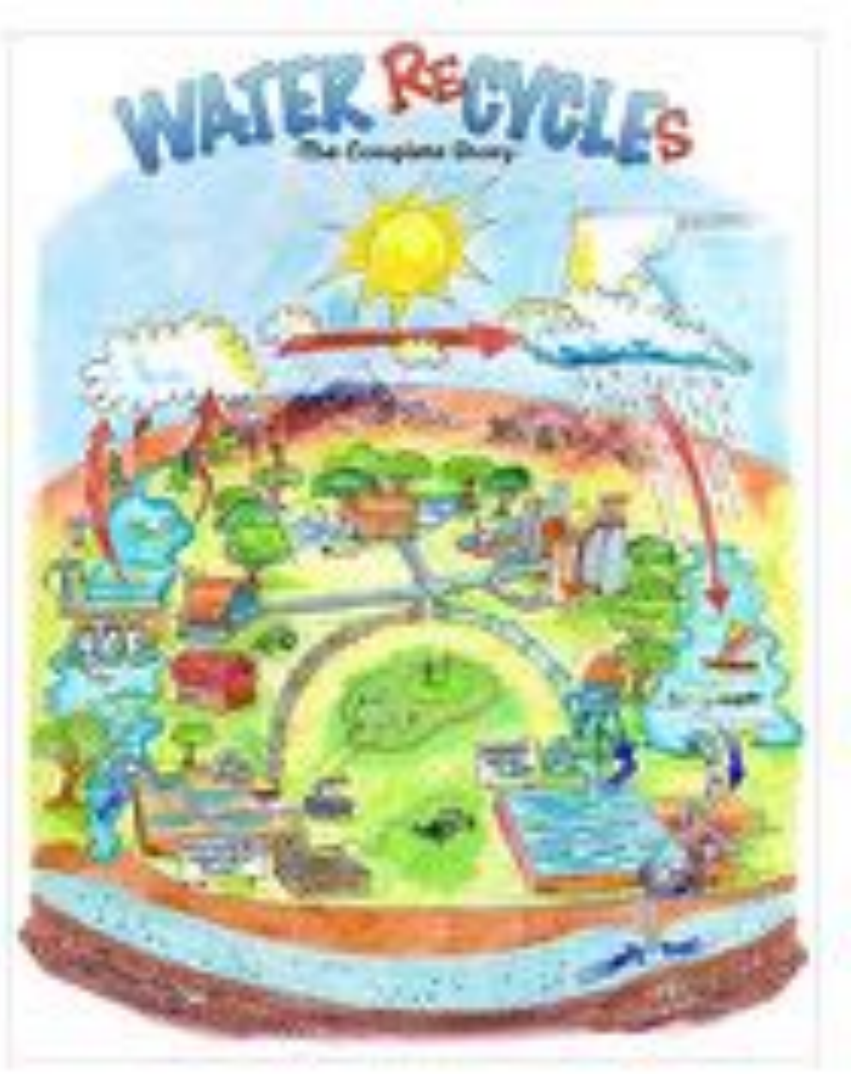
Training: Anaerobic Digestion

NHWPCA • NEBRA • NH DES
November 16, 2016 – Franklin, NH



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What NEBRA Does For You

- **Tracking news & research; advancing best practices**

Distilled biosolids and residuals news for New England and eastern

It's History - Except for Presentations Online!

North East Residuals & Biosolids Conference

a wrap

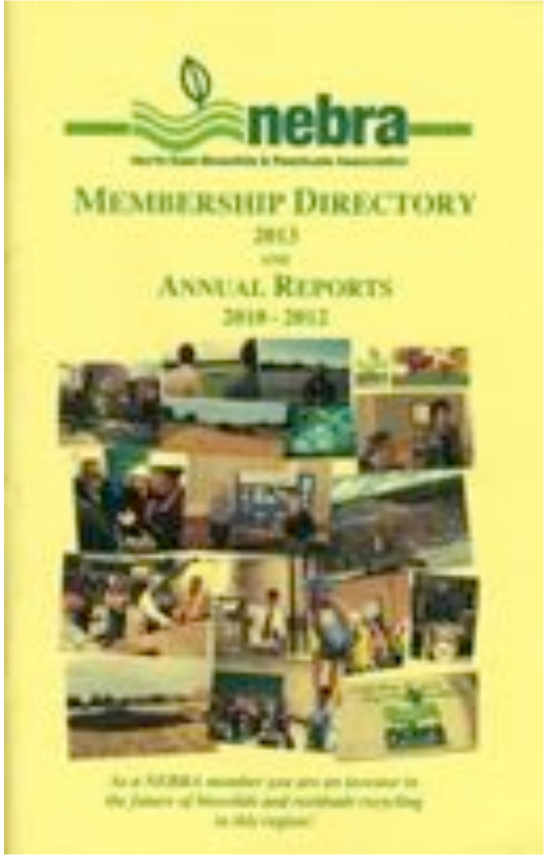
The energy was high at this year's annual northeast residuals conference. It began on November 9th with a record turnout at the optional tour of the Greater Lawrence Sanitary District and the adjoining NEFCO-operated biosolids pelletizing facility.

A sell-out crowd attended the tour at GLSD & the NEFCO

CALENDAR…

Here comes 2011!

NEBRAMail



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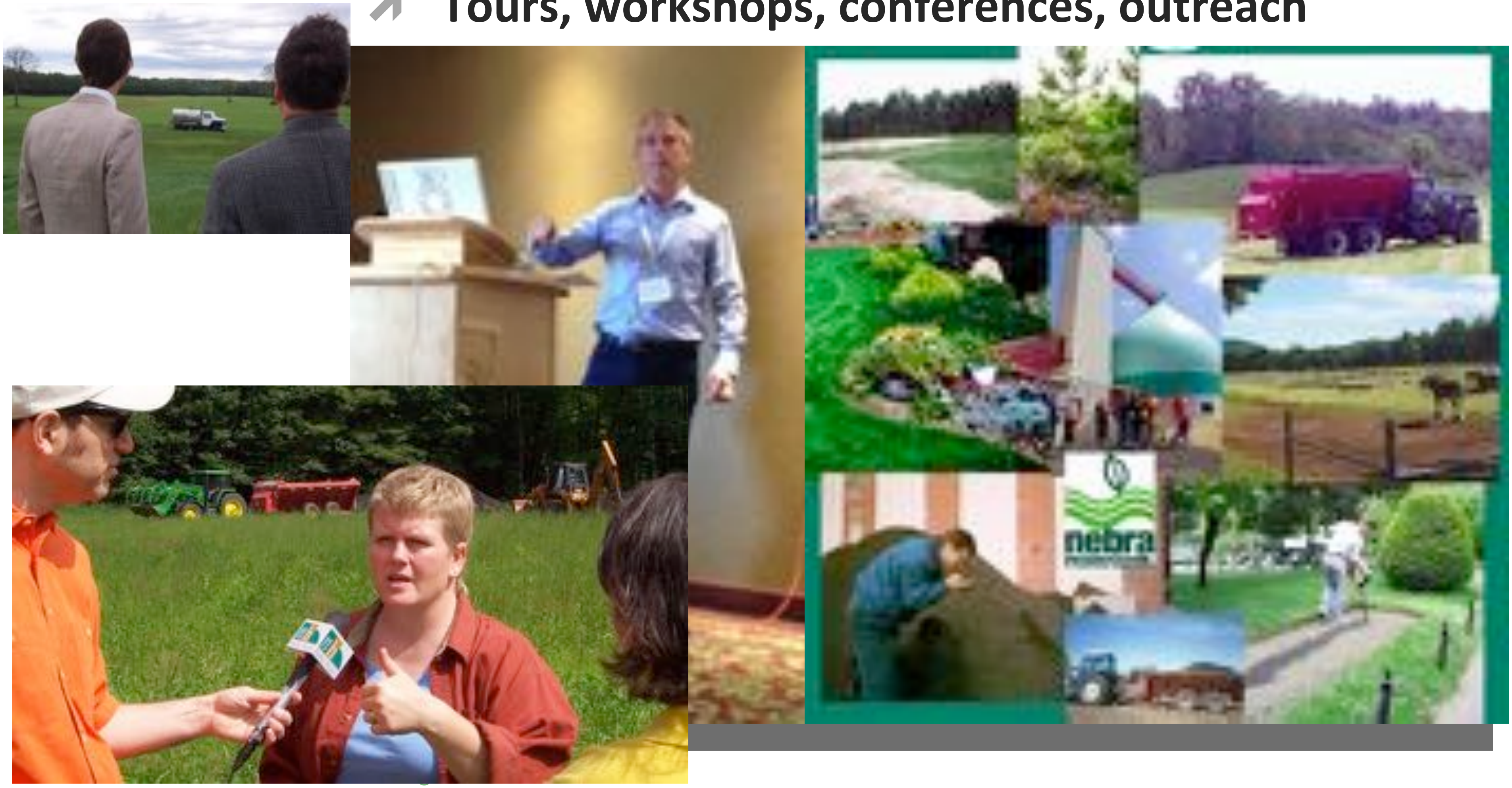
- **Tours, workshops, conferences, outreach**



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Why Anaerobic Digestion?

History, New England facilities, & the potential here & nationwide

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Digester Class
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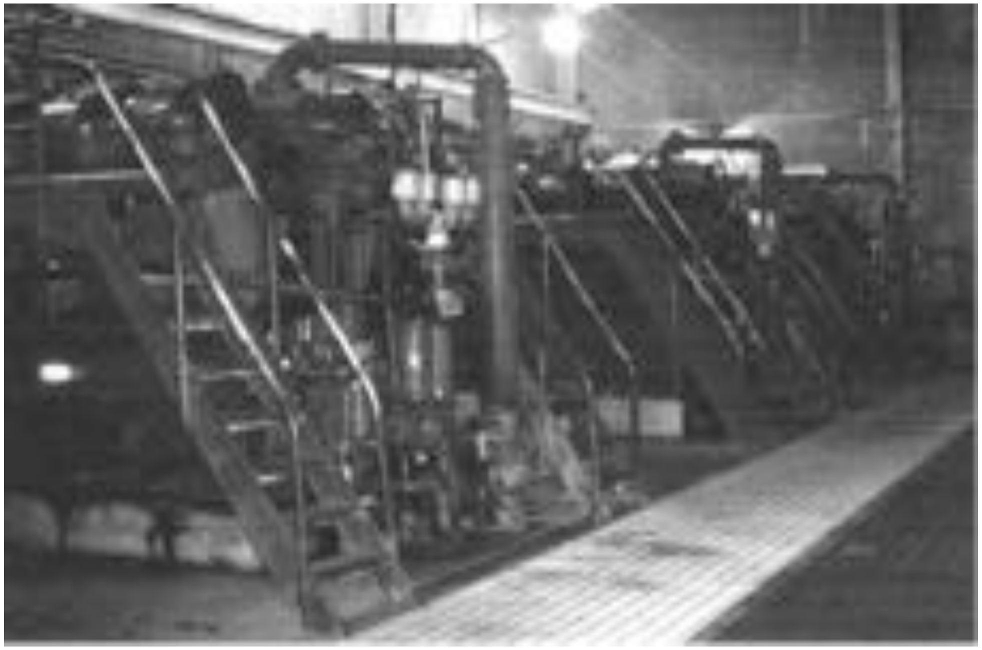
Some history



- Late 1930s: LA County Sanitary District power-plant, driven with AD biogas.
- Net-zero electricity! Generated all the power needed by the treatment plant (just primary treatment at the time).

New digesters

CRMC, New Bedford, MA:
food scraps, FOG, etc.

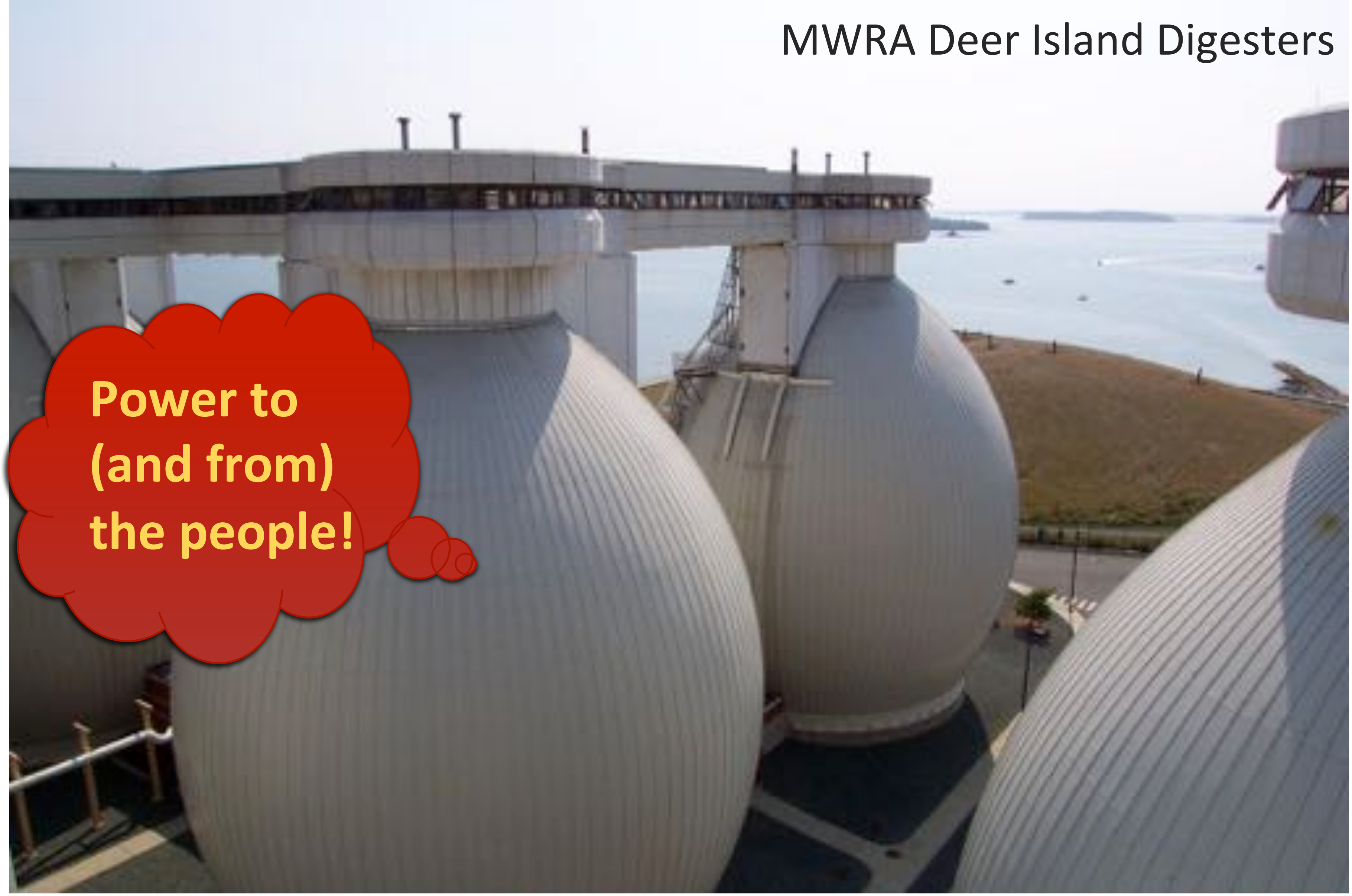
Longview Farm,
Hadley, MA:
manure, food scraps

Farm digesters are becoming common…

Cow power!

Jordan Farm,
Rutland, MA
manure, food scraps
Digestate is land
applied on farm.

MWRA Deer Island Digesters



Power to (and from) the people!

Today's high-tech system at Wooster, OH

- See video at top of this page:

http://www.quasarenergygroup.com/

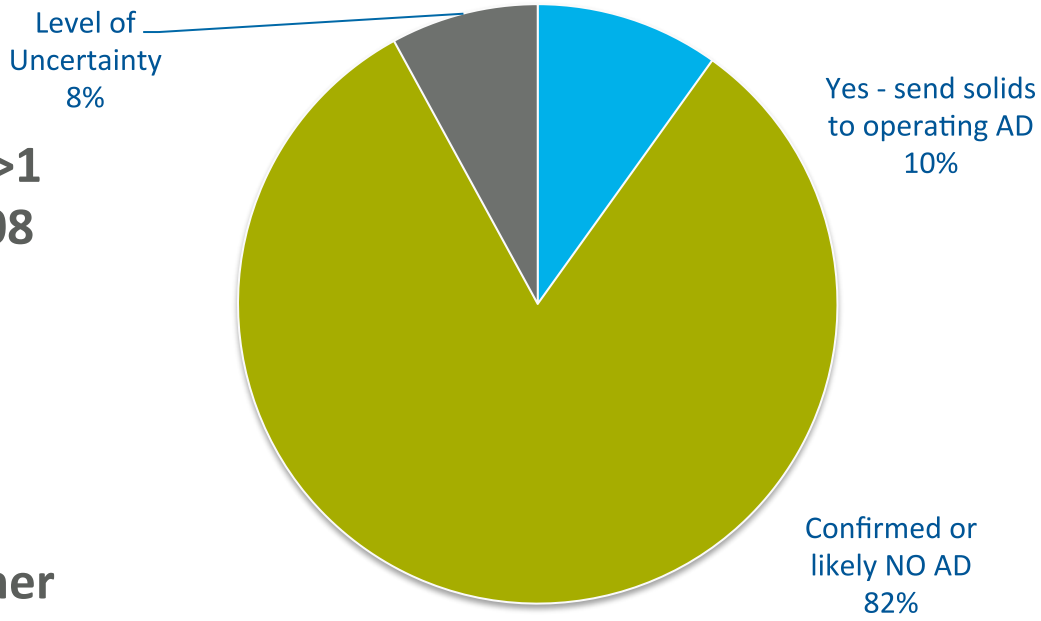
ANAEROBIC DIGESTION NATIONWIDE

- **14,886** total facilities in 50 states reported by 2008 Clean Watershed Needs Survey
- **3,208** Major facilities (>1 mgd), according to the 2008 Clean Watershed Needs Survey
- **1,238** facilities whose solids are treated with AD (some send solids to another facility) – we have a relatively high level of confidence in this number – almost all of these are Major facilities

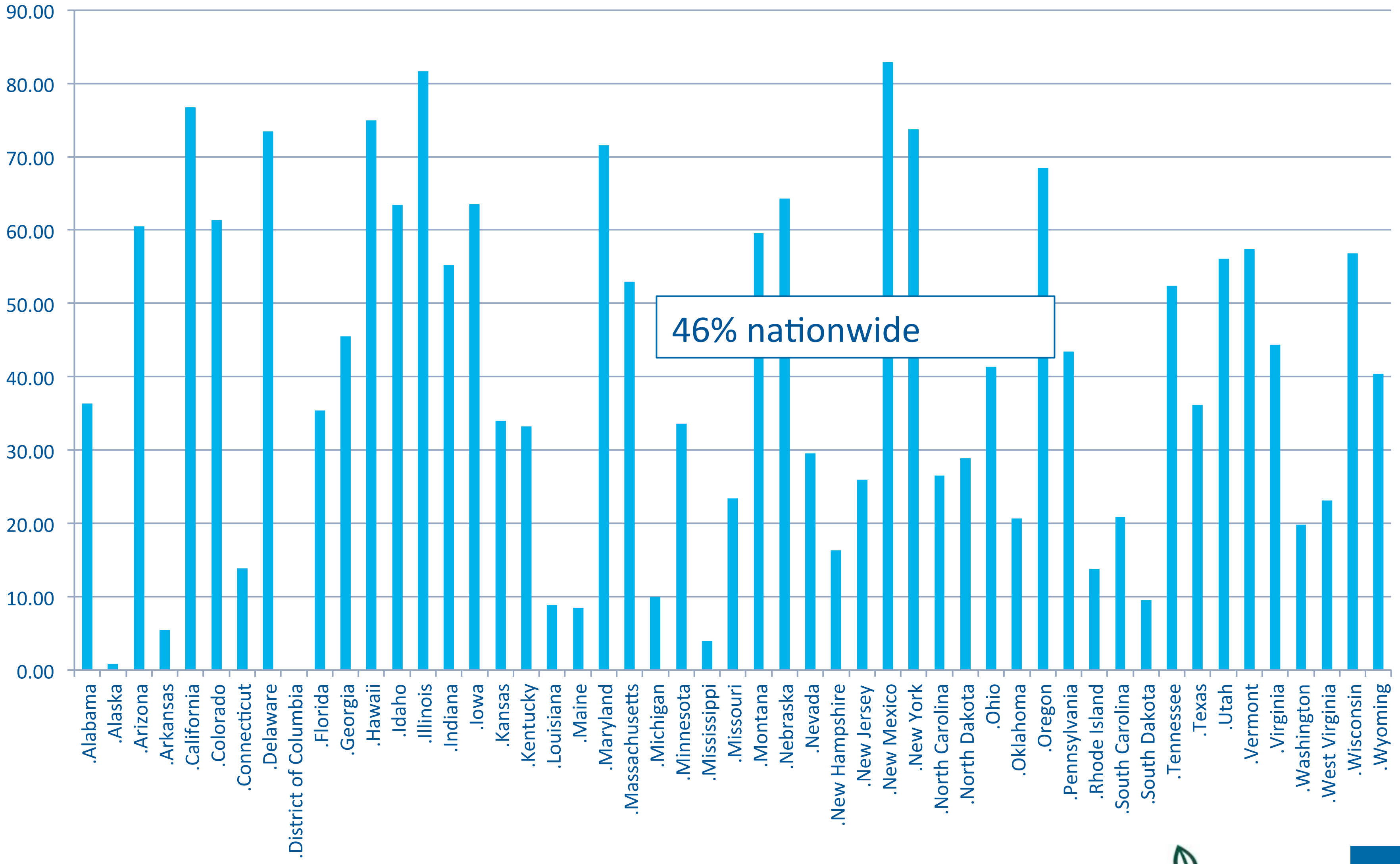
Percentage of Facilities Sending Solids to AD

and showing level of uncertainty

(comparing survey data to CWNS 2008 total WWTPs)



