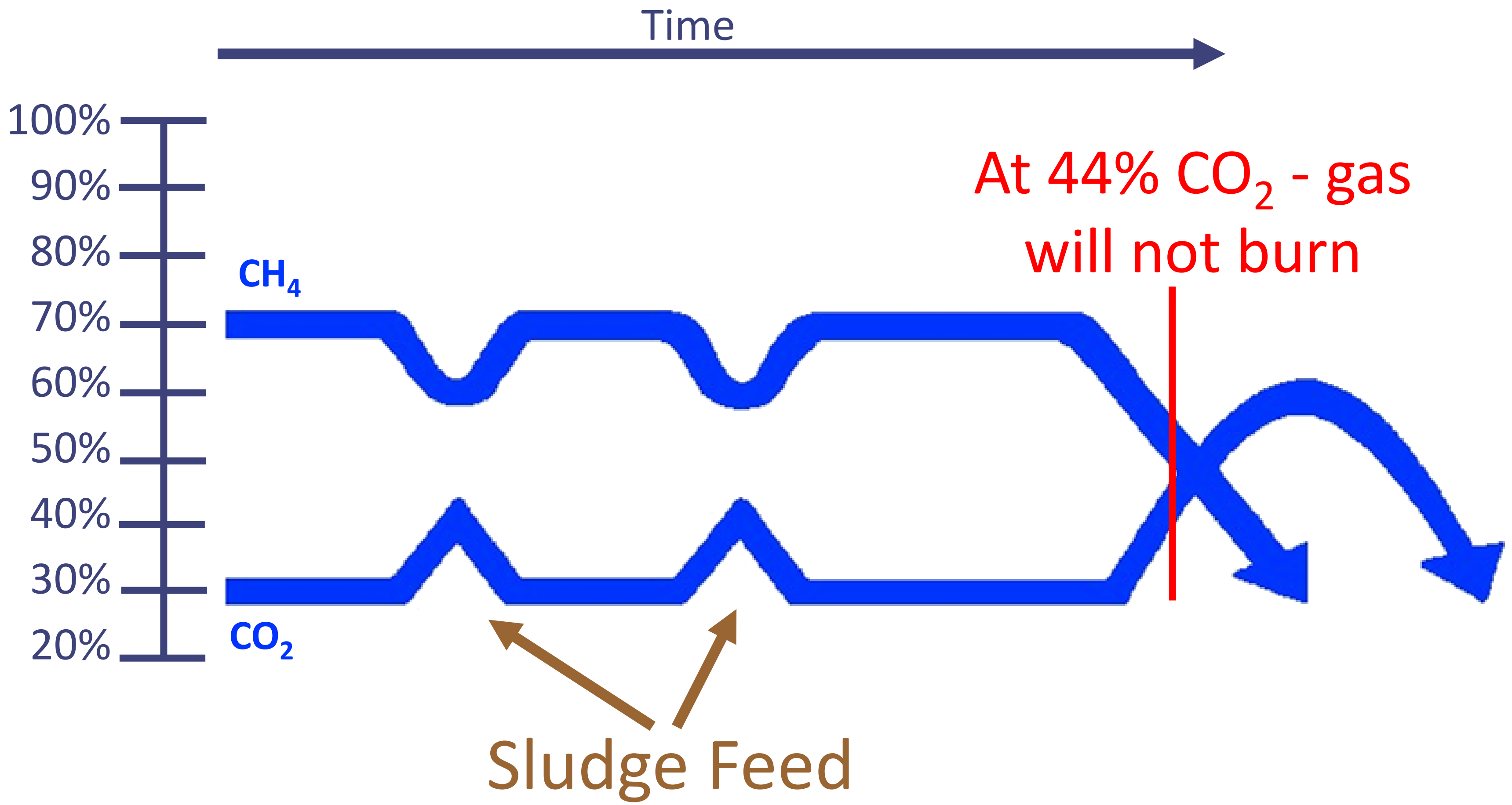
Specific Gravity (Air = 1)		0.9044
Specific Volume	ft3/lb	14.49
Gross Heating Value (Dry Gas @ 60 F, 14.696 psia)	BTU/ft3	642.6
Net Heating Value (Dry Gas @ 60 F, 14.696 psia)	BTU/ft3	578.6
Gross Heating Value (Water Saturated at 0.25636 psia)	BTU/ft3	629.5
Net Heating Value (Water Saturated at 0.25636 psia)	BTU/ft3	566.8
Gross Heating Value (Dry Gas @ 60 F, 14.696 psia)	BTU/lb	9,310.3
Net Heating Value (Dry Gas @ 60 F, 14.696 psia)	BTU/lb	8,383.0
Compressibility Factor "Z" (60 F, 14.696 psia)		0.9969

Available Gas Composition Tests:*

- Non-methane Organic Compounds
- Sulfur Compounds
- Fixed Gases (H_2, O_2, N_2, CH_4, CO, CO_2)
- BTU
- Volatile Organic Compounds (VOCs)

**Offered by ALS Global Laboratory*

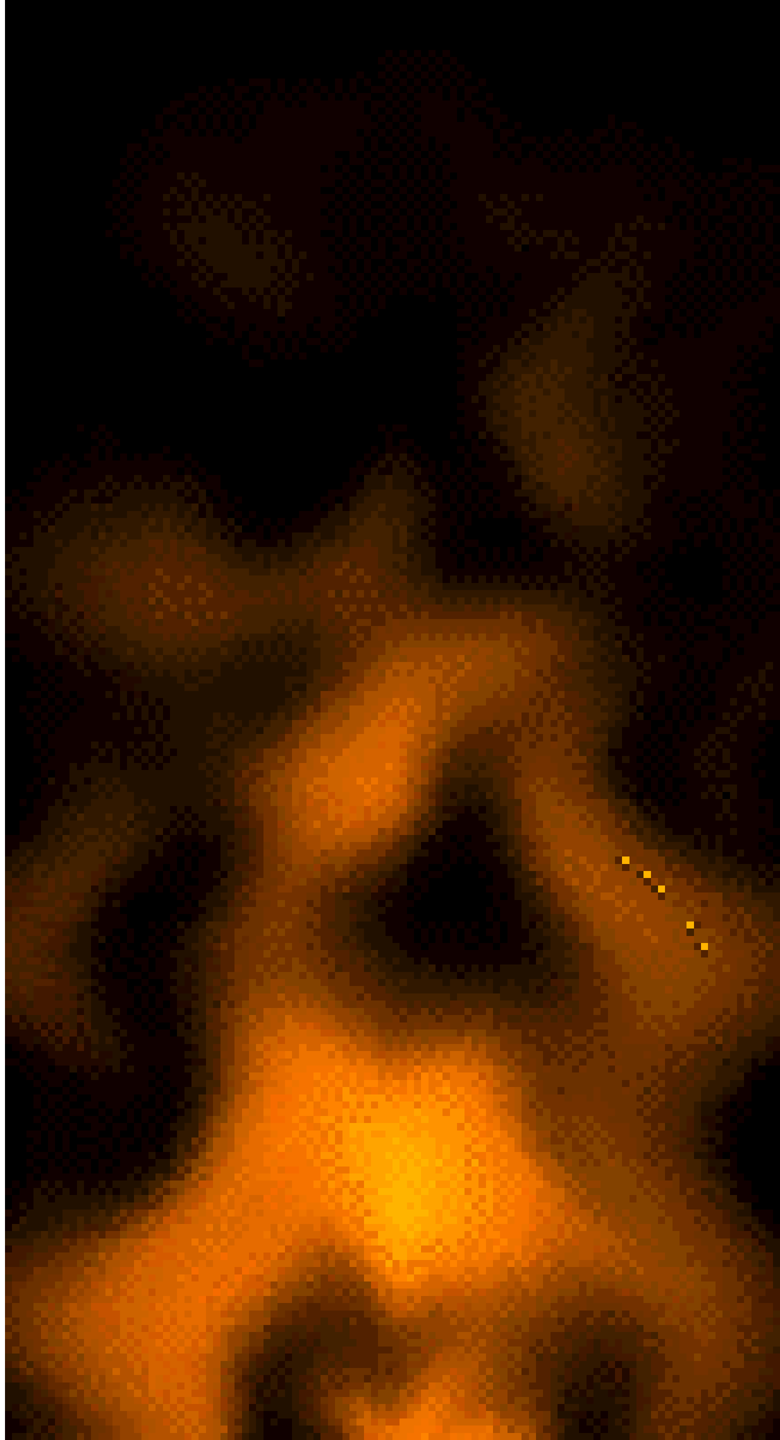
Relationship Between CH_4 and CO_2



Biogas Characteristics of a Healthy Digester

Composition of Biogas

	Range
Methane	65 - 69%
Carbon Dioxide	31 - 35%
Nitrogen	0.5 - 3%
Oxygen	0.1%
Carbon Monoxide	0.1%
Hydrogen	1 - 10%