% WASTEWATER FLOW TREATED BY AD

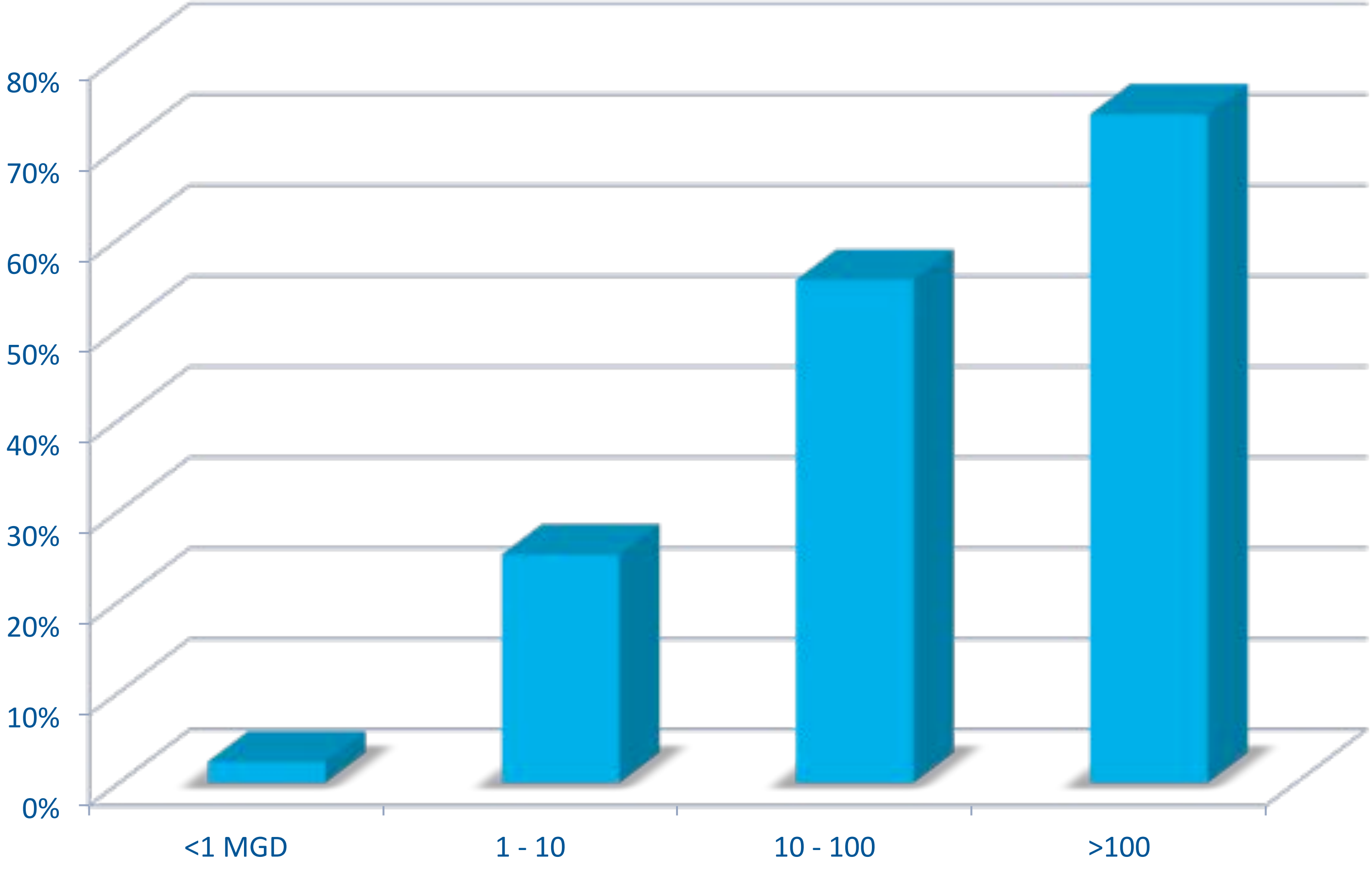


46% nationwide

Percent Total Wastewater Flow Anaerobically Digested (2012)

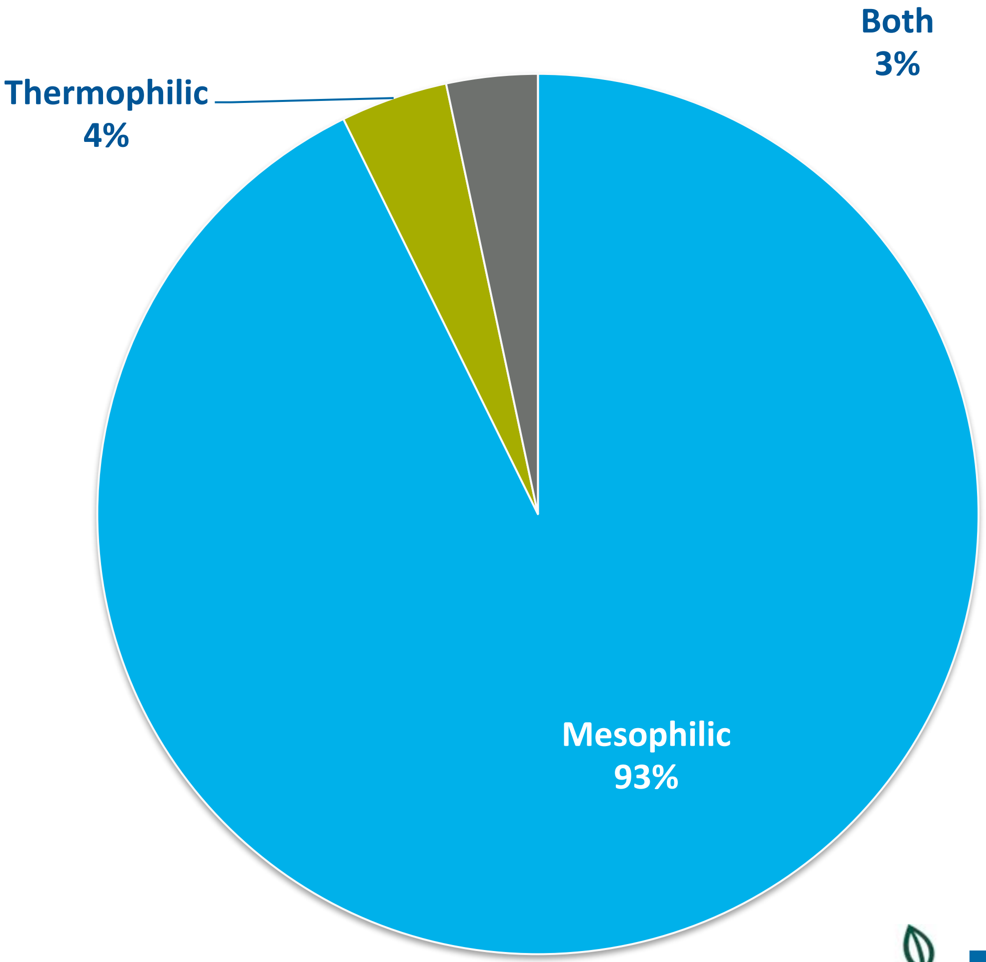
% FACILITIES SENDING SOLIDS TO AD

Based on total number of U. S. WWTPs in each size grouping (CWNS 2008)



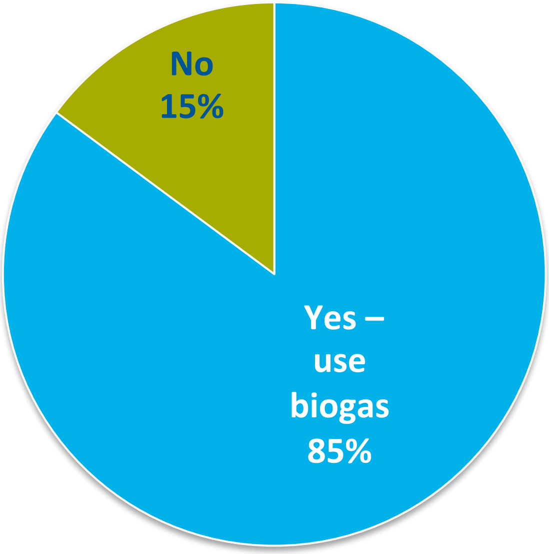
Larger facilities are more likely to have AD.

TYPES OF DIGESTION IN USE

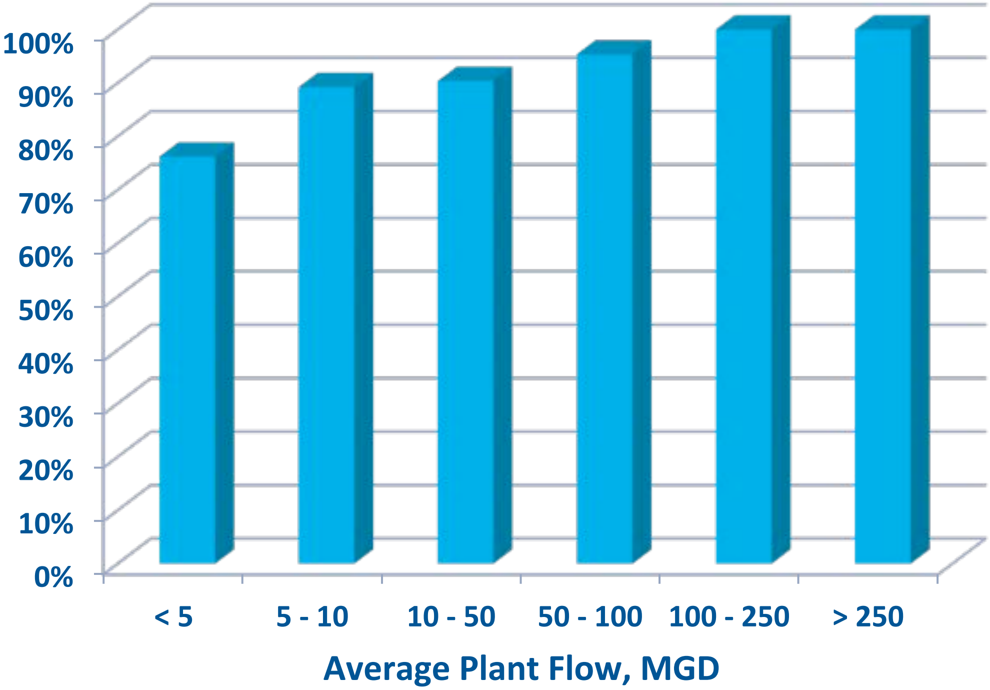


NOTE: We found that, in 2012, 17% of WWTPs with AD import outside waste directly into their digesters.

AD FACILITIES THAT USE BIOGAS



Out of the 1,238 facilities that have AD, 1,054 of them beneficially use biogas



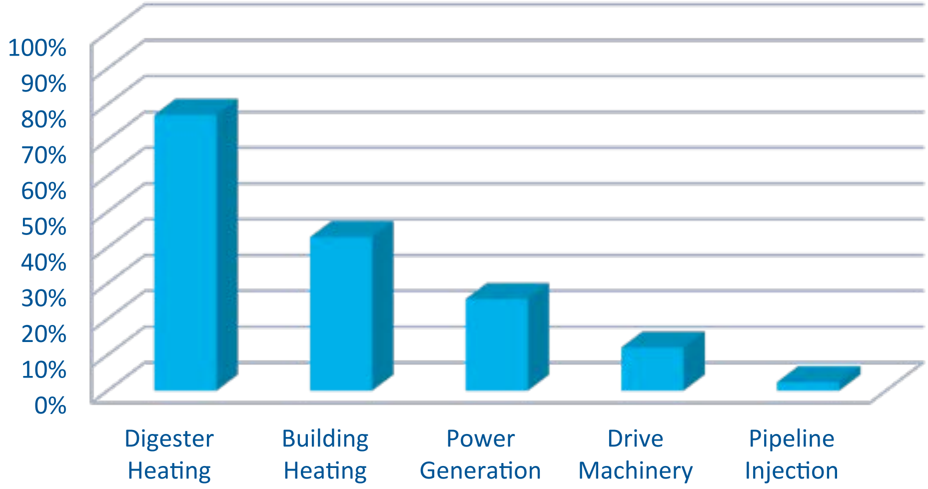
Percentage of AD facilities that use biogas increases with plant capacity **(based on only those facilities we have confirmed have AD)**

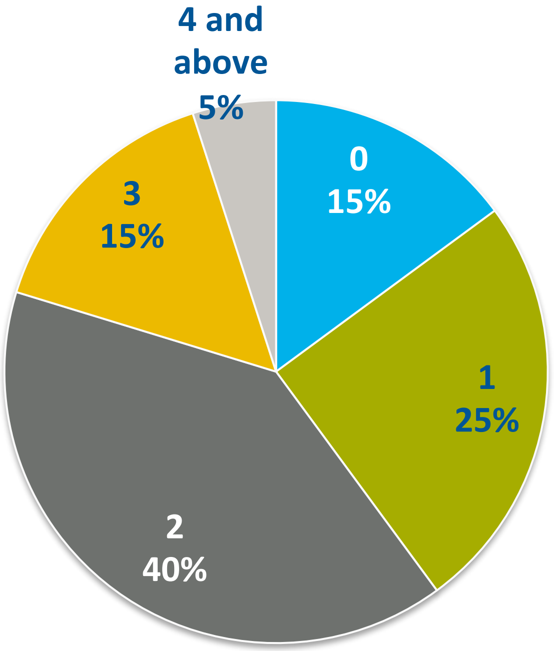
BIOGAS USE TECHNOLOGIES

1,054 facilities use biogas

(1,666 distinct technologies are in use; some facilities use more than one)

How biogas is used at AD facilities

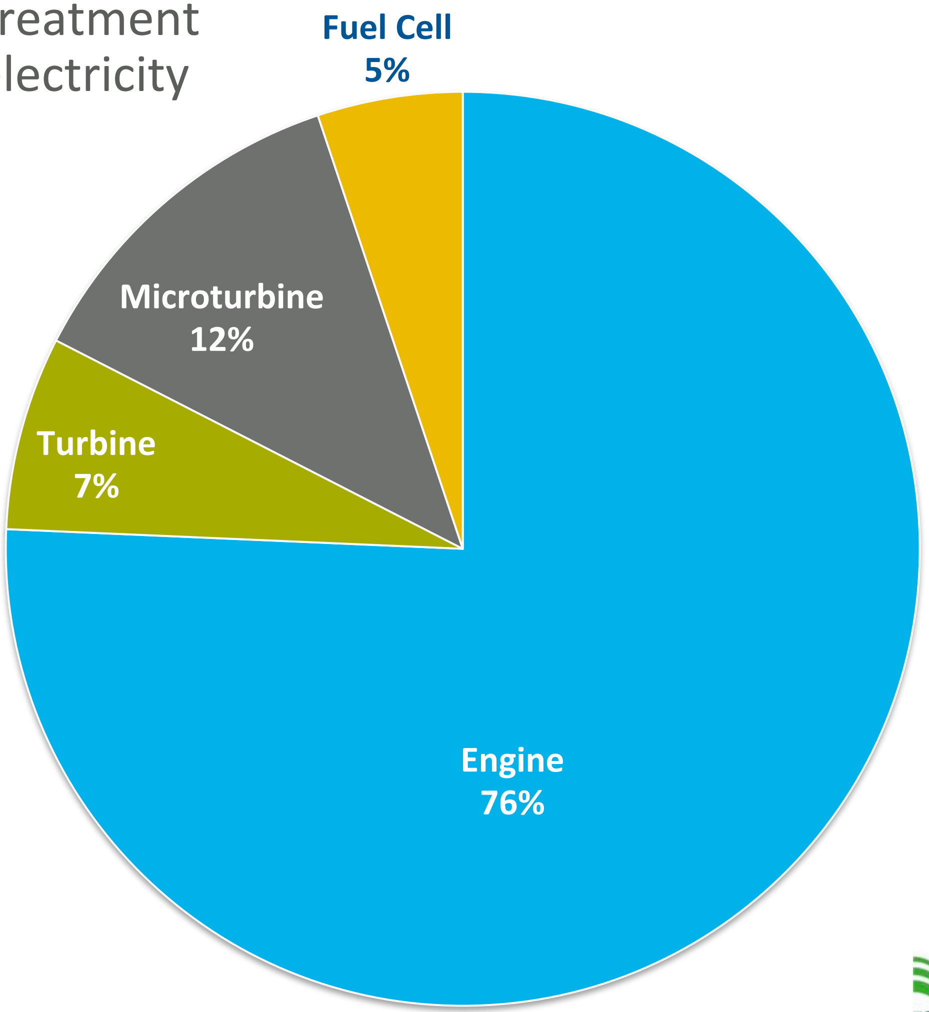




No. of biogas use technologies used at each facility

POWER GENERATION TECHNOLOGIES

292+ wastewater treatment facilities generate electricity from biogas



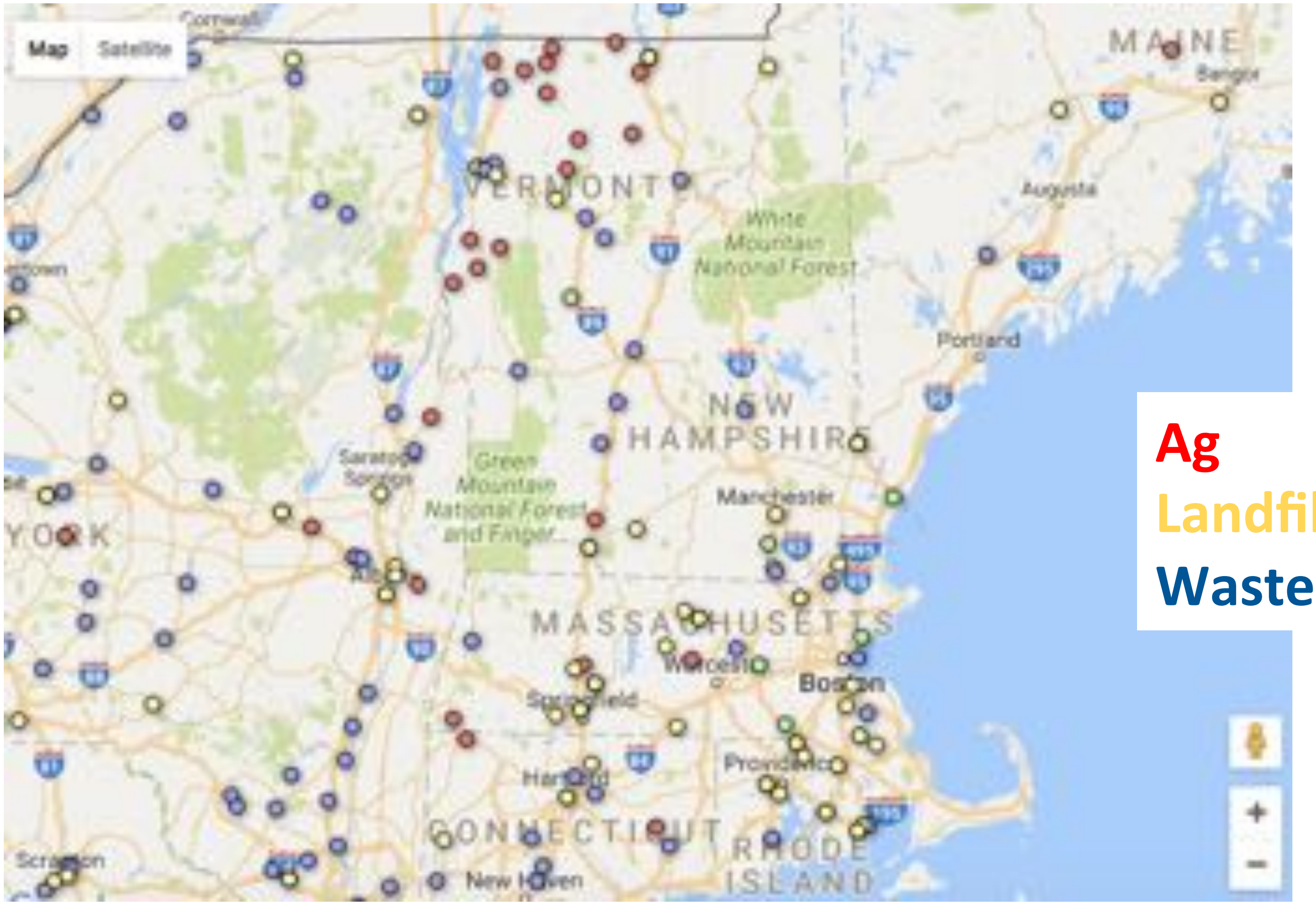
ONLINE DATA: UNITED STATES

Ag
Landfill
Wastewater

www.biogasdata.org

www.americanbiogascouncil.org/
biogas_maps.asp

ONLINE DATA: NEW ENGLAND



Ag
Landfill
Wastewater

www.biogasdata.org

www.americanbiogascouncil.org/biogas_maps.asp

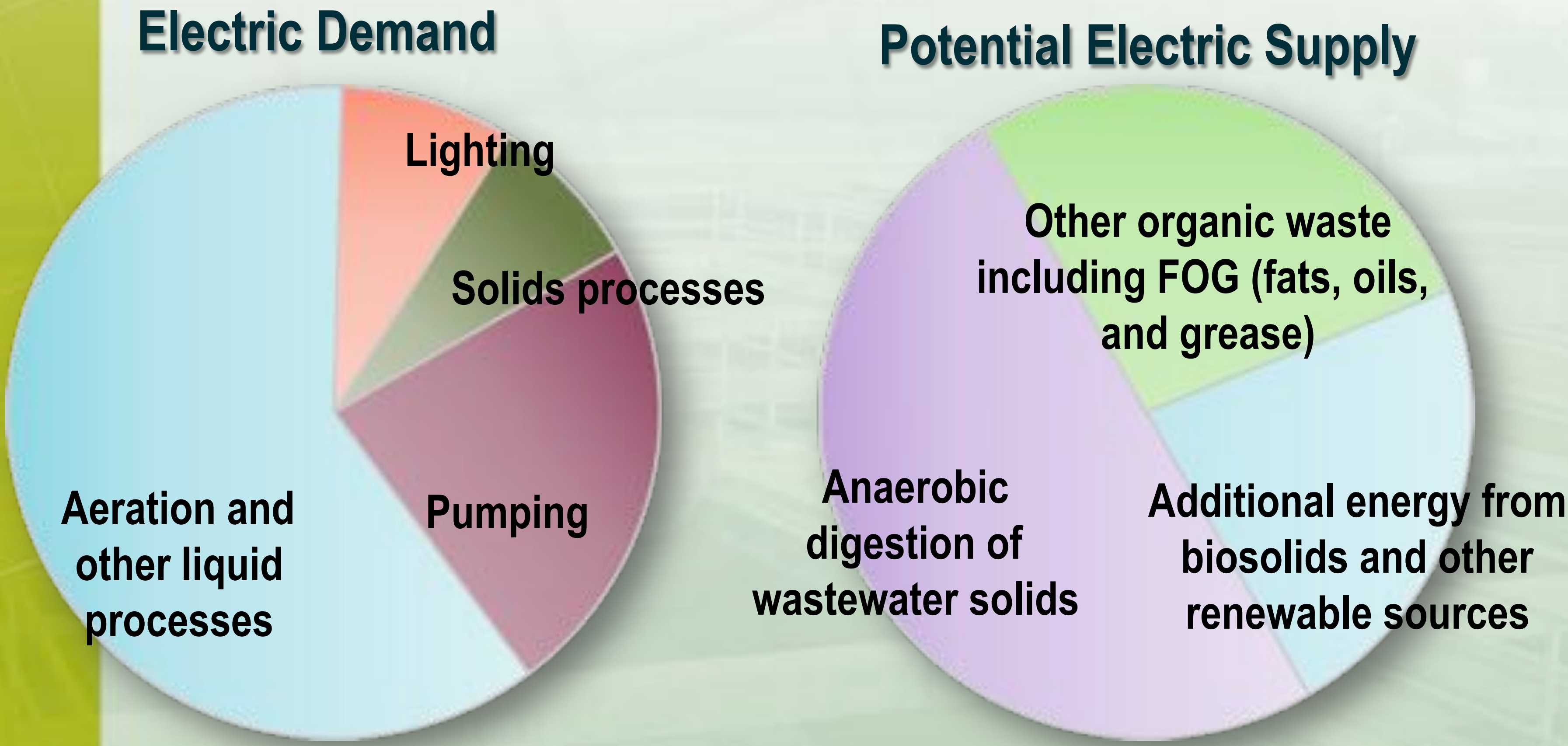
The information in these slides is for general understanding and guidance on the operations of anaerobic digesters. Do not rely on this information solely. It is not intended as advice for dealing with any particular system or situation. The operation of any particular digester system requires careful analysis of the particular configuration and situation.

AD Theory & Systems

Why Anaerobic Digestion (AD)?

- Class B (mesophilic AD) or Class A (thermophilic) biosolids stabilization process
- Less biosolids to manage
- More stabilized solids = lower odor potential
- Reduction of organic contaminants (e.g. phenols, toluene, other hydrocarbons, alcohols, ketones)
- Production of biogas that can be used for renewable (green) energy
- Tried & true process!

Wastewater Plants Can Produce Enough Electricity to Meet Demands



Source: David L. Parry, CSWEA, Oct. 2010

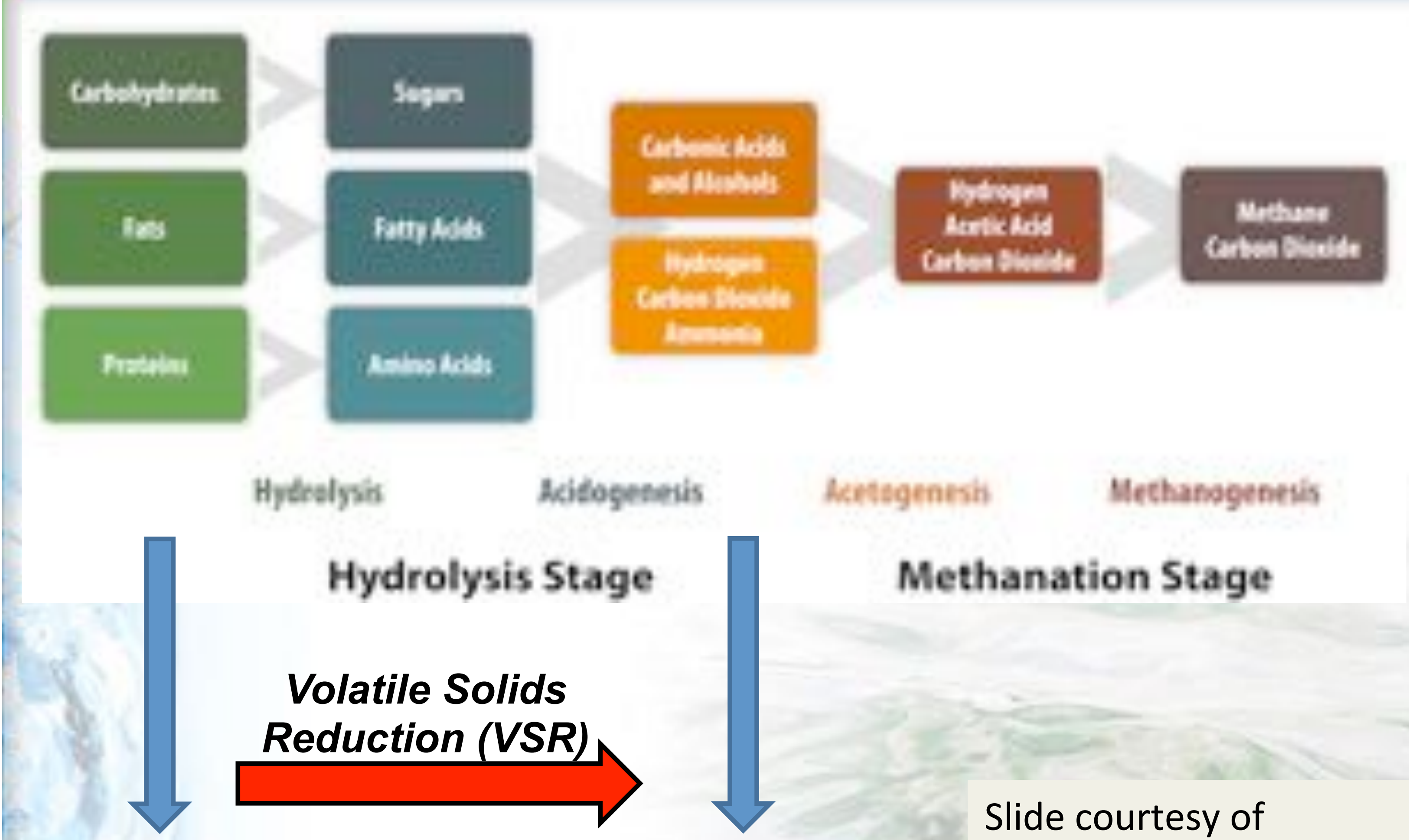
Slide courtesy of CDM Smith

Challenges of Digestion

- High capital cost
- Somewhat complex process, especially if biogas is to be used for electricity & heat.
- Not familiar to some operators & managers; requires training, especially if biogas is to be used for electricity & heat.
- Requires managing energy carefully to have net energy benefits.
- Can impact liquid stream with high-ammonia recycle.
- Need to consider how AD fits into the full treatment process.

Digestion Biology:

Digester Gas Production Directly Related to Volatile Solids Reduction



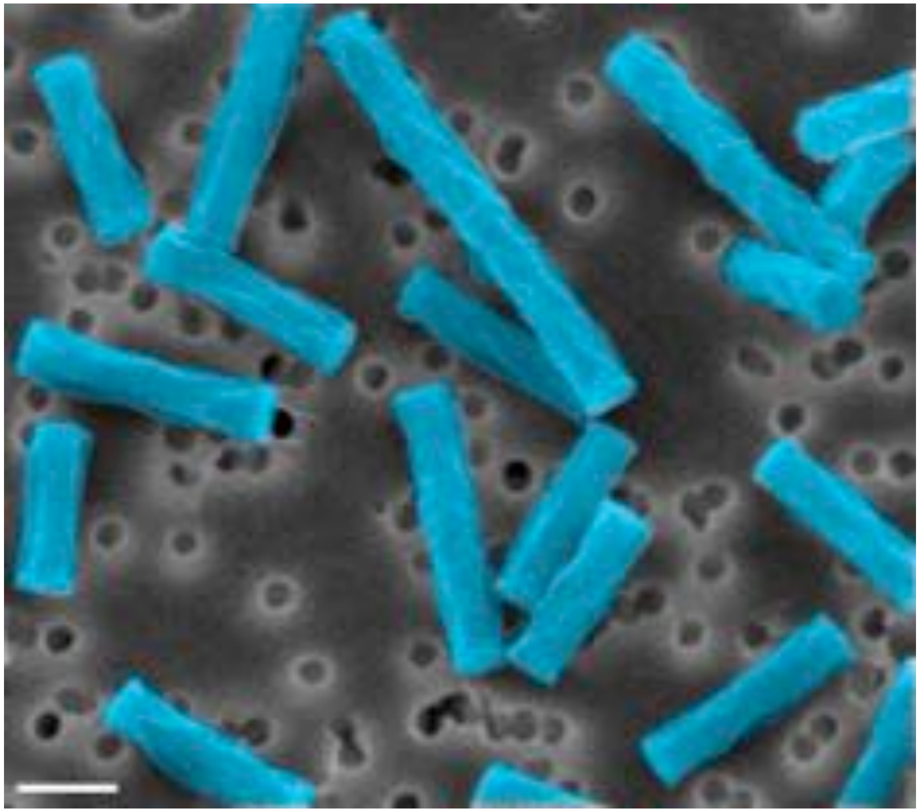
Volatile Solids Reduction (VSR)

Volatile Solids

Soluble Organics Gases

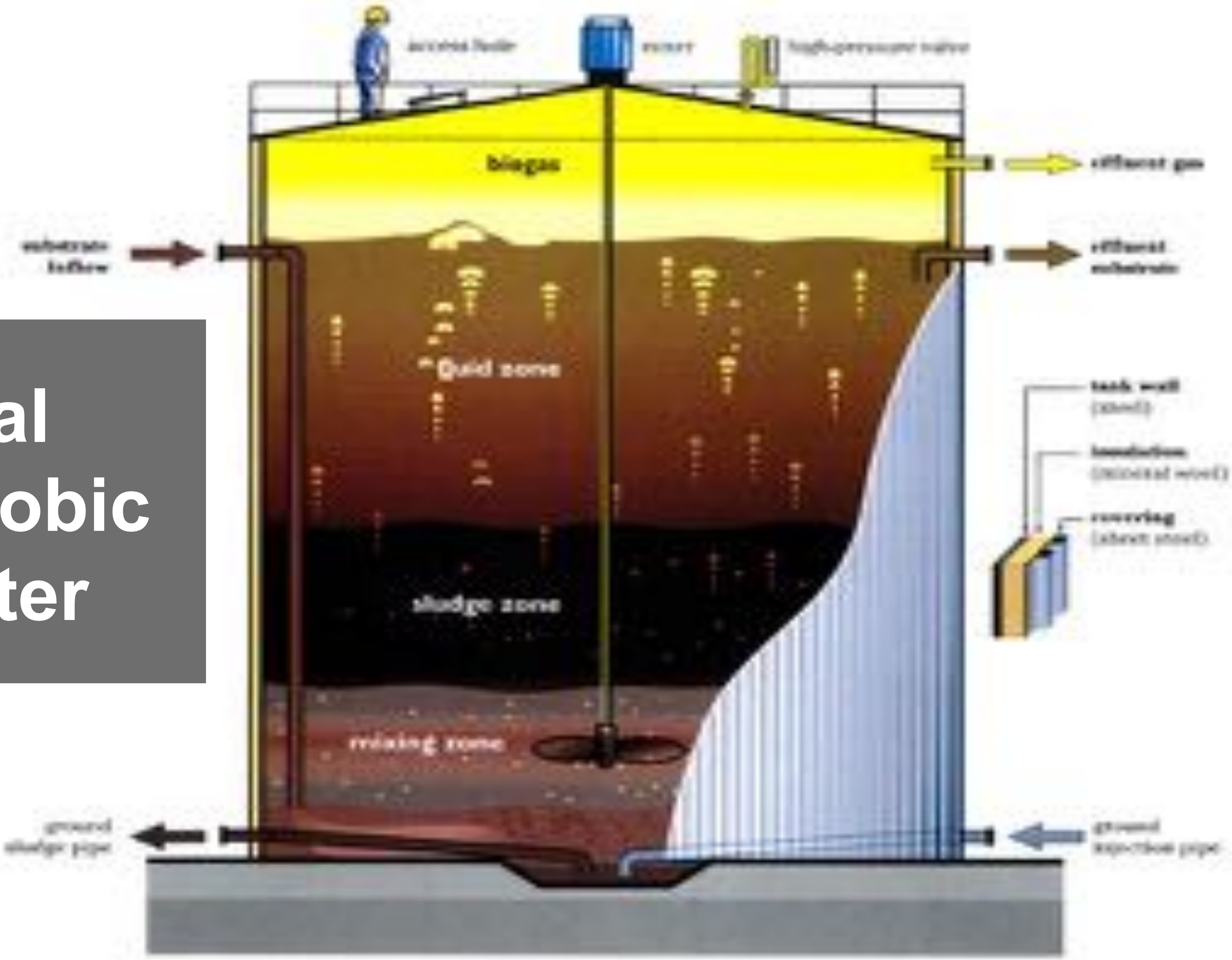
Slide courtesy of
Matthew Van Horne,
Hazen and Sawyer

Ya gotta love the bugs!



- *Methanosaeta sp.* – the microbes that likely produce most methane
- Recent research at UMass finds this microbe can even convert CO_2 to methane (CH_4) using conductive nanowires that another anaerobe, *Geobacter*, produces.
- *Geobacter* can produce electricity from mud! http://www.geobacter.org/mud-bat

Typical anaerobic digester



AD Configurations

- Modern digestion (high-rate) = heated & mixed
- Tankage is typically:
  - pancake (<1:1 depth to diameter) or
  - tall cylinder (>1:1) or
  - egg-shaped
- Covers:
  - fixed or floating, sealed
  - with biogas storage or not
  - Include liquid overflow, pressure release, flame trap