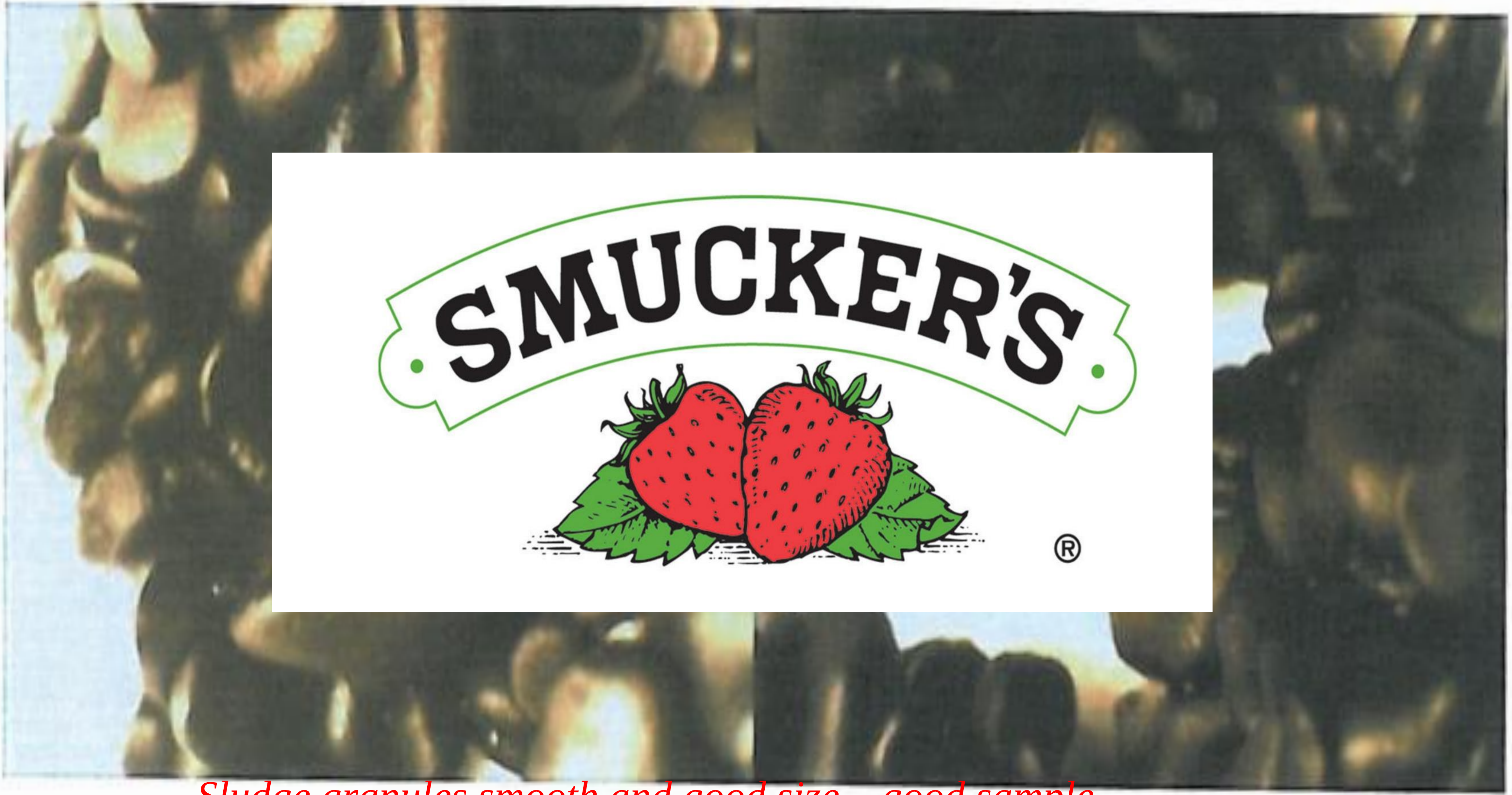


Well Digested Sludge

Characteristics

1. Less Solids
2. Lumpy Appearance
3. Black
4. Less Objectionable Odor
5. Volatile Content Reduced

Reactor 1



Sludge granules smooth and good size – good sample

MIXING

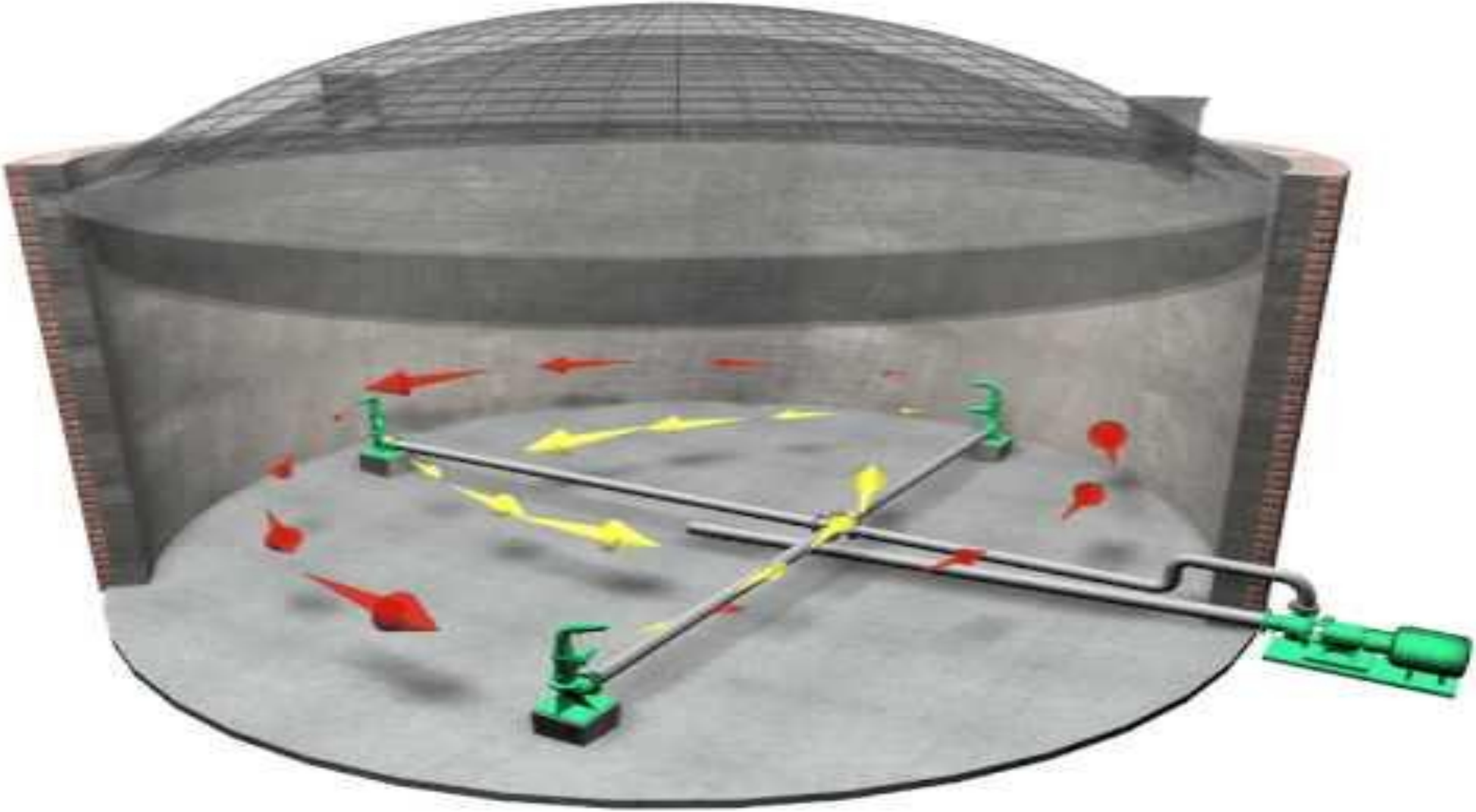
Completely Mixed Systems:

80 pounds of Volatile Solids/1,000 Ft^3/Day

Moderately Mixed Systems:

40 pounds of Volatile Solids/1,000 Ft^3/Day


DANGER



CONDITION	RANGE
Mesophilic Temperature	95° – 100 °F
pH	6.8– 7.2
Volatile Acids	50 – 300 mg/L
Alkalinity	2000 – 3000 mg/L as $CaCO_3$ equivalent
Gas Composition	65 – 69% Methane 31 – 35 % CO_2
TAN (Total Ammonia- Nitrogen)	<1,500 mg/L