Types of digester covers

Submerged Fixed Concrete

Fixed Steel Cover

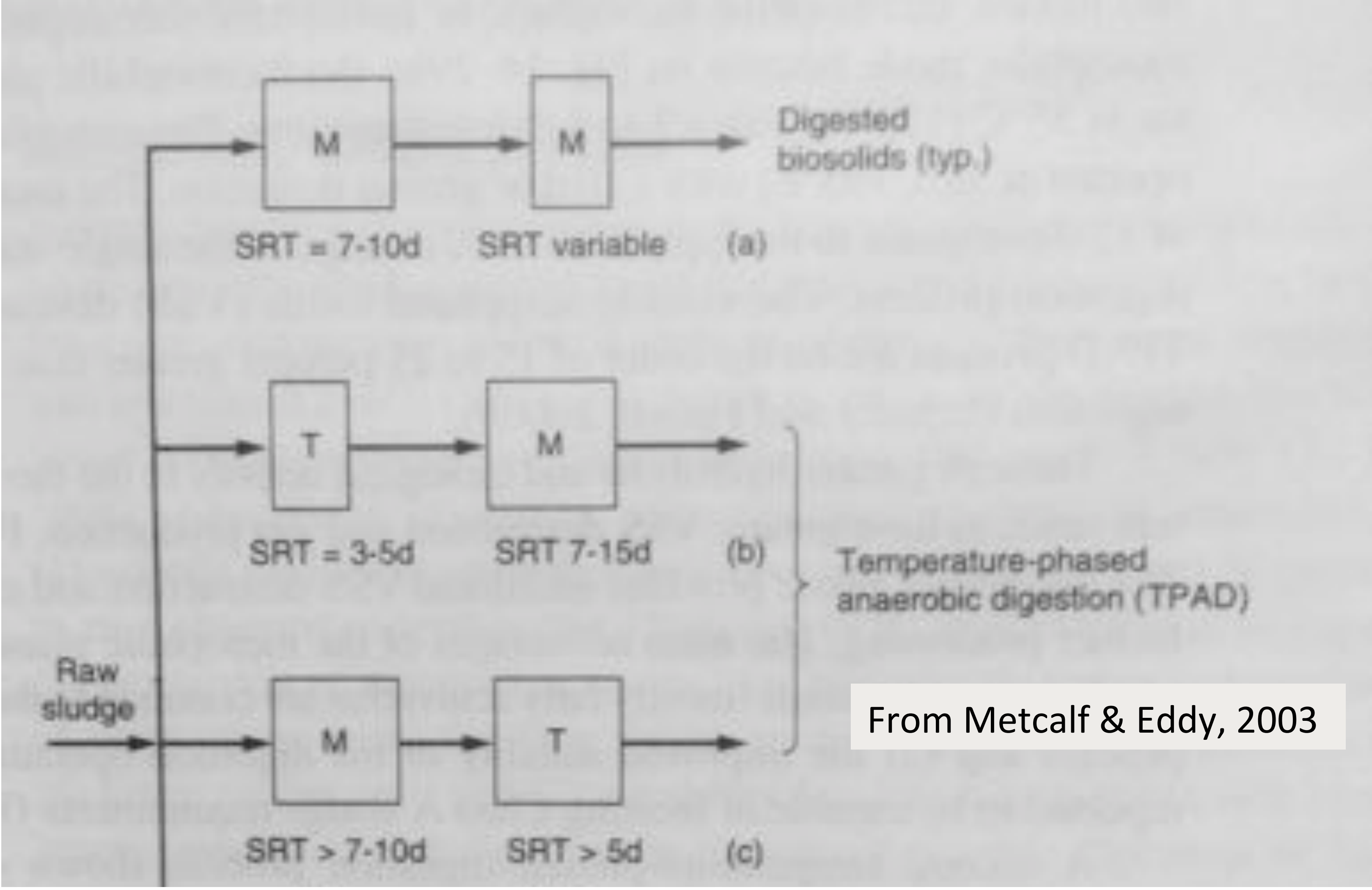
Floating Steel Cover

Gas Membrane Cover

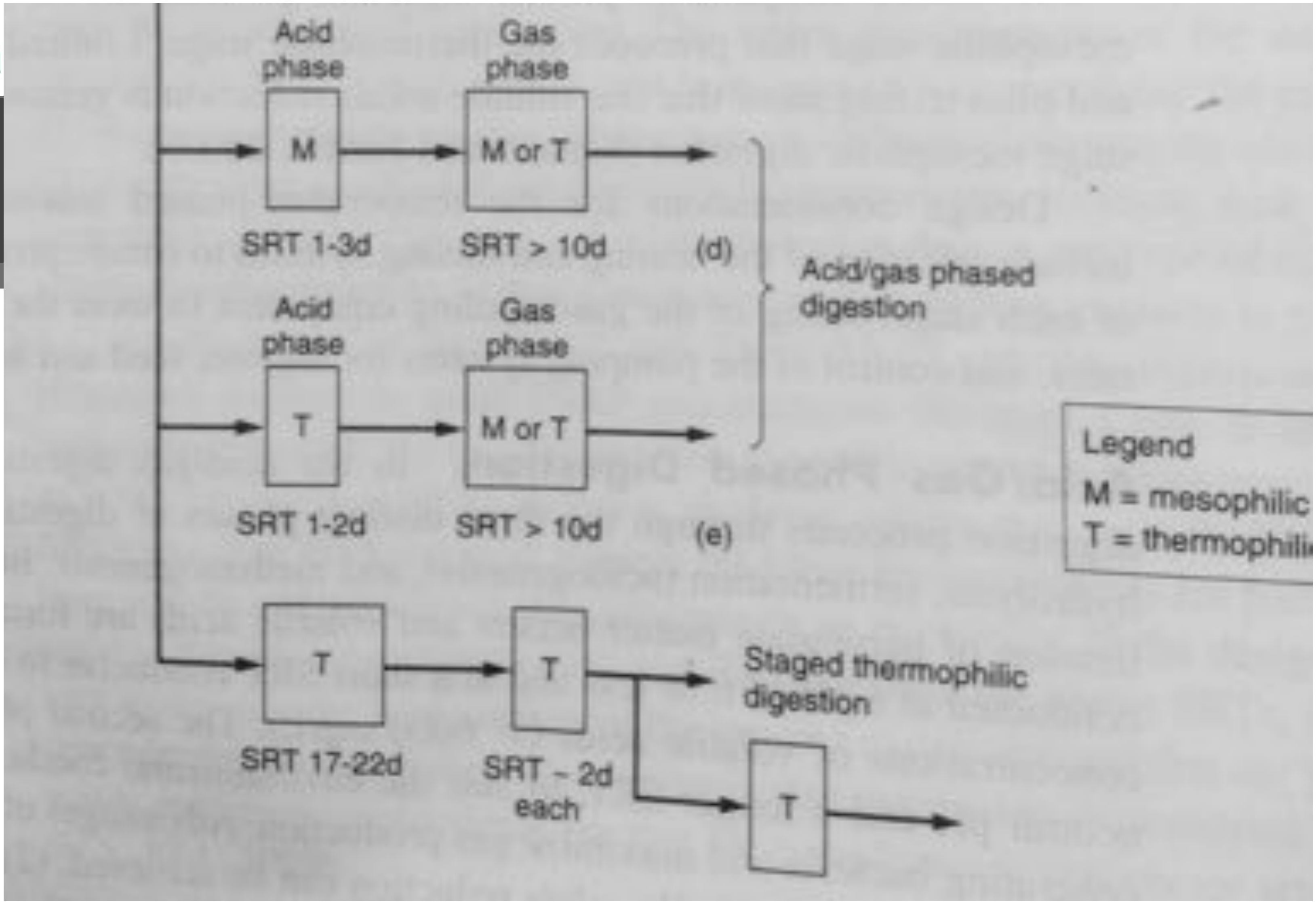
AD phases & stages

- Mesophilic (high-rate): ~35° C (usually one stage, 2-stage more common in the past)
- Thermophilic: ~55° C, can manage shorter SRT & higher solids loading (% solids)
- Temperature-phased (TPAD): ~5-day thermophilic followed by ~10+ day mesophilic: can achieve up to 70% VSR
- Acid/Gas: 2-stage, with 1 – 3 day, low-pH stage followed by 15 – 20 day gas (methanogenic) stage, usually at mesophilic temperatures or at meso- (acid phase) followed by thermophilic (methane phase)
- Extended Solids Retention (recuperative thickening): removing liquid & returning digested solids for longer SRT – still in development
- ATAD followed by mesophilic AD – Tacoma, WA

AD phases & stages…(M & E, 2003)



From Metcalf & Eddy, 2003



From Metcalf & Eddy, 2003

Digester volume

Volatile Solids (VS) Loading

- Amount of volatile solids in sludge entering digester / volume of digester
- TR16 maximum VS loading rate = 120 lbs VS per day / 1,000 ft^3 digester volume
- 1 million gallon tank = 133,680 ft^3 → max. ~16,000 lbs. VS per day to that tank

AD volume vs. SRT

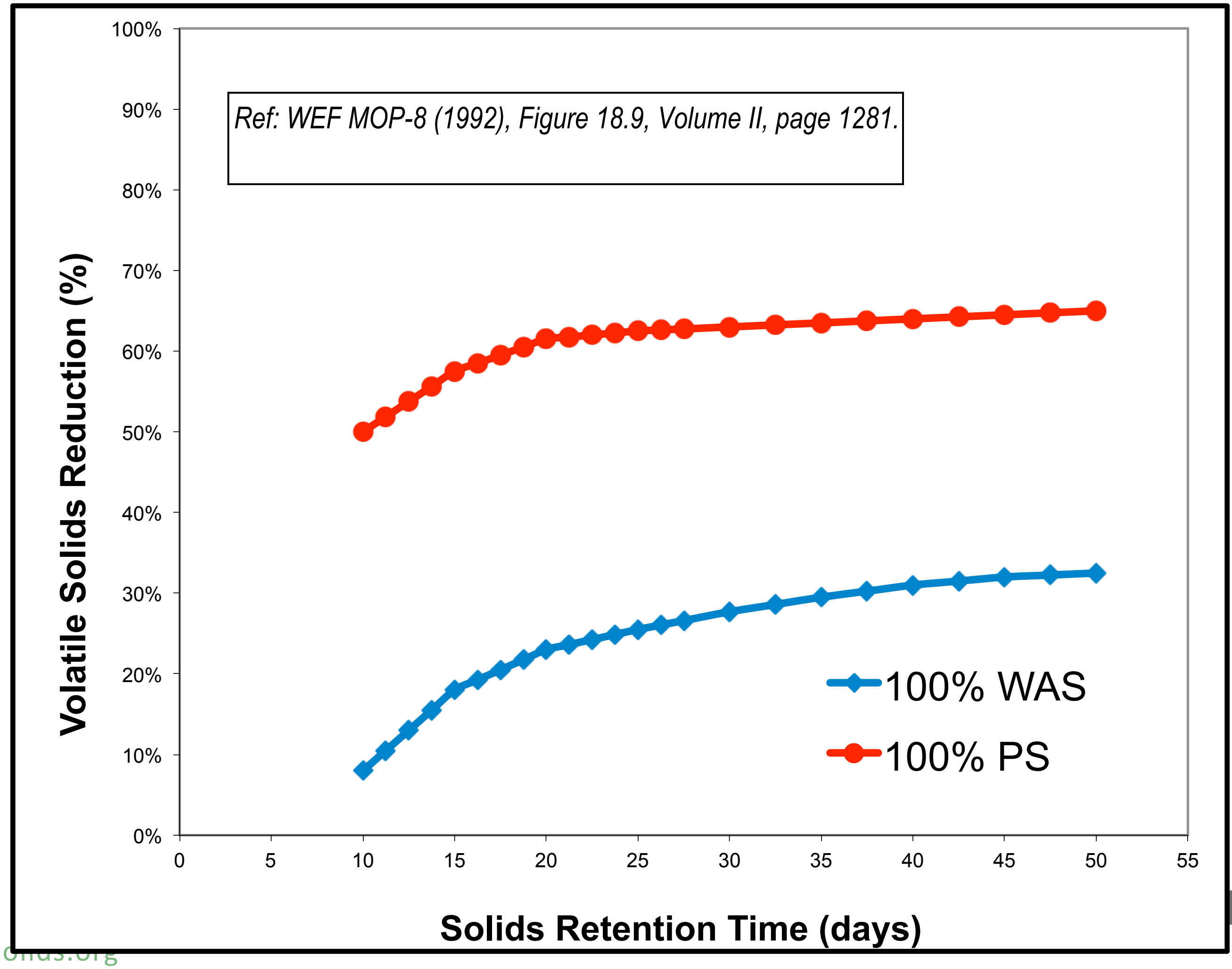
- SRT (days) = Vol. of tank (m^3) / Flow (Q) removed (m^3/day)
- Washout of methanogens occurs at SRTs of <5 days
- Minimum SRT to meet PSRP = 15 days at 35 – 55° C (or 60 days at 20° C.)
- Effective digester volume is affected by:
  - maximum flow rate
  - grit accumulation in digesters between cleanings
  - redundancy to allow for one tank to be taken down and cleaned, as needed

Key environmental factors for AD

- Influence of solids retention time:
    - SRT of 15 days → 56% VSR
    - SRT of 30 days → 65.5% VSR
- Hydraulic retention time (HRT = SRT, unless there is recycle)
- Temperature (T)
- Alkalinity (provided by Ca, Mg, & NH_4 bicarbonates, consumed by CO_2)
- pH
- Inhibitory substances (e.g. ammonia)
- Nutrient & metals bioavailability

nebra Recycled organics: Tools for sustainability.

Volatile solids reduction (VSR) is increased with time (SRT)



Digester nutrients and inhibitors

Total Concentrations (mg/l)

Parameter	Digester Effluent	Stimulatory	Inhibitory	Toxic
TS	3.97%	-	-	-
VS	79.9%	-	-	-
VSS	3.2%	-	-	-
COD	17,250	-	-	-
Kjeldajl Nitrogen	651	-	-	-
Ammonia Nitrogen	645	50 (NH_3-N)	500 (NH_3-N)	1,500 (NH_4-N)
Total Phosphorous	112	-	-	-
Potassium (K)	-	200	2,500	-
Sodium	-	100	3,500	-
Sulfate	-	-	1,333	-
pH (s.u.)	7.1	6.8	7.2	-
Volatile Acids (avg mg/l as HAc)	34.2	-	2,000	-
Alkalinity to pH 5.8 (avg ppm as CaO_3)	2,831	500	-	-
Volatile Acids / Alkalinity	0.01	0.05	0.15	
Particle size (um)	150-300	-	-	-

Digester nutrients and inhibitors

Total Concentrations (mg/l)

Parameter	Digester Effluent	Stimulatory	Inhibitory
Cadmium	3.16	-	330
Calcium	43.8	100	2,500
Chromium	1.70	0.02	130
Cobalt	-	0.19	70
Copper	11.4	-	40
Iron	2.85	0.4	-
Lead	1.77	-	8,000
Magnesium	21.4	75	1,000
Molybdenum	18.2	0.1	-
Nickel	1.40	0.8	2,000
Selenium	3.58	0.8	-
Tungsten	-	0.04	-
Zinc	19.3	-	270

Organic nitrogen

Digester Nitrogen Concentrations on 7/18/11 (mg/l)

Parameter	sAmm	sTKN	tTKN
Primary Sludge	53.4	71	63,000
TWAS (DAF)	10.3	18	3,200
Scum	0.0	0	0
Estimated Digester Influent	27	38	27,382
Digester Effluent (4/12/11)	673	847	-
Returned to WWTF	3.5	4.5	-
Digester Out/In Ratio	25	22	

Insoluble organic nitrogen was not analyzed

Nitrogen may be in the scum but the sample could not be analyzed

Process control

- Stability is key! Make few changes & gradually!
- Monitor:
  - Volatile acids : Total alkalinity ratio (leading indicator) – ideal is <0.1 to 0.25 (e.g. VA of 300 mg/l / and Alk of 2000 mg/l = 0.15)
  - VS loading rate
  - Digester temperature
  - pH (a trailing indicator)
  - Volatile fatty acids (VFAs)
  - Ammonia

Solids processed

- Volatile suspended solids (VSS) target feed rate = 0.12 – 0.16 lb. / d / ft^3 of digester volume.
  - 0.2 lb. / d / cubic foot is a typical maximum limit.
  - With very good mixing, a conservative target feed rate is lower, e.g. 0.04 – 0.08 lb. / d/ ft^3
- Estimating VSR (%) = 13.7 ln (SRT_{des}) + 18.9
  - So, for a 25-day SRT, VSR = (13.7)(3.2) + 18.9 = 62.7%

Feeding the digester(s)

- Continuous feeding of uniform solids is the ideal
- Feed cycles are typically continuous or 5 – 10 minutes every 30 - 120 mins.
- Small plants might make 3 manual feeds/day minimum
- Heating solids:
  - often blended in heated solids loop, after circulation pump or
  - in solids heat exchange system
  - best to heat digested solids and then blend in the new raw solids
- Remove solids from AD before feeding; avoid short-circuiting.

Blending tank

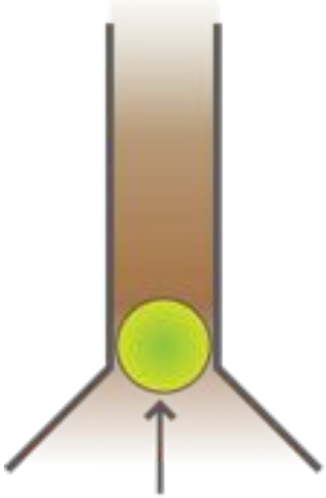
- Provides storage & a wide spot in the process
- Needed to mix primary & WAS - and especially helpful with co-digestion feedstocks (e.g. food scraps, FOG, etc.)
- 4 – 8 hours typical storage
- Make solids feed to digester consistent
- Mixing recommended
- Heating may be necessary to prepare solids for AD and if FOG is part of blend

Mixing

- Critical requirement to avoid dead spots & reduced effective digester volume
- Controls scum & grit accumulation
- Design & evaluate mixing efficiency with temperature measurements, tracer studies, etc.
- Types of mixing systems:
  - Gas injection / diffusion
  - Hydraulic – solids recirculation
  - Paddle mixing / mechanical draft tubes
  - Linear-motion

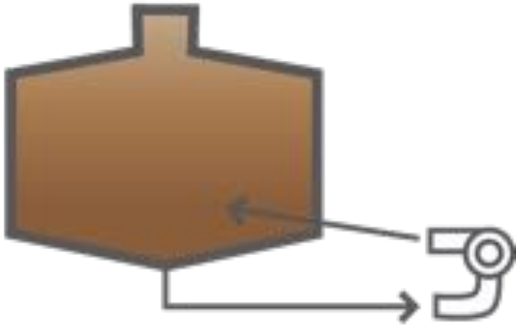
Poor mixing reduces effective volume

Some mixing technologies:



Gas Bubble

Mechanical Draft Tubes



Pumped Recirculation

Pretreating solids before AD - Required

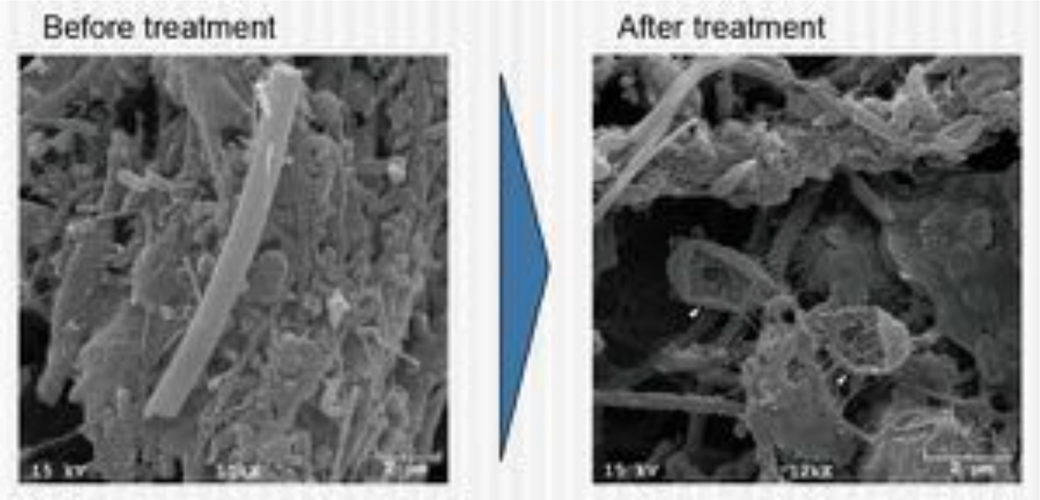
- Goal: provide consistent, small pieces of food, free of debris
- Debris removal: fine headworks screening, solids grit removal, thickening, solids screening
- Consider any special characteristics of influent (industrial, chemical), ratio of primary & secondary, biodegradability of solids
- Thickening: upper limit is determined by AD mixing system. Co-thickening of primary & WAS is often recommended.

Pretreating solids –hydrolysis (optional)

- Lysing of tough (e.g. lignin) WAS cell walls
- Occurs naturally, but can be sped up
- Can achieve Class A (best done before AD to avoid re-activation/re-growth of pathogens)
- More biogas, increased digestion capacity, increased VSR, lowered viscosity, less foaming, improved dewaterability (usually), reduced final biosolids mass

Examples of enhanced hydrolysis

- Thermal:
  - elevated T & P, e.g 30 mins at 165^{o} C, @100 psi (e.g. Cambi)
- Biological: e.g. acid-gas phased AD (e.g. GE Monsal)
- Mechanical:
  - Ultrasonication
  - maceration / shearing
  - high pressure
  - electrical pulse (e.g. OpenCel)
- Chemical:
  - acid or alkaline
  - hydrogen peroxide
  - ozonation



Designing AD for specific purposes

- Original goals of AD:
    - stabilize solids
    - reduce pathogens
    - reduce mass of biosolids
- Additional design goals:
    - maximize biogas production
    - further pathogen reduction, produce Class A
    - reduce trace organic chemical contaminants

Summary: Key parameters to focus on

- Excellent environment for the bugs (microbes)!
  - Uniform feed to the digester(s)
  - Adequate mixing
  - Constant temperature
  - Monitor VA:Alkalinity ratio

The information in these slides is for general understanding and guidance on the operations of anaerobic digesters. Do not rely on this information solely. It is not intended as advice for dealing with any particular system or situation. The operation of any particular digester system requires careful analysis of the particular configuration and situation.

Operating an Anaerobic Digester

ANAEROBIC DIGESTION

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Operations Section

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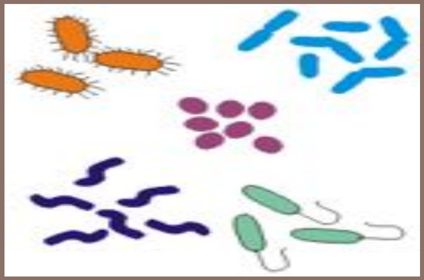
Concord, N.H. 03031

Phone 1-603-271-2586

ANAEROBIC DIGESTION



Operating an Anaerobic Digester

- The primary functions of the anaerobic digestion system is to reduce the concentration of pathogenic (disease-causing) organisms which are normally present in biosolids and to reduce the total volume of sludge to be dewatered and disposed.

ANAEROBIC DIGESTION

Operating an Anaerobic Digester

- Biosolids produced from the dewater process can be easily used for beneficial uses such as, soil enhancements and land reclamation projects.

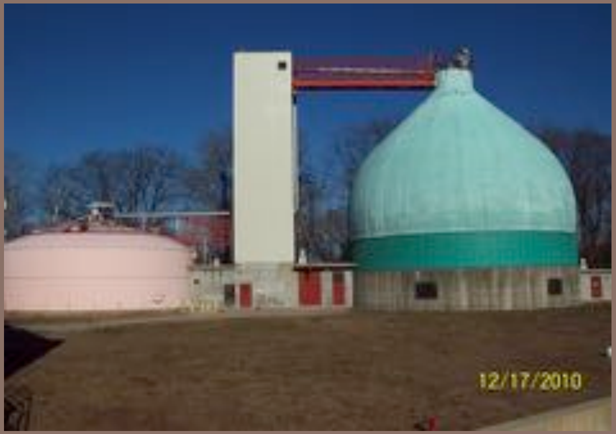
ANAEROBIC DIGESTION

Operating an Anaerobic Digester

- Additional energy production from methane gas

ANAEROBIC DIGESTION

Key Components of the Nashua Digestion Complex



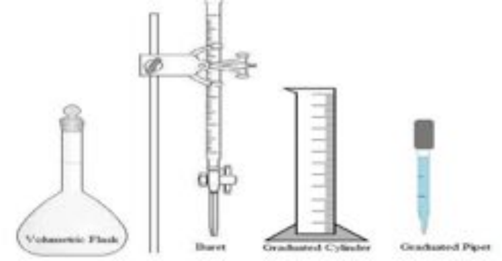
- Egg Shaped Primary Digester -1.3 Million Gallons
- Fix Cover Secondary Digester – 0.275 Million Gallons
- Gas Holding Tank
- Flare
- Gas safety equipment
- Gas cleaning/scrubbing system
- Alfa Laval Heat Exchanger
- Various pumps, valves and piping to move solids around.
- Co-Generation, Waukeshaw Generator 380KW, along with energy recovery.
- Gas boilers for heating the Primary Digester and complex
- SCADA for system/process control

ANAEROBIC DIGESTION

Operational Parameters of an Anaerobic Digester

- Constant temp. (delta of no more than 1 deg. F in a day with Mesophilic Bacteria)
- Continuous, consistent feed (may include secondary sludge thickening)
- Characterization of wastes to avoid sudden changes in BOD/ COD
- Continuous mixing
- Consistent, repetitive, regular sampling and testing is critical to tracking digestion health
- Dramatic changes , as well as air leakage or a toxic slug, can cause upsets

ANAEROBIC DIGESTION



Operational Parameters of an Anaerobic Digester

Measure daily:

- Alkalinity 2000 – 5000 mg/L
- Volatile acids = 50 – 300 ppm; > 1000 = likely problem
- VA/Alk ratio = .1 - .35 (.1 - .25 is ideal; ≥.5 = sour digester; if it trends up, back off feed)
- pH 6.6 – 7.2 (6.8 – 7 is ideal); raise with bicarbonate; pH is a lagging indicator
- T = 93 – 100 deg. F. (85 – 90 works, but requires more retention time) – measure continuously & control
- CO2 = 30-35%; CH4 = 65-70%; significant change in CO2 % indicates problem

Digester Math for Nashua Anaerobic Digester

- Thickened waste activated sludge dry solids = 10,600 lb/day

@4.9% feed solids $\frac{10{,}600 \text{ lb/day}}{0.049\ (8.34 \text{ lb/gal})} = 26{,}000 \text{ gal/day}$

- Separate Feed:

  Thickened primary sludge dry solids = 21,300 lb/day

@6.0% feed solids $\frac{21{,}300 \text{ lb/day}}{0.06\ (8.34 \text{ lb/gal})} = 43{,}000 \text{ gal/day}$

- Combined Feed:

  21,300 + 10,600 = 31,900 lb/day

@5.5% feed solids $\frac{31{,}900 \text{ lb/day}}{0.055\ (8.34 \text{ lb/gal})} = 70{,}000 \text{ gal/day}$

Combined Feed 70,000 gal/day x 18 days = 1.26MGD

Digester Math for Nashua Anaerobic Digester

Volatile Solids Reduction:

Units - %
Typical Values - 35 - 60%
Calculations:

Digester feed TSS - 26,000 lbs./day
Volatile Solids - 79%

Digested sludge transfer TSS - 15,000 lbs./day
Volatile Solids - 63%

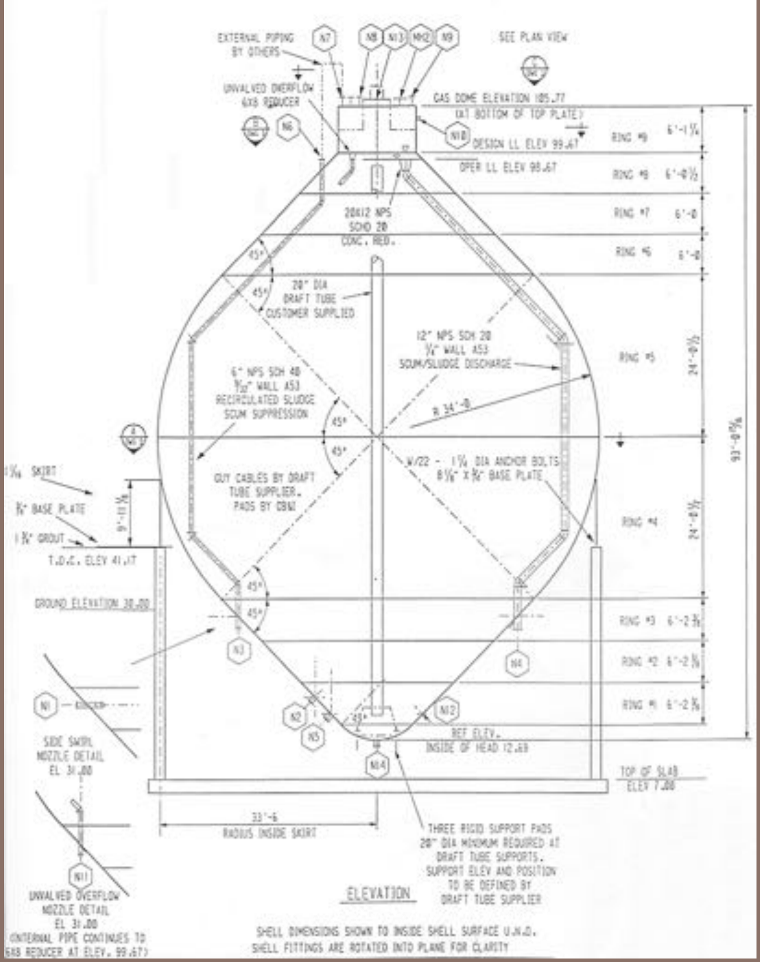
$$\frac{\text{Digested Feed V.S. - Digested Sludge V.S.}}{\text{Digested Feed V.S.}} \times 100\%$$

$$\frac{(2600)(0.79) \times (15000)(0.63) \quad \times 100}{(27{,}000)(0.79)} \quad = 54\%$$

Volatile solids reduction is a measure of the amount of volatile solids destroyed during the anaerobic sludge digestion process and is also used as a measure of pathogen reduction.

ANAEROBIC DIGESTION

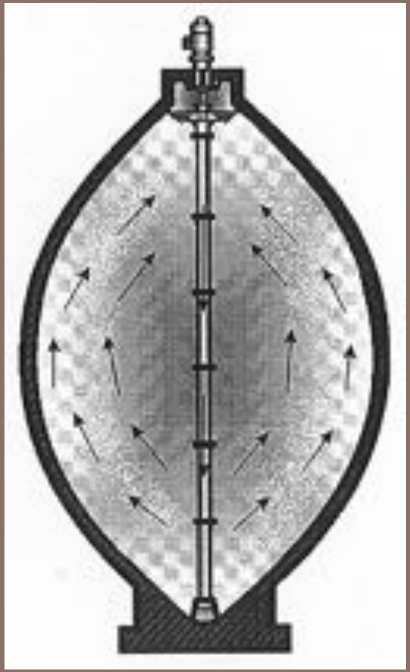
Basic Diagram of an Egg Shaped Digester



ANAEROBIC DIGESTION

Egg Shaped Digester Benefits:

- Efficiency in mixing and heating of content
- Higher reductions in solids resulting from efficient mixing and heating
- Low inert solids build up, increases usable volume



ANAEROBIC DIGESTION

Maintenance of an Anaerobic Digester

ANAEROBIC DIGESTION

Maintenance of an Anaerobic Digester

- Cleaning of Primary Digester

ANAEROBIC DIGESTION

Maintenance of an Anaerobic Digester

- Gas levels and monitoring

DANGER!

ANAEROBIC DIGESTION

Additional Items to think about

- Sludge dewatering costs
- Sludge disposal costs

ANAEROBIC DIGESTION

Additional Items to think about

- Non digested sludge - odors, chemical usage and additional odor control

ANAEROBIC DIGESTION

Additional Items to think about

- Heat exchanger cleaning and maintenance

ANAEROBIC DIGESTION

Additional Items to think about

- Energy recovery losses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ANAEROBIC DIGESTION

Additional Items to think about

- Gas System Maintenance
  - Changing media in the iron sponge
  - Flame arrestors

ANAEROBIC DIGESTION

Additional Items to think about

- Boiler maintenance

ANAEROBIC DIGESTION

Other Items to Think About

- Capital Improvement Plant – Future costs of equipment replacement
- Type of dewatering equipment
- Quality of sludge production
- Side streams to digest for increased gas production

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Digester Upsets

ANAEROBIC DIGESTION

Digester Upsets

2 kinds: sour (low pH) & foaming/rapid rise

Sour digesters look like this:

- Increase in volatile acid-to-alkalinity (VA:Alk) ratio
- Increase in carbon dioxide (CO_2) content of digester gas
- pH starts to drop and CO_2 increases
- Supernatant has a sour odor from either primary or secondary digester
- Scum blanket too thick
- Yellow gas flame from waste gas burner

ANAEROBIC DIGESTION

Sour Digester – Timeline of an upset

VA:Alk ratio increasing above 0.3…..

- Increase in carbon dioxide (CO_2) content of digester gas.

VA:Alk ratio has increased to 0.5.

- pH starts to drop and CO_2 increases further

VA:Alk ratio has increased to 0.8.
Yellow flame in flare = poor quality gas with a high CO_2 content.

- Supernatant has a sour odor from either primary or secondary digester

pH of the digester is low

ANAEROBIC DIGESTION

Digester Upsets

2 kinds: sour (low pH) & foaming/rapid rise

Foaming / rapid rise digesters look like this:

- Sudden volume increase pushes liquid & solids or foam out of top of tank

ANAEROBIC DIGESTION

Sour Digester - Probable Causes

1. Overly fast changes in temperature, mixing, VS loading (too low), etc.
2. Hydraulic overload caused by storm infiltration, accidental over-pump, withdrawing too much sludge.
3. Discharge of toxic materials such as heavy metals, sulfides, and ammonia to digesters (ammonia can build up naturally if N-rich feedstocks are used)
4. Changes in ferric chloride or other chemical addition.

Methanogen (and other bacteria) activity is severely disrupted.

Foaming/Rapid Rise - Probable Causes

1. Overly fast changes in temperature, mixing, VS loading (too high), etc.
2. Viscosity increase due to different feedstock.
3. Changes in ferric chloride or other chemical addition.

Methanogen (and other bacteria) activity may stimulated, too fast.

ANAEROBIC DIGESTION

Digester Upsets - Probable Causes

- Scum blanket too thick

1. Supernatant overflow is plugged.
2. Lack of mixing.
3. Foam suppression system not functioning.

ANAEROBIC DIGESTION

Digester Upsets - Solutions

- Increase in volatile acid-to-alkalinity (VA:Alk) ratio.

1. If ratio increases above 0.3, consider the following:

- Check concentration (VS) of sludge feed; may be too dilute. If so, gradually increase sludge (VS) concentration.
- Add alkalinity (lime)
- Add seed sludge from secondary digester.
- Decrease sludge withdrawal rate to keep seed sludge in digester.
- Extend mixing time.
- Check sludge temperatures closely and control heating if needed.

2. Use any or a combination of the following:

- Solids recycle, liquid dilution and low feed concentration.
- Heavy metals precipitated with sulfur compound (be sure pH in digester is greater than 7.0).
- Iron salts to precipitate sulfides (Ferric or Ferrous Chloride).
- Source control program for industrial wastes.

ANAEROBIC DIGESTION

Digester Upsets - Solutions

- Scum blanket to thick

1. Lower contents through bottom drawoff and rod supernatant line to clear plugging.
2. Break up blanket by using mixers in "bottom to top" mode.
3. Check and clean foam suppression lines and nozzles.

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TIME OUT:
Think Safety!

ANAEROBIC DIGESTION

Safety Awareness

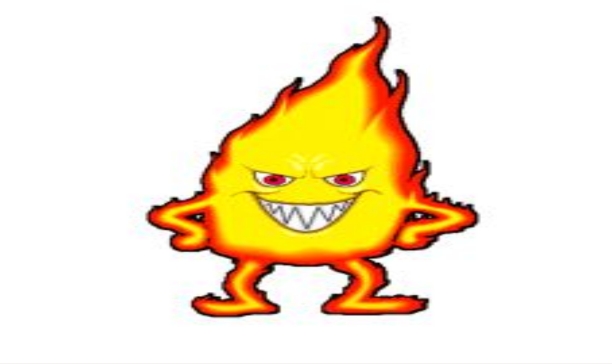
SAFETY IS MY RESPONSIBILITY

- Take safety seriously!
- Complacency.
- Don't let emotions get in the way.
- Distractions can be dangerous and costly.
- Fatigue Recklessness - Being afraid to ask questions.
- Always be aware of hazards.
- Show safety leadership and take responsibility for your own safety as well as your co-workers.

Safety Electrical Hazards

- Electricity has the power to shock, burn, and cause fires and explosions.
- Always use Lockout/Tag-out ground fault circuit interrupter (GFCI).
- Don't work on live electrical circuits while standing in water.
- Don't contact electrical circuits with anything metal Inspect power tools for damage before each use. Treat extension cords with care.

ANAEROBIC DIGESTION



Safety Fire Prevention

- Many workplace fires can be prevented through good housekeeping practices:
- If a fire is too large or fast-moving and cannot be safely extinguished with a portable fire extinguisher call emergency number (911).

ANAEROBIC DIGESTION

Confined Space Safety

Emergency, Health, and Safety Hazardous Atmospheres

- Oxygen deficient atmospheres in collection systems or wastewater treatment operations can cause asphyxiation. Methane or carbon monoxide can replace oxygen, especially in a confined space.
- Toxic atmospheres can be caused by the presence of hydrogen sulfide, ammonia, chlorine or by other chemicals that have been put into the sewer system. Explosion or fire may occur when chemical concentrations exceed their Lower Explosive Limits (LEL). Use spark proof tools in designated areas. Never smoke in or near an open manhole.

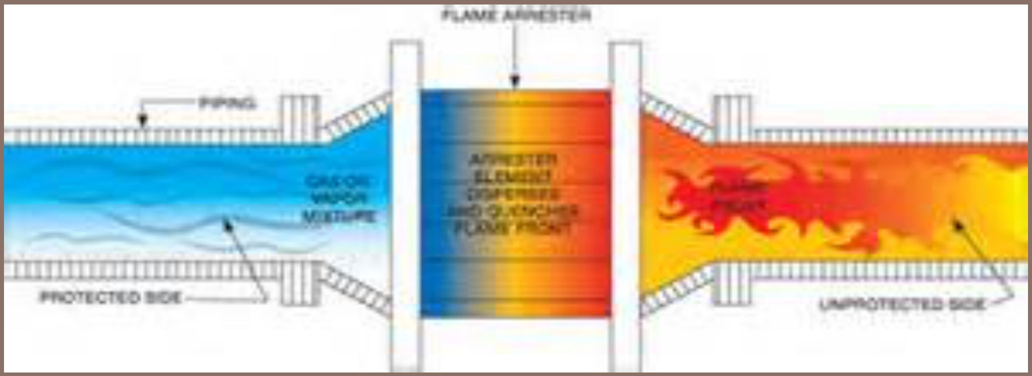
Oxygen 19.5-23.5% - LEL 10% - CO 35 ppm - H_2S 10 ppm -SO_2 2 ppm

ANAEROBIC DIGESTION

Emergency, Health, and Safety Hazardous Atmospheres

Other safety topics and equipment:

- Methane gas limits for explosive conditions are 5-15% in relation to total volume of air at room temperature and atmospheric pressure.
- Safety equipment such as flame arrestors are used to prevent fire from spreading if ignition happens.



ANAEROBIC DIGESTION

Emergency, Health, and Safety Hazardous Atmospheres

Other safety topics and equipment:

- Equipment includes pressure relief valves, gas gauges and monometers.

ANAEROBIC DIGESTION

Emergency, Health, and Safety Emergency Planning and Preparation

- Emergencies can happen suddenly. Always be prepared for them. Quick and proper response to emergencies can save lives and property. Always react immediately upon hearing an alarm, even if it may only be a drill. Handle any emergency tasks assigned, then evacuate calmly and quickly.
- Pre-planning for emergencies allows for quick response and may reduce the severity of losses. Be aware of the emergency response features:
- Emergency evacuation plans posted in each building.
- Know the locations of emergency showers and eyewashes and test them periodically.
- Know the locations of fire extinguishers.
- Know the locations of plant telephones and emergency phone numbers.

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Managing Biogas

Managing biogas

- VSR → biogas produced
- Biogas = ~50% – 65% CH_4, 35% - 50% CO_2, with some H_2S, moisture, etc.
- Thermophilic & enhanced systems, and systems taking FOG, food scraps, etc. have higher biogas production.
- Typical production from wastewater solids = 13 – 18 ft^3 / lb. of VS destroyed
- Flammable ~ 1 volume gas / 15 volumes air

Methane (CH_4)

- Qualities
  - Simplest paraffin hydrocarbon, lighter than air
  - Significant greenhouse gas: 21 times more impacting than CO_2
- Combustion characteristics
  - Wide flammability range
  - Coolest burning flame (AFT) of all common fuels
  - Highest ignition temperature, burns slow and cool
  - Has been called “the ideal fuel”
- Easily reformed to H_2 and CO, can be feedstock for other hydrocarbons
- An excellent fuel!

Comparing biogas to natural gas

Component	Biogas	Natural gas
Methane	60%	80 to 95%
Carbon dioxide	39%	1%
Nitrogen	1%	1 to 5%
Heavier hydrocarbons	zero	2 to 12%
Sulfides	up to 2500 ppm	up to 7 ppm
Energy content, Btu/ft^3	600	1000
Origin	Last week's sludge	Biomass 100 million year

Table courtesy of Brown and Caldwell

Biogas uses

Generate Power and Heat On-Site

- Gas Turbine Generators
- IC Engine Generators
- Steam Turbines
- Fuel Cells
- Microturbines
- Stirling Cycle Engines
- Organic Rankine Cycle

Other On-Site Uses

- Biosolids drying (via steam, hot air/oil/ water)
- Building and Process Heating and Cooling (i.e., digester heating, absorption chilling, etc.)
- Steam to drive large pumps and blowers

Off-Site Sale/Use

- "As-Is" Unscrubbed
- Scrub CO_2, Sell Methane
- Scrub CO_2, Vehicle Fuel
- Scrub CO_2, Make LNG
- Convert to Methanol
- Convert to Hydrogen
- Convert to Biodiesel

Adapted from Brown and Caldwell

Challenge: Biogas production varies

- Production goes up and down by the hour / day
- Having gas storage capacity allows for steady feed of biogas to end uses, even as the rate of gas production varies
- Maintaining steady gas feed to engines and other technologies is important; use natural gas to supplement biogas feed, if needed.

Challenge: Biogas is a dirty fuel

- Lots of moisture!
- Hydrogen sulfide (H_2S)
- Siloxanes – there are many types that become SiO_2 (silica)
- Biogas needs to be treated to meet the requirements of its end use; some end uses (e.g. vehicle fuel) require far more treatment than others (e.g. little clean-up needed for boiler use).
- Temperature & pressure may need adjusting.