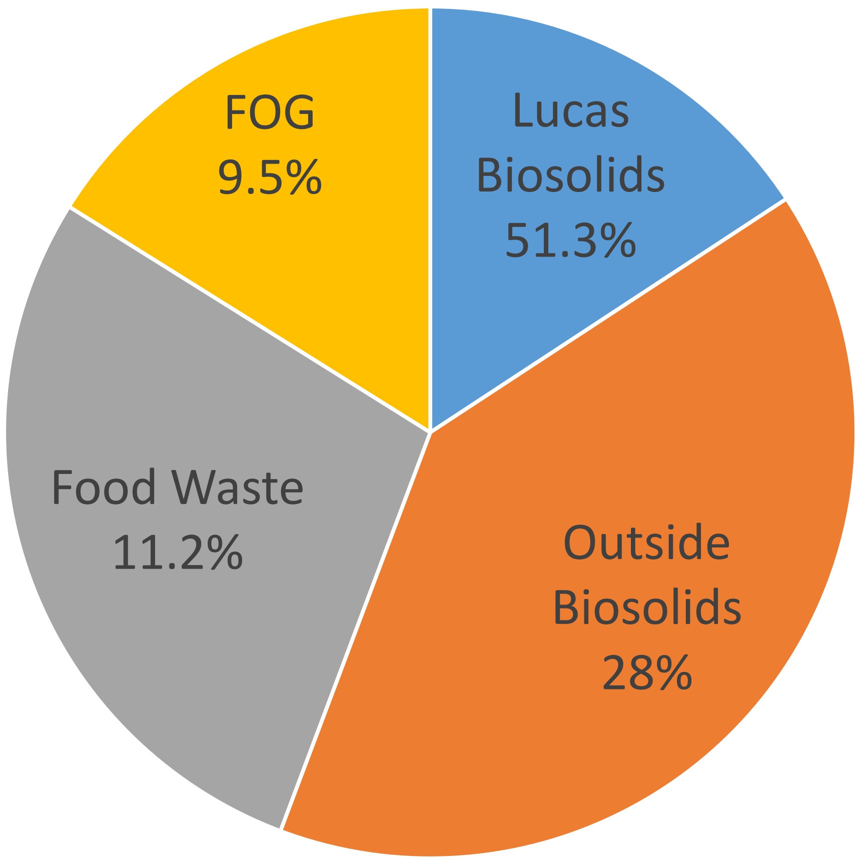
Utility Of The Future

Case Study II: Lucas County, Ohio

Codigestion summary:

- Enough material sourced to make 1.5 MW WWTP energy neutral
- Between tip fees, energy cost-savings and REC revenue, Lucas County will realize over $2M of revenue/cost savings each year.
- Currently producing Class B solids. New system will produce Class A solids with fewer disposal regulations.

Biogas Production by Feedstock



Case Study II: Lucas County, Ohio

Overall	Wet Tons Per Day	% TS	% VS	Dry Tons Per Day	Tons VS Per Day	% CH_4	BMP	Tip Fee ($/ton)	Daily Revenue
Lucas Biosolids	233.6	4%	68%	9.1	6.2	55%	10.00	$0.00	$0.00
Outside Biosolids	127.3	21%	58%	26.7	15.6	52%	9.51	$24.00	$3,054.47
FOG and Septage	43.1	11%	92%	4.5	4.2	60%	13.78	$16.28	$700.58
Food & Processing Waste	51.5	22%	81%	11.3	9.1	58%	11.28	$21.03	$1,083.64
TOTAL/ AVERAGE	**455.5**	**11%**	**68%**	**51.6**	**35.1**	**55%**	**10.57**	**$21.81**	**$4,838.68**