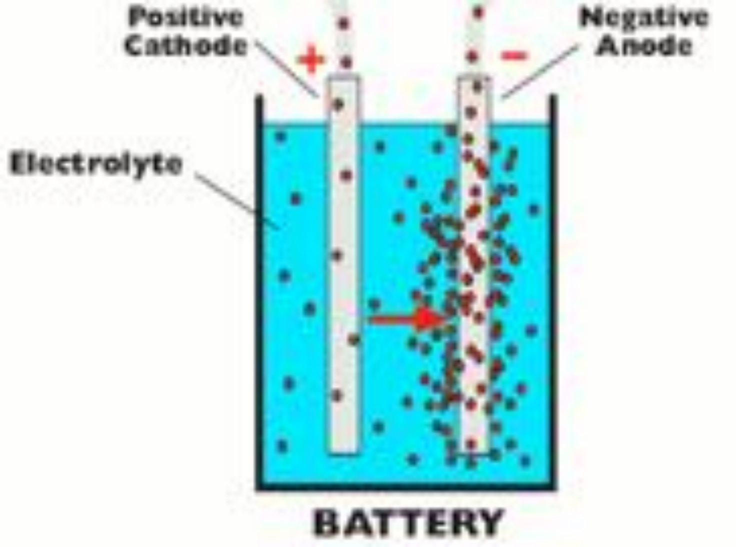
Flares / Waste gas burners

- Required
- Loss of useful fuel

BIOGAS UTILIZATION

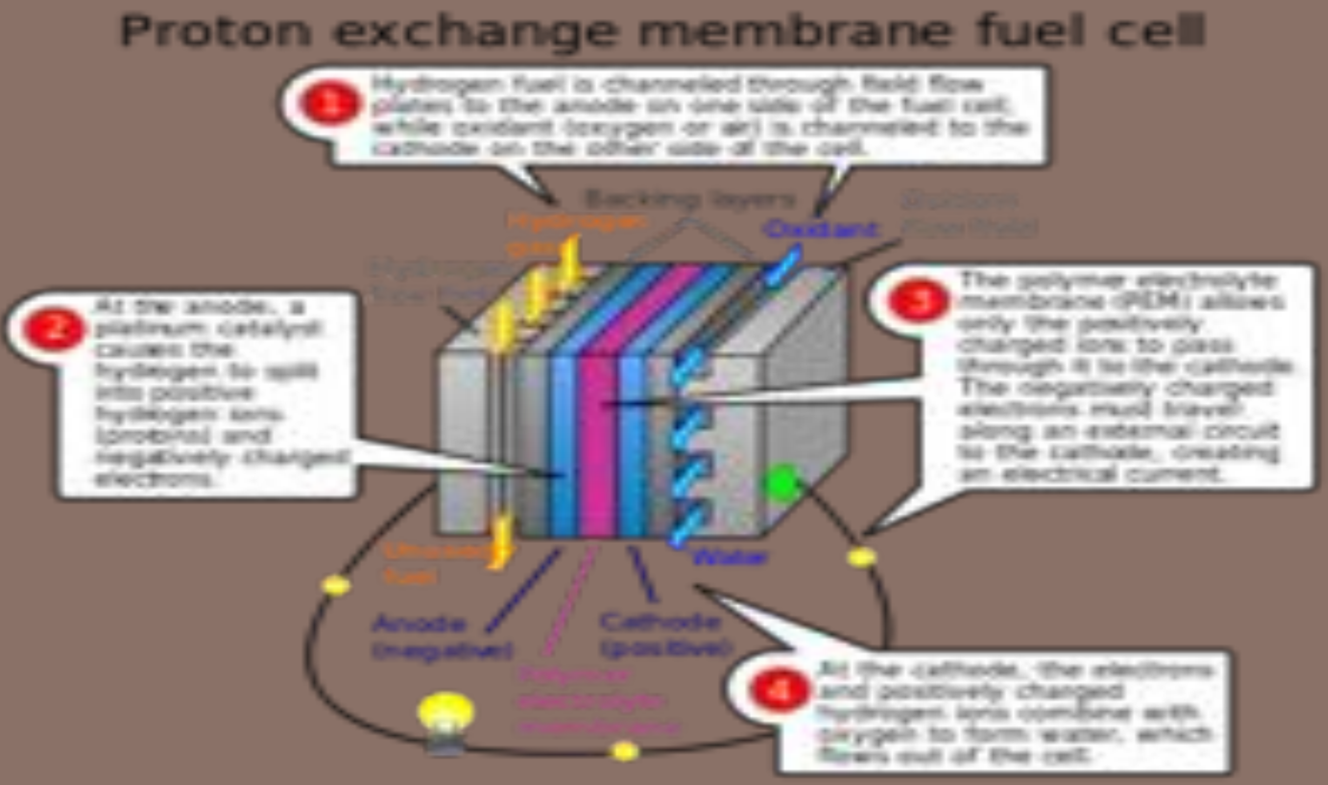
Technologies

Typical Battery



BIOGAS UTILIZATION

Technologies



Proton exchange membrane fuel cell

1 Hydrogen fuel is channeled through field flow plates to the anode on one side of the fuel cell, while oxidant (oxygen or air) is channeled to the cathode on the other side of the cell.

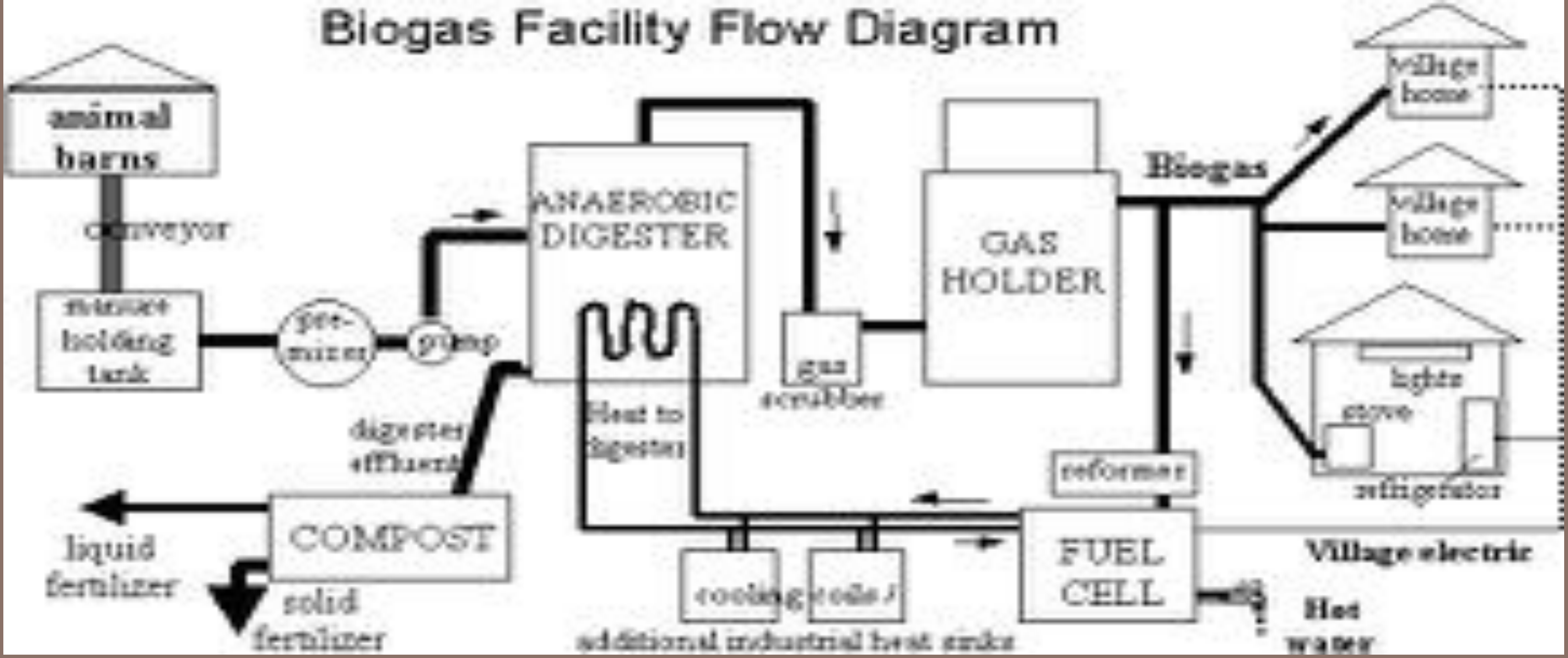
2 At the anode, a platinum catalyst causes the hydrogen to split into positive hydrogen ions (protons) and negatively charged electrons.

3 The polymer electrolyte membrane (PEM) allows only the positively charged ions to pass through it to the cathode. The negatively charged electrons must travel along an external circuit to the cathode, creating an electrical current.

4 At the cathode, the electrons and positively charged hydrogen ions combine with oxygen to form water, which flows out of the cell.

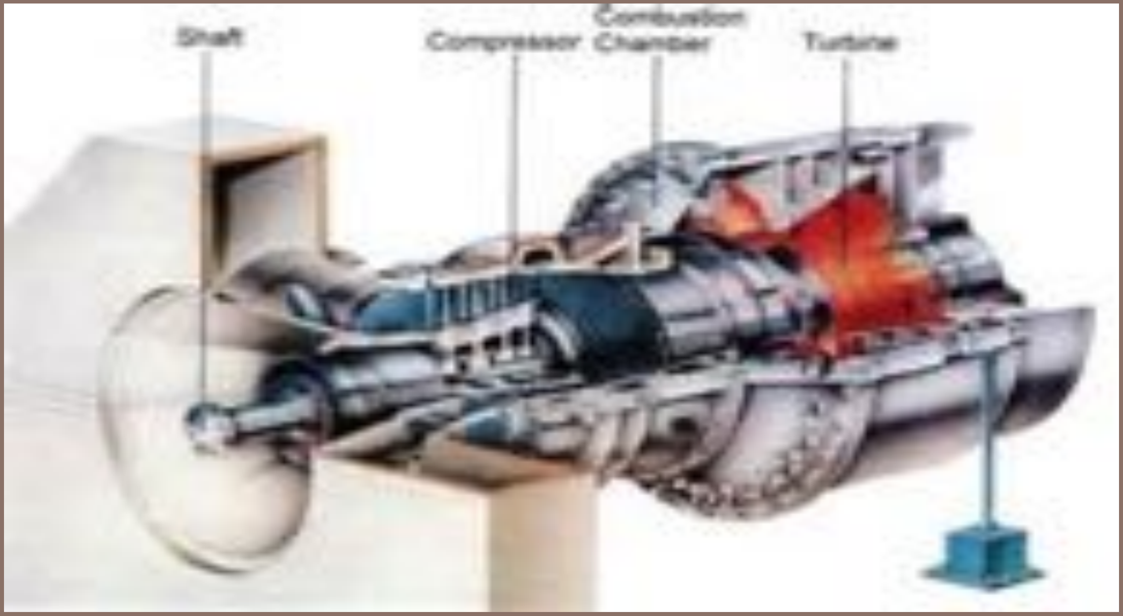
BIOGAS UTILIZATION

Technologies



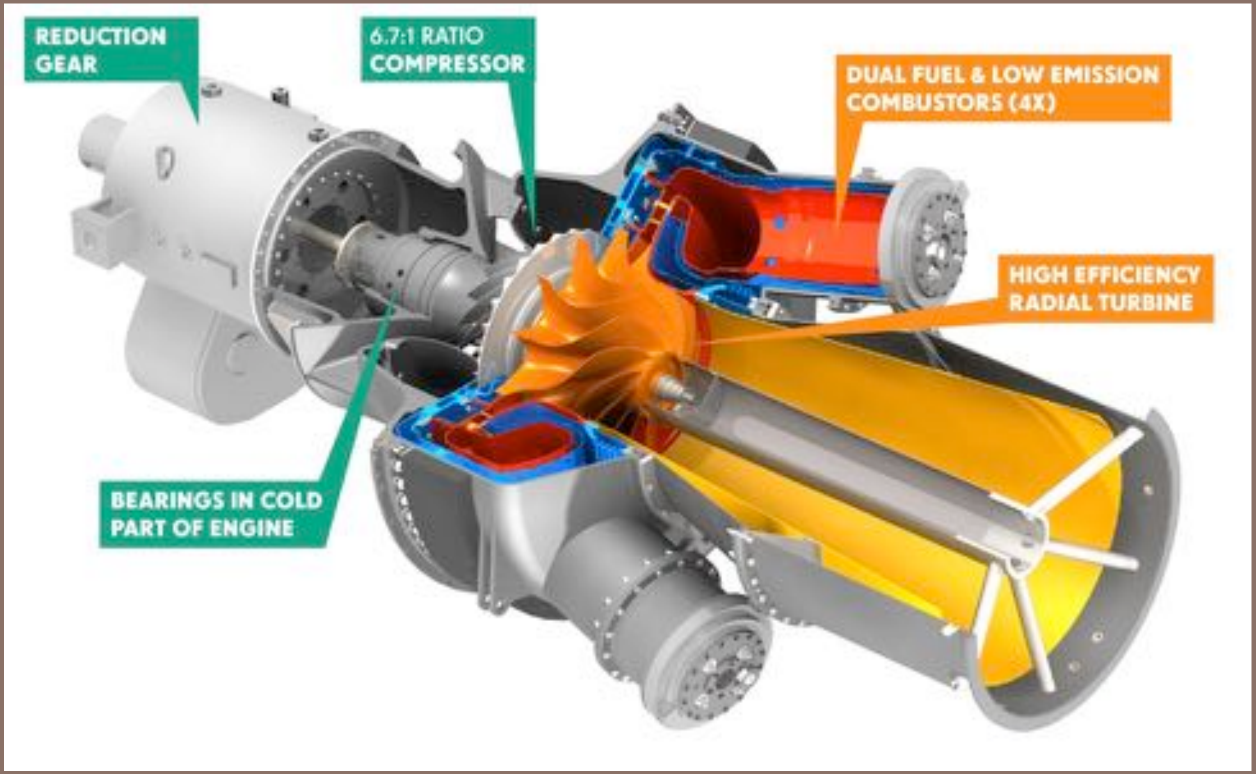
BIOGAS UTILIZATION

Methane Turbine for Electrical Generation



BIOGAS UTILIZATION

Micro Turbine for Electrical Generation



BIOGAS UTILIZATION

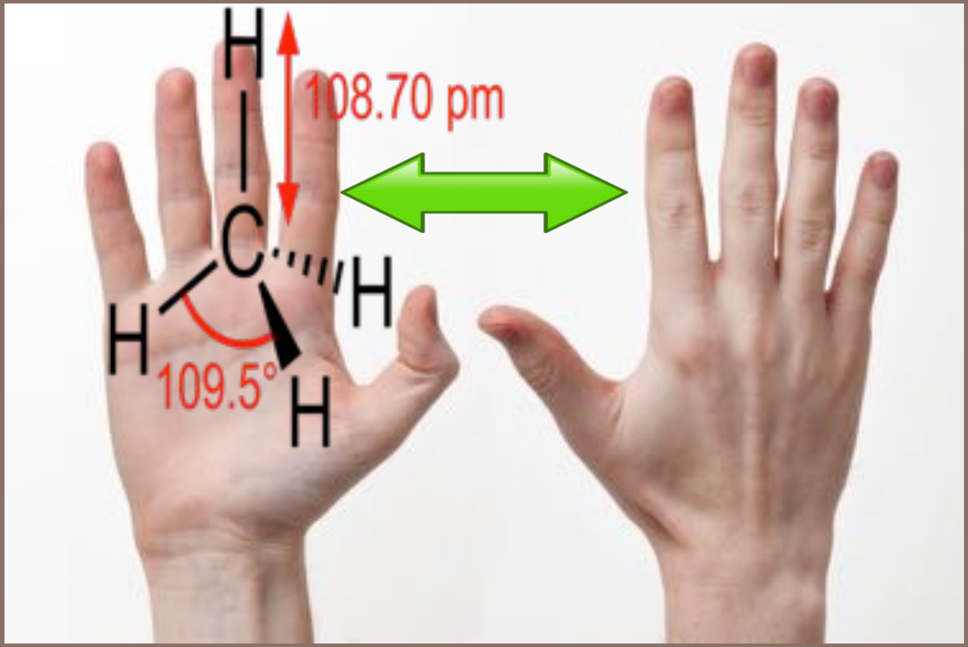
Technologies

- Reciprocating Engine

BIOGAS UTILIZATION

Technologies

- Compressing Methane Gas
- Compressing gas as fuel alternative



Managing Biogas

Richard Weare
Greater Lawrence Sanitary District

AD TRAINING
Franklin, NH
November 16, 2016

GLSD BIOGAS DATA

(Analysis of 2013 – 2016)

Oxygen:	
O_2	**1.2 %**
Nitrogen:	
N_2	**3.8%**
Methane:	
CH_4	**60%**
Carbon Dioxide:	
CO_2	**35%**
Hydrogen Sulfide:	
H_2S	**73 ppmv**
	w/ Ferric Chloride
BTU/CF	**605**
Sp. Gravity	**0.9**
Siloxanes	**1110 ppbv**

BIOGAS TREATMENT

Boiler or Furnace Uses

Treatment:
Moisture Removal – Drip Traps

GLSD Biogas Glycol Boiler

BIOGAS TREATMENT

Combustion Engine Uses

Treatment:

- Moisture Removal
  - Drip Traps
- Hydrogen Sulfide Removal
  - Ferric Chloride
  - Iron Sponge
- Siloxane Removal
  - Activated Carbon Media

Power Generation Unit

Comparing costs of electricity generation

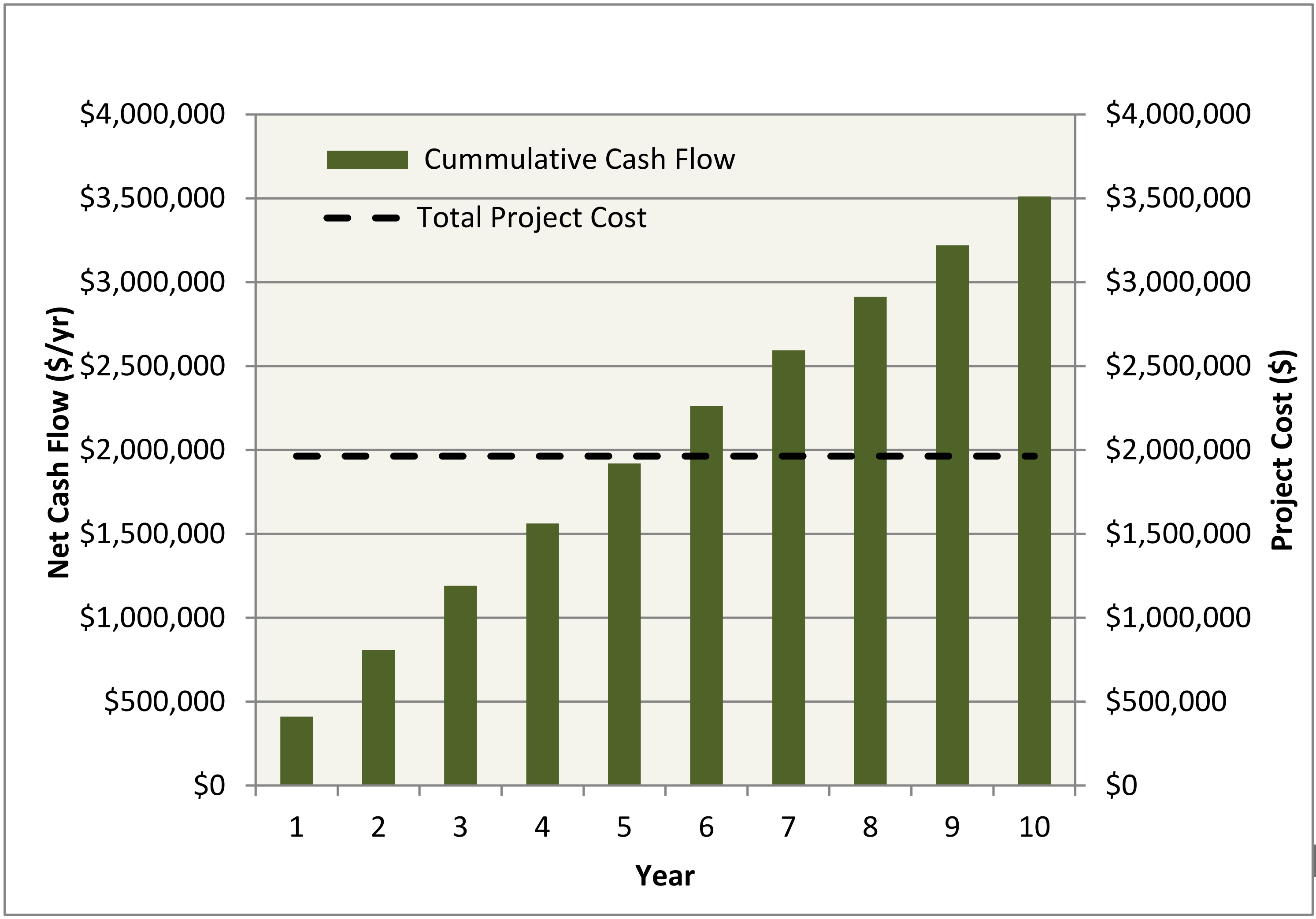
- Per kW of power, fuel cells cost far more: ~$4500
- Compared to gas turbine (~$1600)
- Compared to microturbine (~$1300)
- Compared to internal combustion engine (~$1100)

IC engines are in most common use at U. S WWTFs.