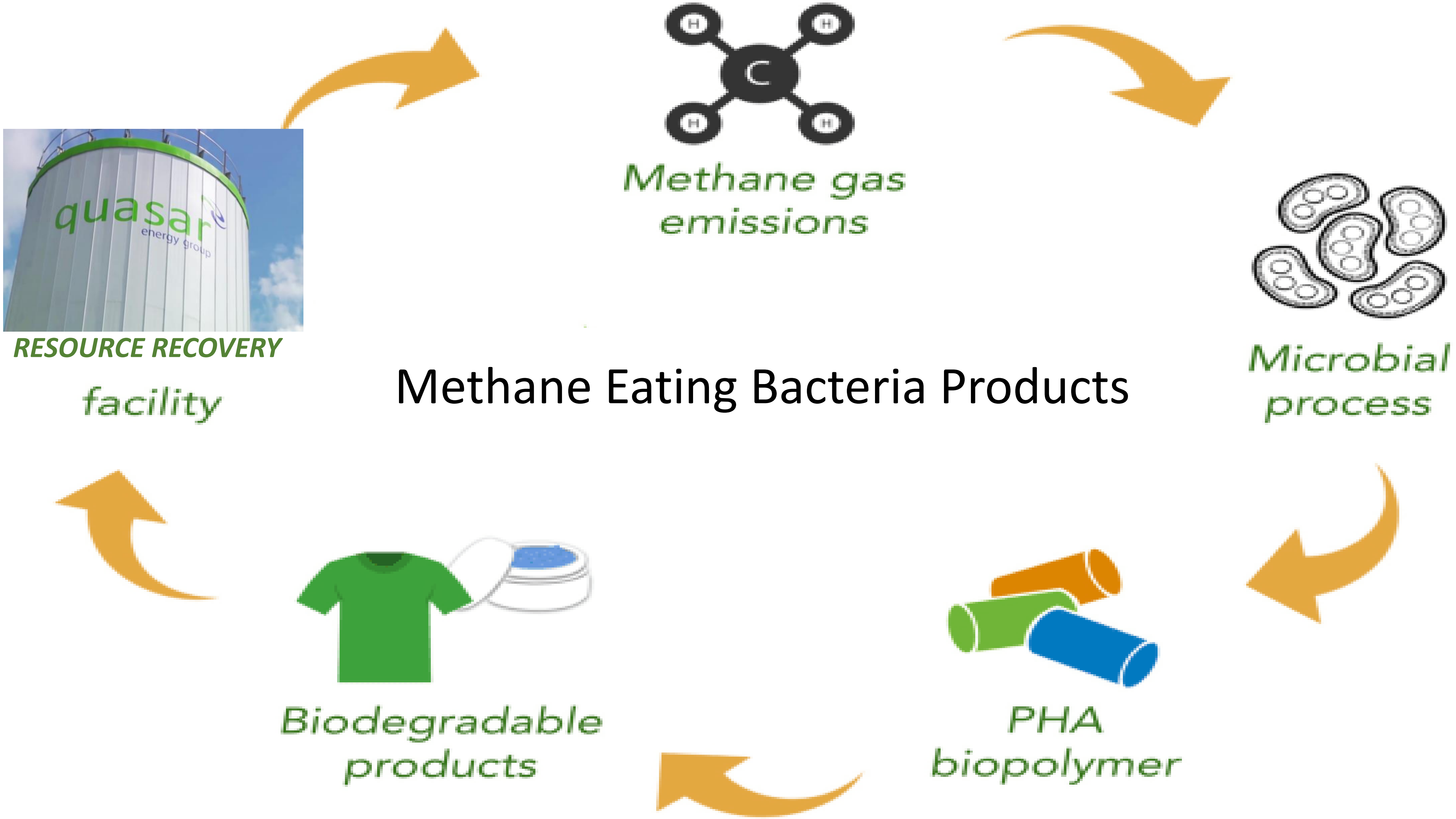
Case Study II: Lucas County, Ohio

Projected Outcome:

Once complete, the new **energy neutral** Lucas County digester will

- provide the plant with a contingency plan for biosolids processing,
- save over $700,000 per year in energy costs,
- produce $128,000 worth of sellable RECs annually
- generate $1,240,000 in revenue from tipping fees, and
- have an estimated payback period of 7.5 years

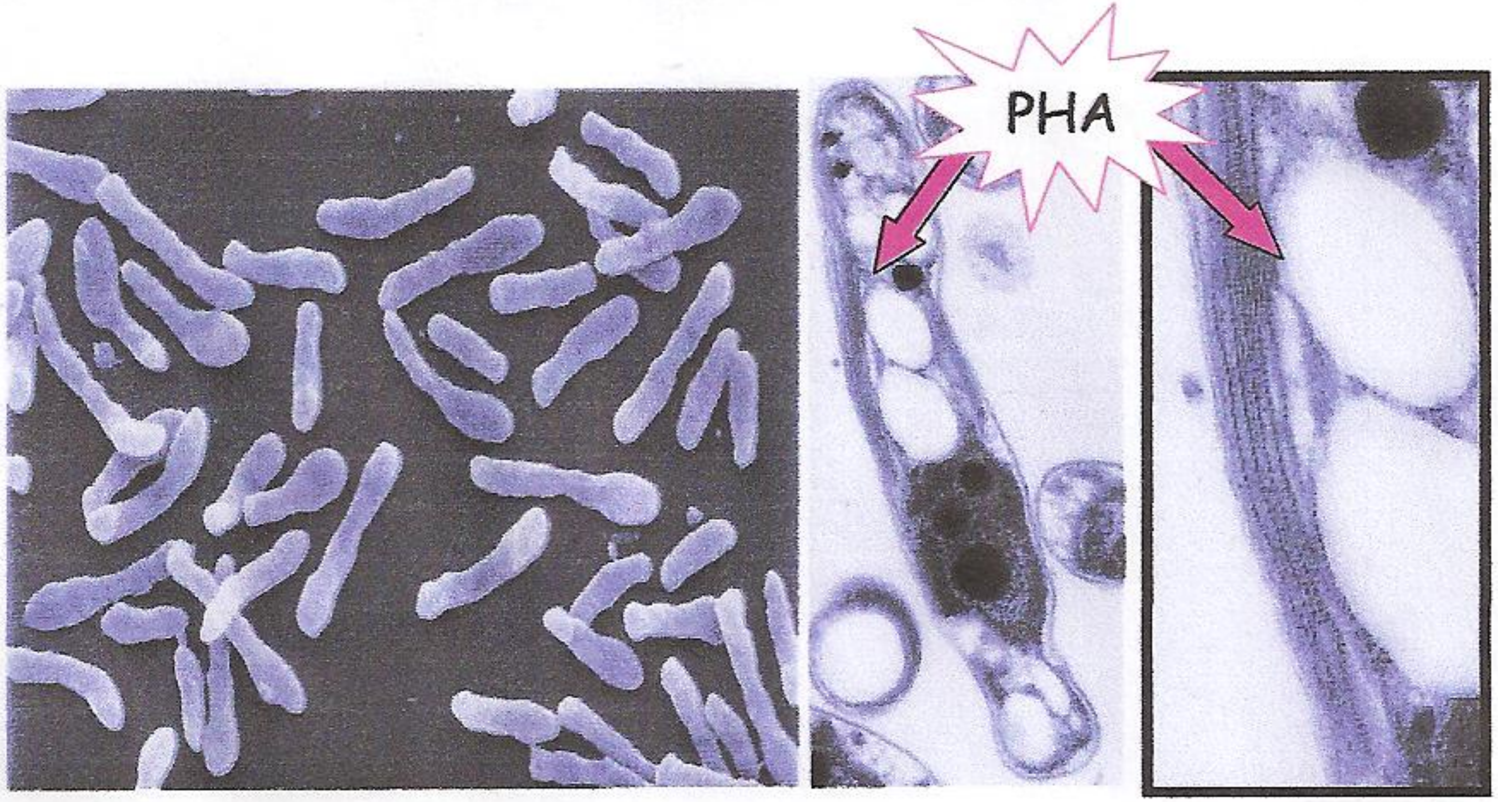
Methane Eating Bacteria Products

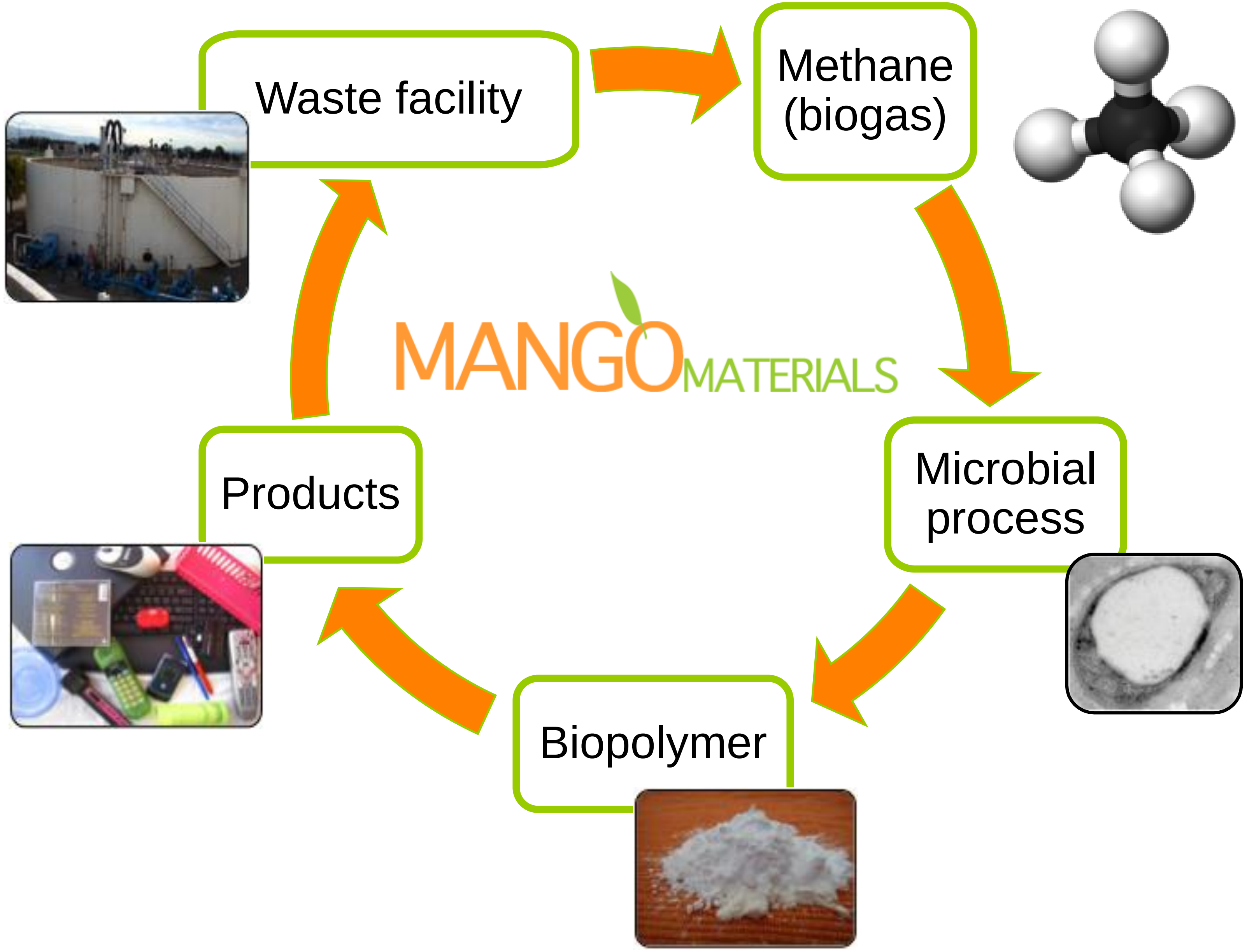


[The Shirt Of The Future Will Be Made By Methane-Eating Bacteria]