Gas & other turbines are used at some large WWTFs, but, though they are few, the installed capacity (kW) is relatively large.

Microturbines are used at smaller WWTFs.

Biogas Engine Payback



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Real-World Challenges with Biogas

Managing biogas

- Gas handling and safety equipment is required.
- Plenty of gas storage is highly recommended & requires proper sizing and safety (see NFPA 820).
- Plan for adequate gas cleaning/treatment for intended use (siloxanes & H_2S are significant!)

NFPA 820
Standard for
Fire Protection in
Wastewater Treatment
and Collection Facilities
2003 Edition

- Consider confined space requirements and designations of spaces due to presence of biogas (ventilation & separation can help avoid restrictive designations of spaces).

Regulatory Considerations

Regulatory considerations

- Part 503 – biosolids regulations
  - Class A vs. Class B
- EPA air regulations
  - Methane
  - Engine exhaust

Air Regulation Considerations

Check with State Regulatory Agency!

Typical contaminants of concern

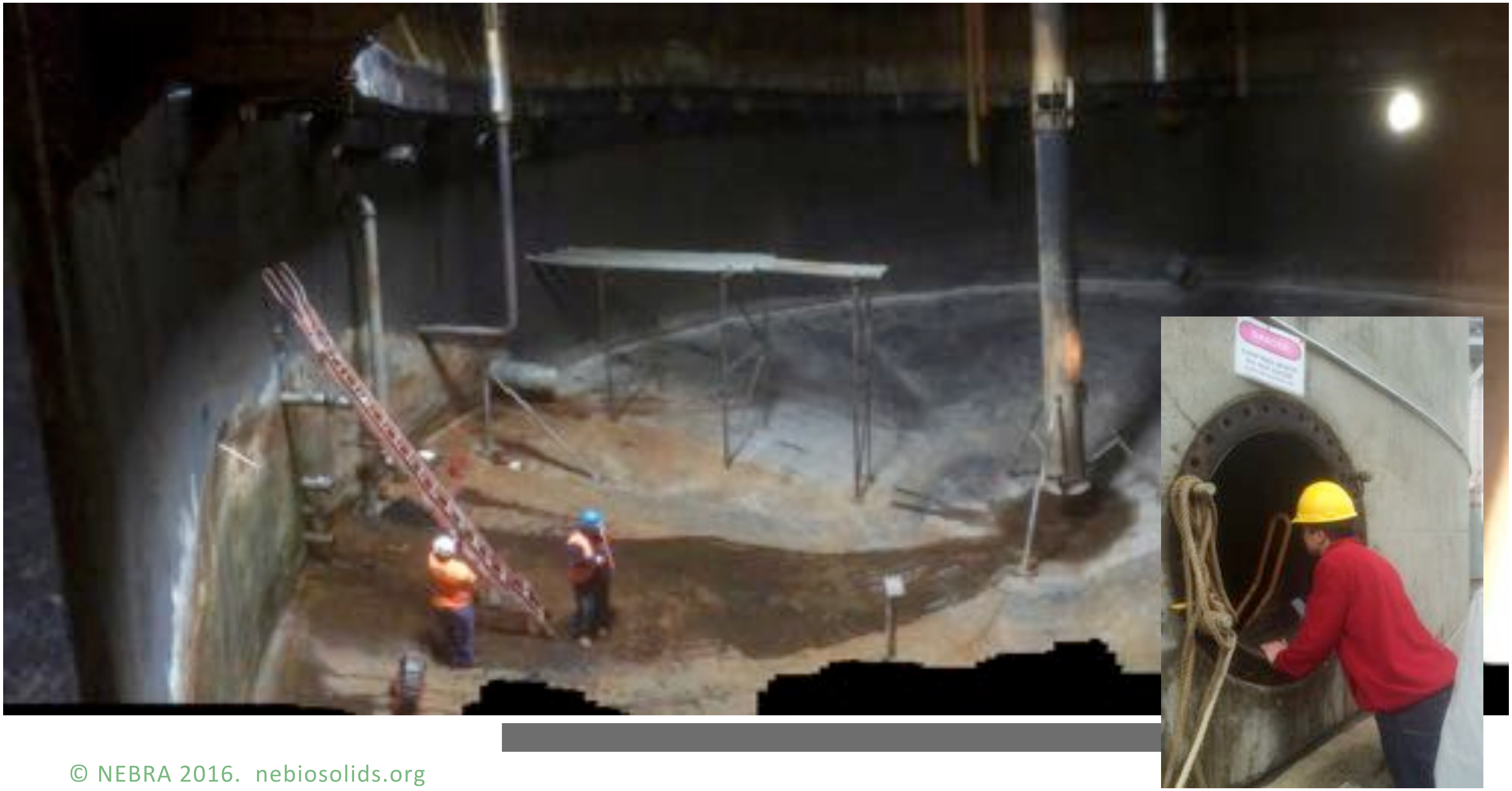
- Particulate Matter
- Sulfur dioxides
- Nitrogen dioxides
- Carbon monoxide
- Volatile Organic Compounds (VOCs)

Optimizing Digestion

Digester cleaning

- Every 1 – 10+ years
- Solids pumped down to grit level
- Grit liquified (e.g. with fire hoses), pumped to mobile dewatering

Digester cleaning



Optimizing AD

- Improve process operations
  - VSR
  - Biogas production
  - Biosolids quality/stability (reduce odors)
- Reduce solids volume & hauling
  - Fuel costs, hauling costs
- Increase renewable energy production
  - Heating during peak conditions
  - Power/fuel production
- Maximize the value of infrastructure investments

Adapted from Chris Muller, Brown and Caldwell

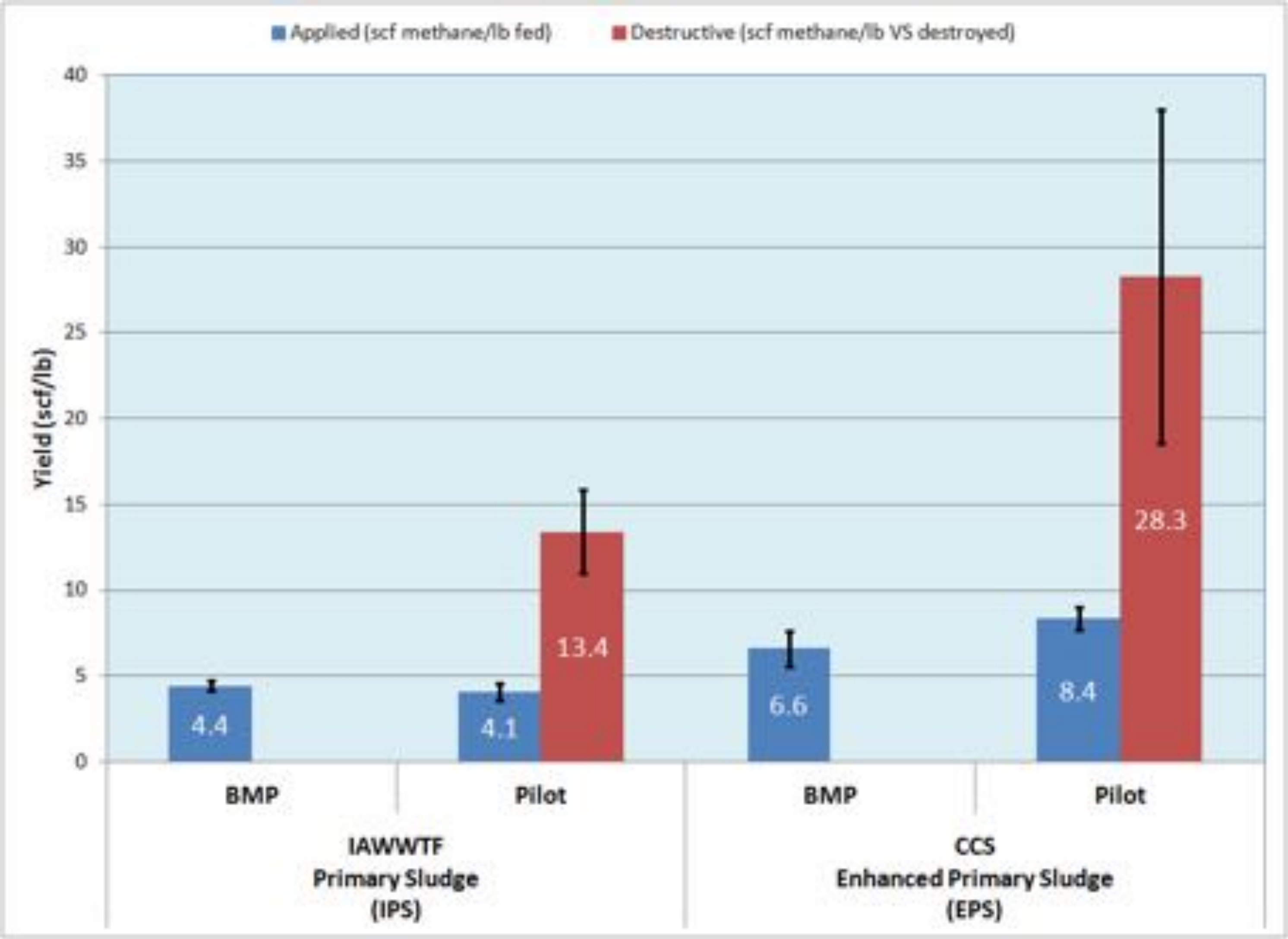
Optimizing AD

- Enhanced primary (e.g. Clear Cove)
- WAS pretreatment: MicroSludge®, OpenCell®
- Extended thermophilic
- Temperature phased
- 2-stage (series) digestion (e.g. Port Angeles, WA)

Options for optimizing the digestion process

- Better digester mixing
- Tank sequencing or separation of phases
- More precise digester feeding
- More precise sludge withdrawal
- Stress testing of process
- Adjusting operating temperature
- Adding supplemental feedstocks (e.g. FOG, food scraps)

Enhanced primary treatment



Graph from ClearCove pilot at Ithaca, NY WWTP

Enhanced primary treatment

Parameter	Units	Current	EPT with SCP	CNG Equivalent (GGE)
Energy consumption	kWh/yr	3,300,000	2,700,000	
Energy Production	kWh/yr	2,200,000	7,000,000	530,000
Energy Savings	$/yr	$0	$56,000	$56,000
Energy Production	$/yr	$210,000	$665,000	$1.3M
Total Energy Value	$	$210,000	$721,000	$1.36M

Data from ClearCove pilot at Ithaca, NY WWTP

9.5 cents/kWh
$2.50/GGE

Chance to recover nutrients! (P!)

OSTARA
Creating Value
from Waste

MULTIFORM
HARVEST

Struvite recovery options

Name of Technology	Ostara Pearl®	Multiform Harvest struvite technology	Phospaq	Crystalactor®	NuReSys
Name of product recovered	Crystal Green ®	struvite fertilizer	struvite fertilizer	Struvite, Calcium-phosphate, Magnesium-phosphate	BioStru®
% efficiency of recovery from sidestream	80-90% P 10-40% NH_3-N	80-90% P 10-40% NH_3-N	80% P 10-40% NH_3-N	85-95% P 10-40% NH_3-N	>80% P 5-20% N
Product marketing/ resale	Ostara	Multiform Harvest	N/A	Third party facilitated by Procorp	N/A
# of full-scale installations in design/operation	8	2	2	4	7

Adapted from Wendell Khunjar, Hazen and Sawyer

Example: Nansemond WWTF, Virginia

- Ostara system installed
- 85% orthophosphorus average removal across the WRRF
- 25% ammonia average removal across the WRRF

Example: Optimizing digester feed

- Natural Systems Utilities has developed a computer model that includes detailed data on the quality of each digester feedstock.
- The model helps the Ridgewood, NJ WRRF feed a precise mix of feedstocks at all time that will provide a consistent rate of VS, nutrients, etc. to keep the digesters at their optimum.

Example: Optimizing biogas production & use

- Some facilities are using biogas in multiple ways and adjusting where the gas is sent depending on where it will bring them the most cost savings or income at that particular moment!
- Several U. S. facilities now achieve net-zero energy consumption by producing enough biogas through co-digestion of wastewater solids & outside wastes.
- Generating power onsite enhances sustainability:
  - Can mean 100% External Power Offset
  - Lower Energy Costs
  - Reduction in Energy Price Risk
  - Enhanced Resiliency for the WRRF

Co-digestion – Potential issues

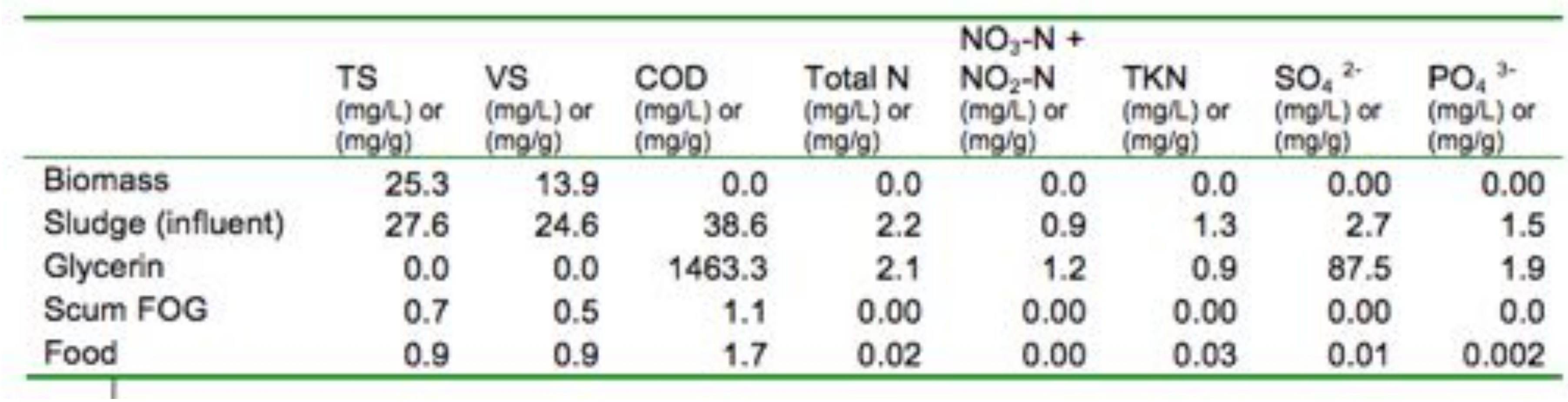
- Digester upsets / foaming
- Spikes in biogas production
- Pipe blockages (issue with FOG especially)
- Contaminants (grit, utensils, rags, trash, etc.)
- Consider ammonia toxicity (e.g. poultry DAF skimmings = 1226 mg N/L in one study; FOG is typically <100 mg N/L)
- Impacts on dewatering & biosolids quality?

Selection of codigestates

Three different potential organic wastes within 50 miles from BPWWTP

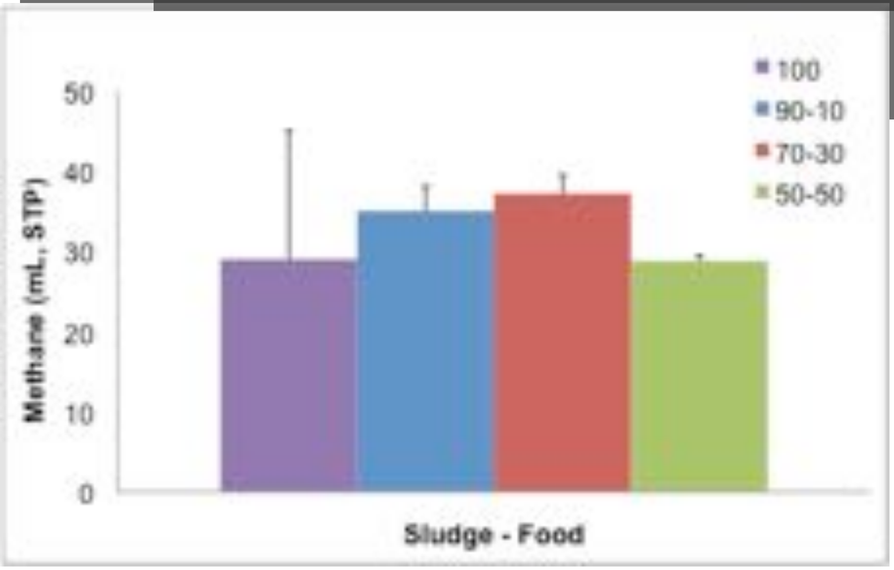
Glycerin: Biodiesel factory
Food scraps: Dining Services URI
Scum: BPWWTP

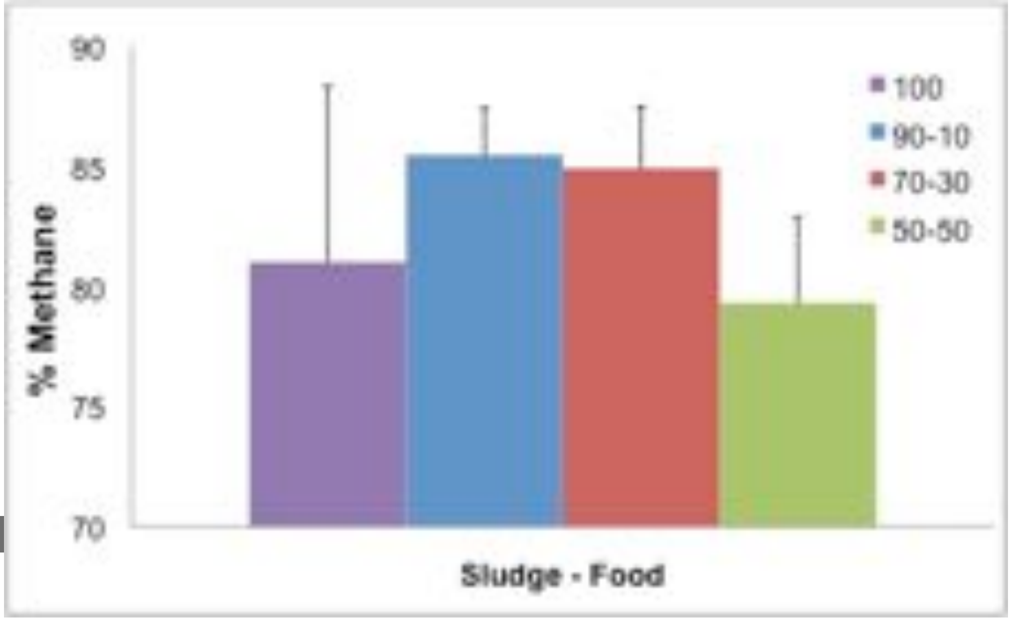
Slide courtesy of Vinka Craver, University of RI



	TS (mg/L) or (mg/g)	VS (mg/L) or (mg/g)	COD (mg/L) or (mg/g)	Total N (mg/L) or (mg/g)	NO_3-N + NO_2-N (mg/L) or (mg/g)	TKN (mg/L) or (mg/g)	SO_4^{2-} (mg/L) or (mg/g)	PO_4^{3-} (mg/L) or (mg/g)
Biomass	25.3	13.9	0.0	0.0	0.0	0.0	0.00	0.00
Sludge (influent)	27.6	24.6	38.6	2.2	0.9	1.3	2.7	1.5
Glycerin	0.0	0.0	1463.3	2.1	1.2	0.9	87.5	1.9
Scum FOG	0.7	0.5	1.1	0.00	0.00	0.00	0.00	0.0
Food	0.9	0.9	1.7	0.02	0.00	0.03	0.01	0.002