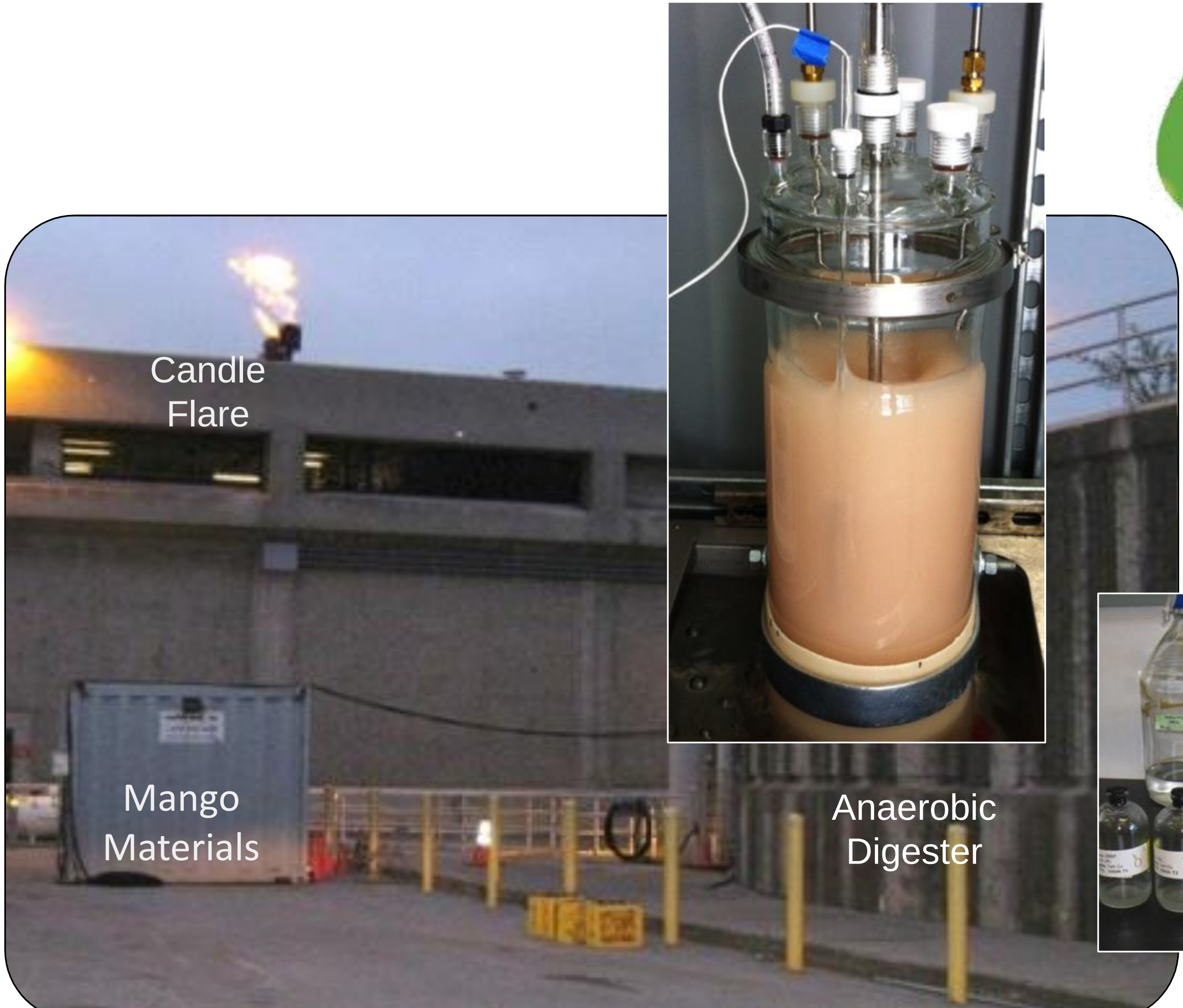

BIOPOLYESTER

PHA produced by bacteria




Waste facility
Methane (biogas)
MANGO MATERIALS
Microbial process
Biopolymer
Products

Verify process on biogas (vs. pure methane)



Good news!


100% Degradation in 1
month


100% Degradation in 4
months


100% Degradation in 4
months


100% Degradation in 12
months

PHA bottle biodegradation over a period of 2 months.

Biogas Utilization – RNG/CNG

Digester Biogas
Contaminants:
H_2S, O_2, N_2, H_2O, CO_2, VOCs

Gas Upgrade system

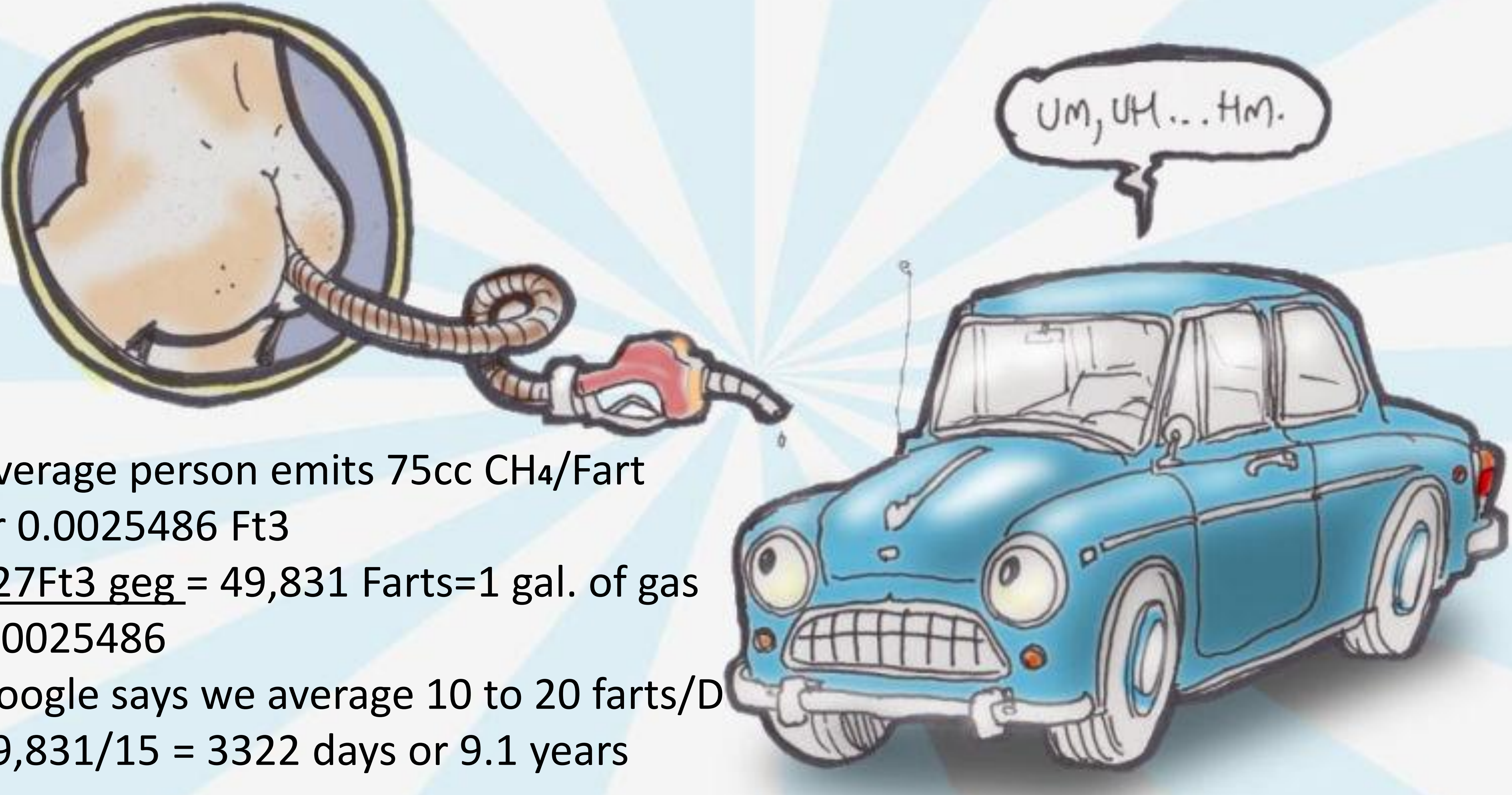
Fueling Station

RNG/CNG

Biogas can be upgraded to almost pure methane and utilized as natural gas for vehicle fuel. RNG Pipelines often have very strict gas content tariffs that must be met.

Knowing the contaminant concentration will allow for gas upgrade equipment to be properly designed.

TO ANSWER PAT



Average person emits 75cc CH_4/Fart
or 0.0025486 Ft3
127Ft3 geg = 49,831 Farts=1 gal. of gas
0.0025486
Google says we average 10 to 20 farts/D
49,831/15 = 3322 days or 9.1 years

DEVELOPING BIOPLASTICS
From
WASTEWATER TREATMENT PLANTS

Maneewan (Joy) Suwansaard Ph.D.
Michael Maringer

On Dec 3, 2018, at 9:15 PM, Somchai Dararat <somchai_d@tistr.or.th> wrote:

เรียน คุณมณีวรรณ

1 ผมและคณะ สะดวก วันที 13 ธค ครับ ขอเป็นช่วงเช้าครับ

2 ผมขอเสนอแนะ เป็น วว ครับ ส่วนการเดินทาง ผมจะประสานอีกที ครับ

3 วว มีระบบบำบัด แบบกึ่ง full scale ทีลำตะคลอง โดยระบบมี หน่วยผลิต VFA biogas และ MBR ผมสะดวกทีจะนำ เยียมชม ครับ

4 วว และภาคเอกชนในไทย มีความสนใจ ในการผลิต PHA ใน ระบบบำบัดน้ำเสียและระบบbiogas เพื่อเพิ่มความหลากหลายในการใช้ประโยชน์

เรียนมาเบื้องต้น ครับ เบอร์โทรของ ผม 089 793 4123

สมชาย

On Dec 3, 2018, at 9:15 PM, Somchai Dararat <somchai_d@tistr.or.th> wrote:
Dear Khun Maniwan
1 I and the faculty are convenient. Day 13, December. Please be in the morning.
2 I would like to suggest it as a travel section. I will coordinate again.
3, with a semi-full scale treatment system at the canal, with the VFA production unit
biogas and MBR. I am convenient to take a visit.
4 Wor and private sector in Thailand are interested in producing PHA in
Wastewater treatment and biogas systems To increase diversity in
make use of
Learned in advance. My telephone number is 089 793 4123.

Somcha

Thailand Institute of
Scientific and Technological
Research

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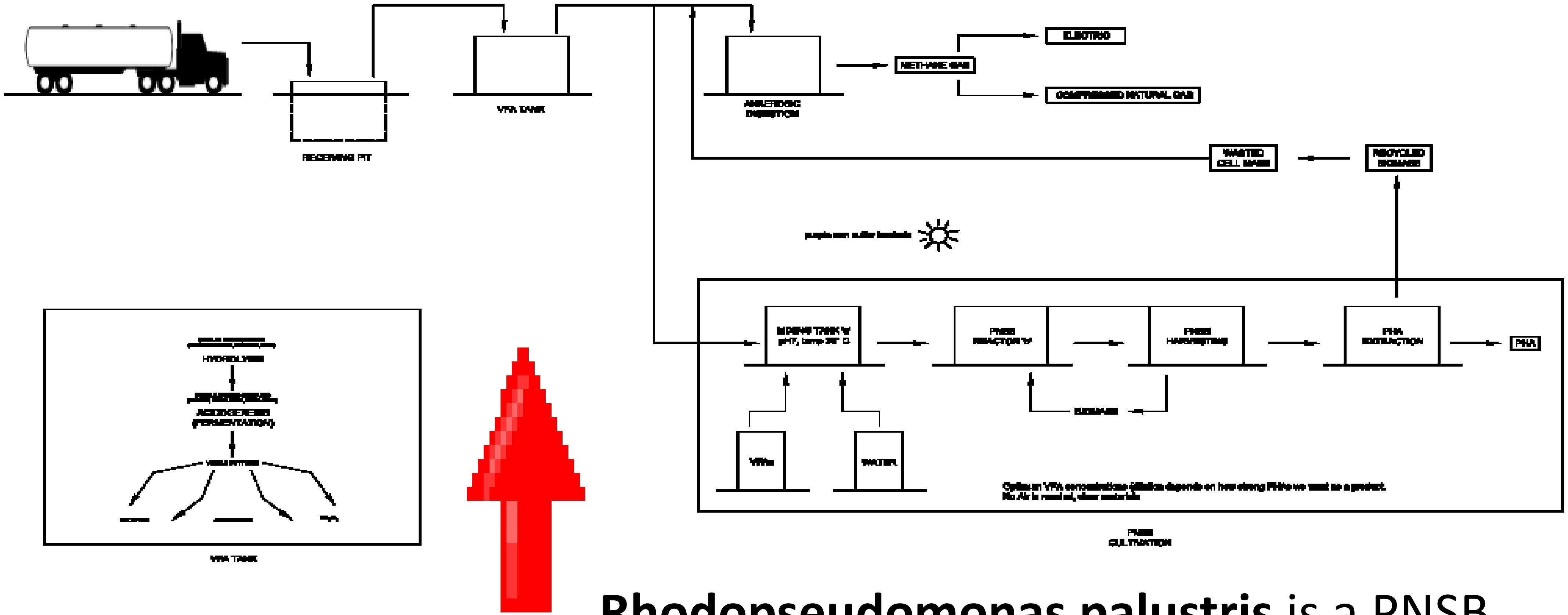


Rhodopseudomonas palustris is a PNSB belonging to the class Alphaproteobacteria.

From cells with PHA to PHA powder

Organic Solvent to Release PHA from Cells **We use chlorox bleach**

Centrifugation to separate PHA from Bacterial Cell

Evaporator

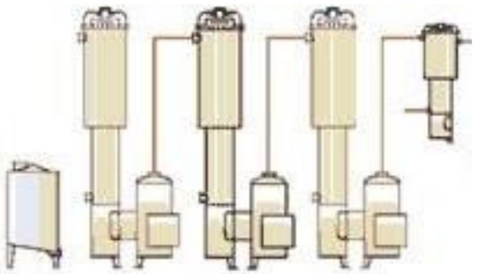
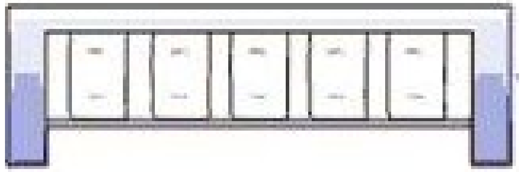


Fig 1 - Tall Form Chamber

PHA Powder



Palletizer

Bagging Machine


White Material - PHA

BioFerment Recovery

Co - Founders

Maneewan Suwansaard (Joy) & *Mike Maringer*

THANK YOU WASTEWATER PROFESSIONALS