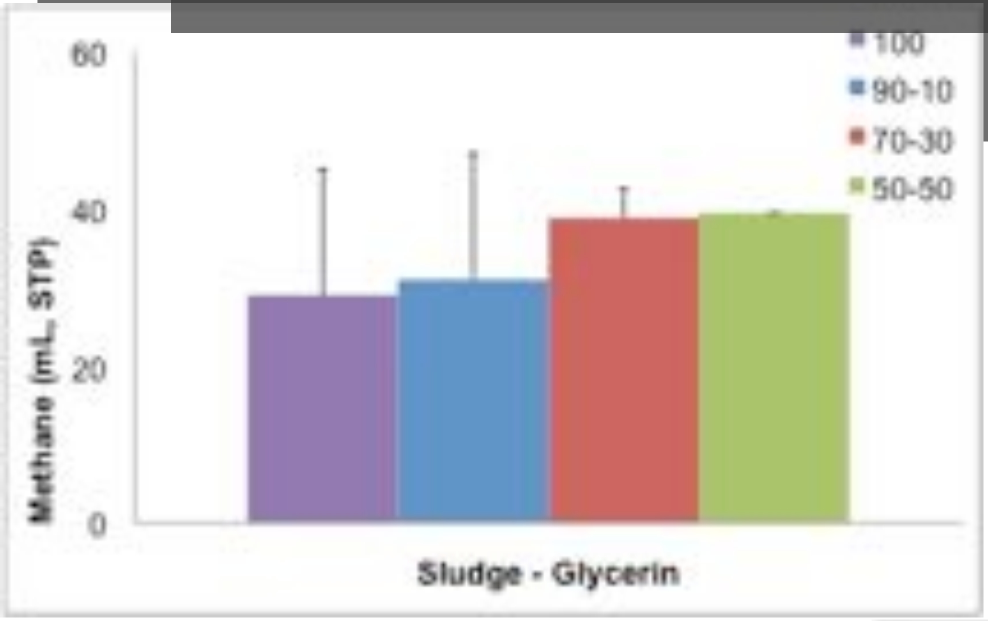
Food scraps as codigestate

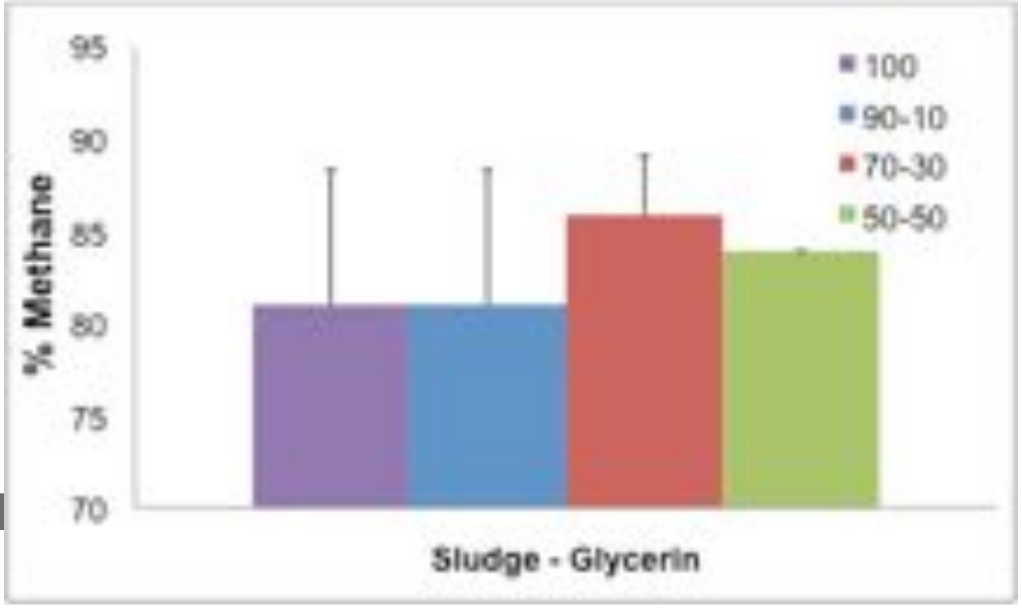




Slide courtesy of
Vinka Craver,
University of RI

Glycerin as codigestate



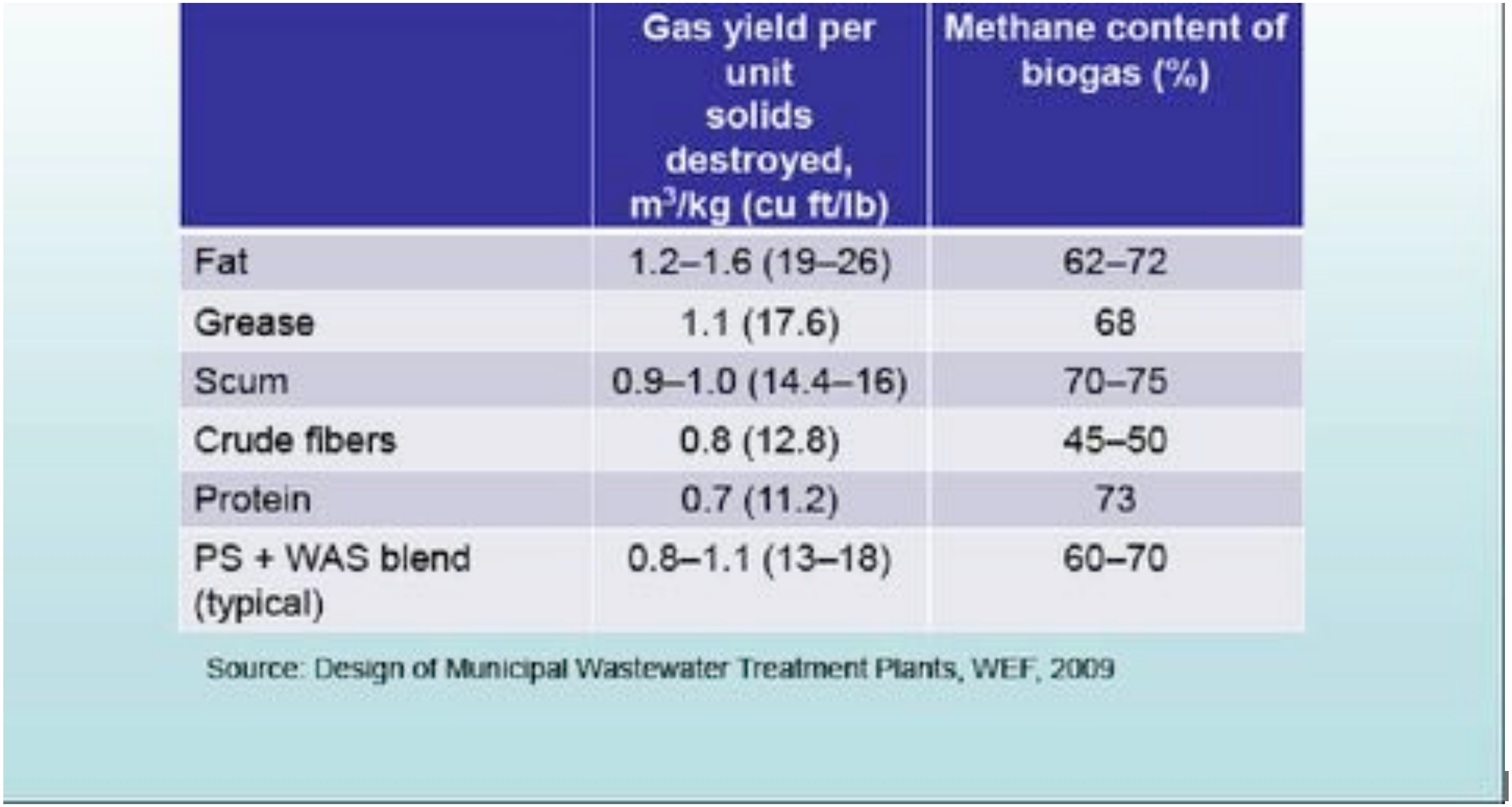


Slide courtesy of
Vinka Craver,
University of RI

Digestibility of outside feedstocks is key

- Analyze all outside feedstocks
- Understand the VS content and how digestible the VS is… will it break down quickly in the digester (e.g. glycerine) or will it take longer and break down more slowly (WAS)
- Consider running lab or pilot experiments with different mixes of feedstocks to find the optimum for steady, high-rate digestion in your system.

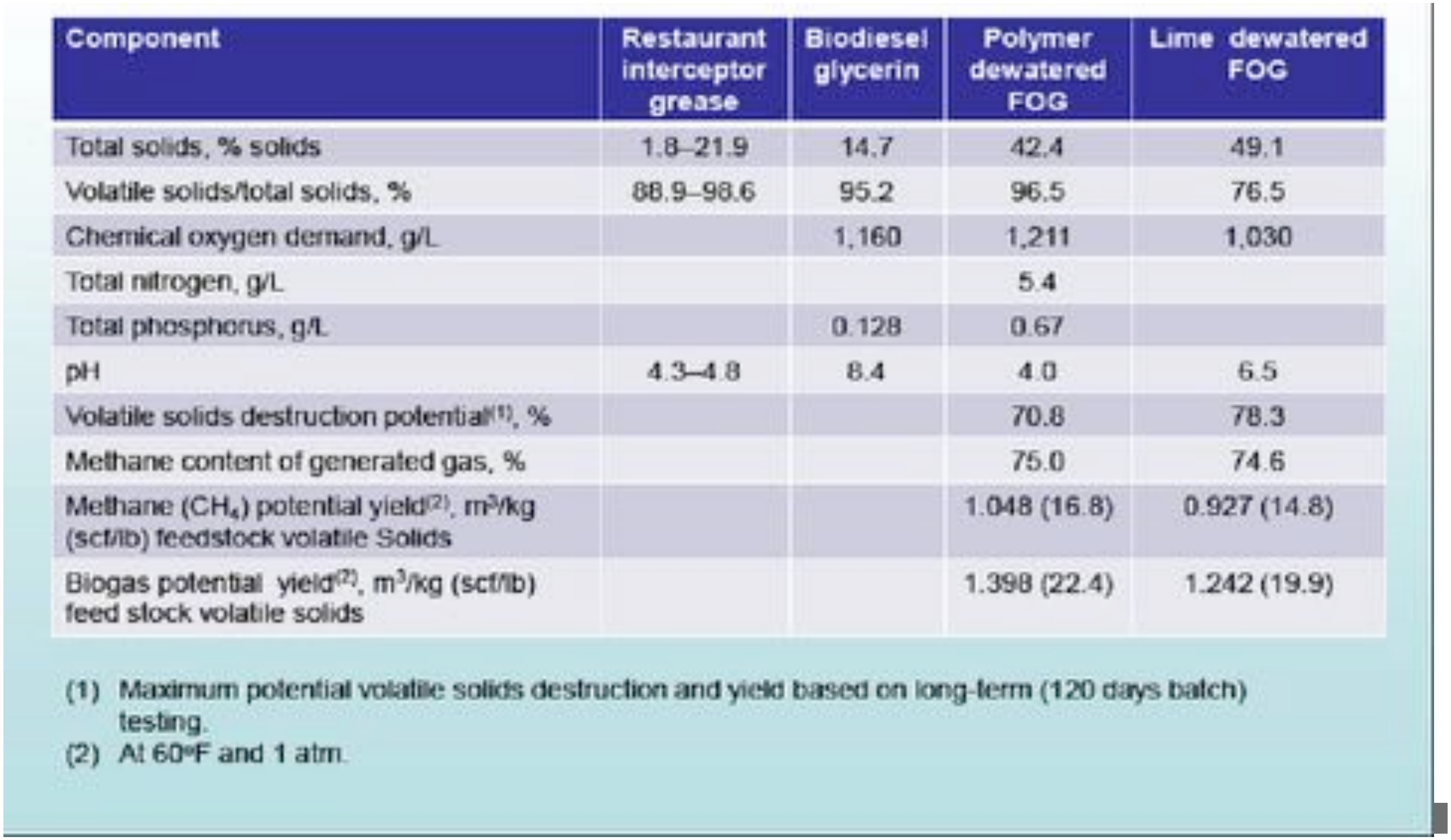
Feedstock affects biogas production



	Gas yield per unit solids destroyed, m^3/kg (cu ft/lb)	Methane content of biogas (%)
Fat	1.2–1.6 (19–26)	62–72
Grease	1.1 (17.6)	68
Scum	0.9–1.0 (14.4–16)	70–75
Crude fibers	0.8 (12.8)	45–50
Protein	0.7 (11.2)	73
PS + WAS blend (typical)	0.8–1.1 (13–18)	60–70

Source: Design of Municipal Wastewater Treatment Plants, WEF, 2009

Variations in feedstock characteristics



Component	Restaurant interceptor grease	Biodiesel glycerin	Polymer dewatered FOG	Lime dewatered FOG
Total solids, % solids	1.8–21.9	14.7	42.4	49.1
Volatile solids/total solids, %	88.9–98.6	95.2	96.5	76.5
Chemical oxygen demand, g/L		1,160	1,211	1,030
Total nitrogen, g/L			5.4	
Total phosphorus, g/L		0.128	0.67	
pH	4.3–4.8	8.4	4.0	6.5
Volatile solids destruction potential(1), %			70.8	78.3
Methane content of generated gas, %			75.0	74.6
Methane (CH_4) potential yield(2), m^3/kg (scf/lb) feedstock volatile Solids			1.048 (16.8)	0.927 (14.8)
Biogas potential yield(2), m^3/kg (scf/lb) feed stock volatile solids			1.398 (22.4)	1.242 (19.9)

(1) Maximum potential volatile solids destruction and yield based on long-term (120 days batch) testing.
(2) At 60°F and 1 atm.

The information in these slides is for general understanding and guidance on the operations of anaerobic digesters. Do not rely on this information solely. It is not intended as advice for dealing with any particular system or situation. The operation of any particular digester system requires careful analysis of the particular configuration and situation.

Putting It All Together: Local Case Studies

GREATER LAWRENCE SANITARY DISTRICT

Case Study Anaerobic Digester Systems

NEBRA TRAINING
FRANKLIN, NH

November 16, 2016

TOPICS

- Background on the Greater Lawrence Sanitary District (GLSD)
- GLSD 15 Years of AD History
- Overview of Organics Project
- Processed Source Separated Organics
- Questions?

GLSD ORGANIZATION

- District Established by Chapter 750 of the Massachusetts Acts of 1968
- Governed by Board of Commissioners
- Operational Since April 1977
- Serves:
  - Lawrence, Methuen, Andover, North Andover, Dracut, MA and Salem, NH
  - Population of over 200,000
  - As Septage disposal location for 40 communities
- Second largest WWTP in Massachusetts

  (52 MGD design flow)

GLSD Anaerobic Digestion Facility

GLSD AD Process Criteria

- **Three Anaerobic Digesters**
  - 1.4 million gallons each
  - 85 foot diameter
- **GLSD began operation in 2002**
  - Feed to AD: Municipal Sludge and Septage
    - Primary sludge and waste activated sludge

Feed sludge	4-5% TSS
Digester Effluent	1-1/2 to 2% TSS
Solids Reduction	53%
VSS Destruction	55%
Retention in digesters	20 days on average
Feed Rate @20 day SRT	213,000 gpd
Gas Holding Capacity	145,500 cu. ft. @12" water column
Gas Production	78 cu. ft. of gas per lb. of volatile solids destruction

GLSD AD Lessons Learned

- Lessons Learned
  - Rapid Rise Occurrences took place prior to 2014.
  - We Learned:
    - Do not make more than one process change at a time
    - Feed digesters based on <u>consistent</u> lbs. of solids each day
    - Combined primary and waste activated sludges in mix tank prior to sending to AD.
    - GLSD never had process upsets where sludge became sour but had a number of foaming (rapid rise) occurrences
    - Temperature increases/decreases changes slow 1 deg. F. per day change
    - Continuous 24-7 Mixing Important [to avoid rapid rise situations]
    - GLSD keeps temperature at 98 deg F.
    - Maintain 16 to 21 days of retention time
    - GLSD dewaters with Centrifuges prior to sending digested sludge to GLSD's Heat Drying Facility

SLUDGE DRYING FACILITY
New England Fertilizer Co. – Contract Operator

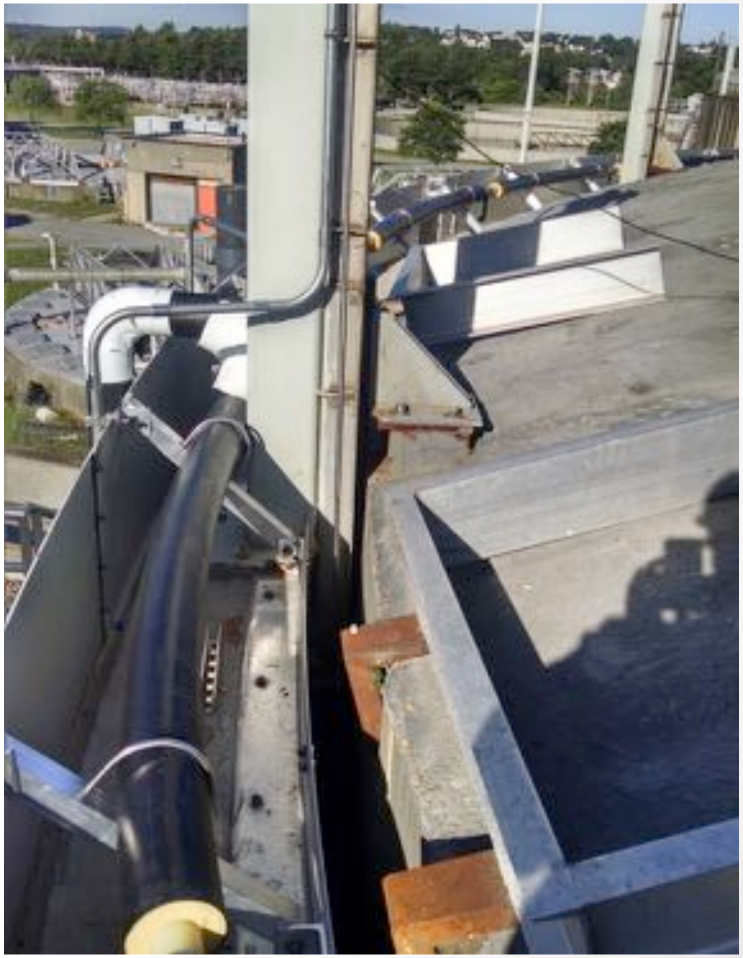
- 11,000 Square Foot Building
- Two Thermal Drying/Pelletization Trains
- Design Capacity = 38 Dry Tons per Day
- On-site Product Storage/Removal by Truck
  - 2 Trucks/Week

Biosolids Product Beneficial Use

- 100% of GLSD Biosolids are Beneficially Used
- Currently, Land Applied in Massachusetts
- Increases Hay Yield by One Cutting per Season
- No Bagged Product Sold
- Distribution Managed by Casella Organics for NEFCO

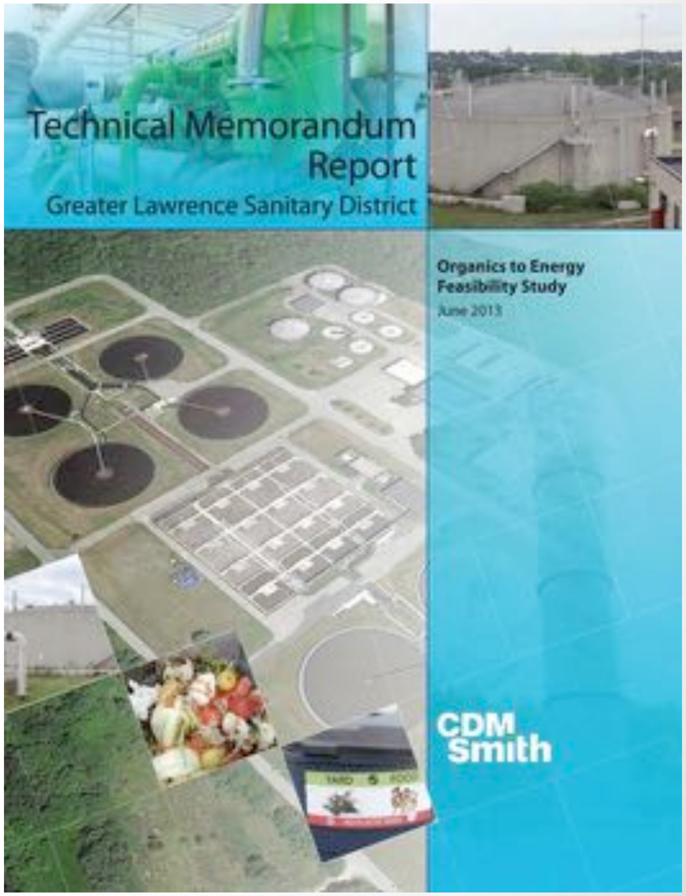
Organics to Energy, Phase 1

- Cleaned AD of accumulated grit
- Installed gutter system to collect any rapid rise occurrences
- Installed secondary containment barriers at ground level for
  - Ease of any potential clean-up
  - To delineate Div. 1 Class 1 areas



ORGANICS TO ENERGY FEASIBILITY STUDY

- Co-digestion at the GLSD facility is feasible with proper revenue stream
- Ability to process ~28,000 gpd (117 wet tons) of SSO material in existing digestion system
- May process up to 92,000 gpd (380 wet tons) of SSO material with a 4th digester
- Can meet up to 40% of the Commonwealth's goal for SSO Diversion



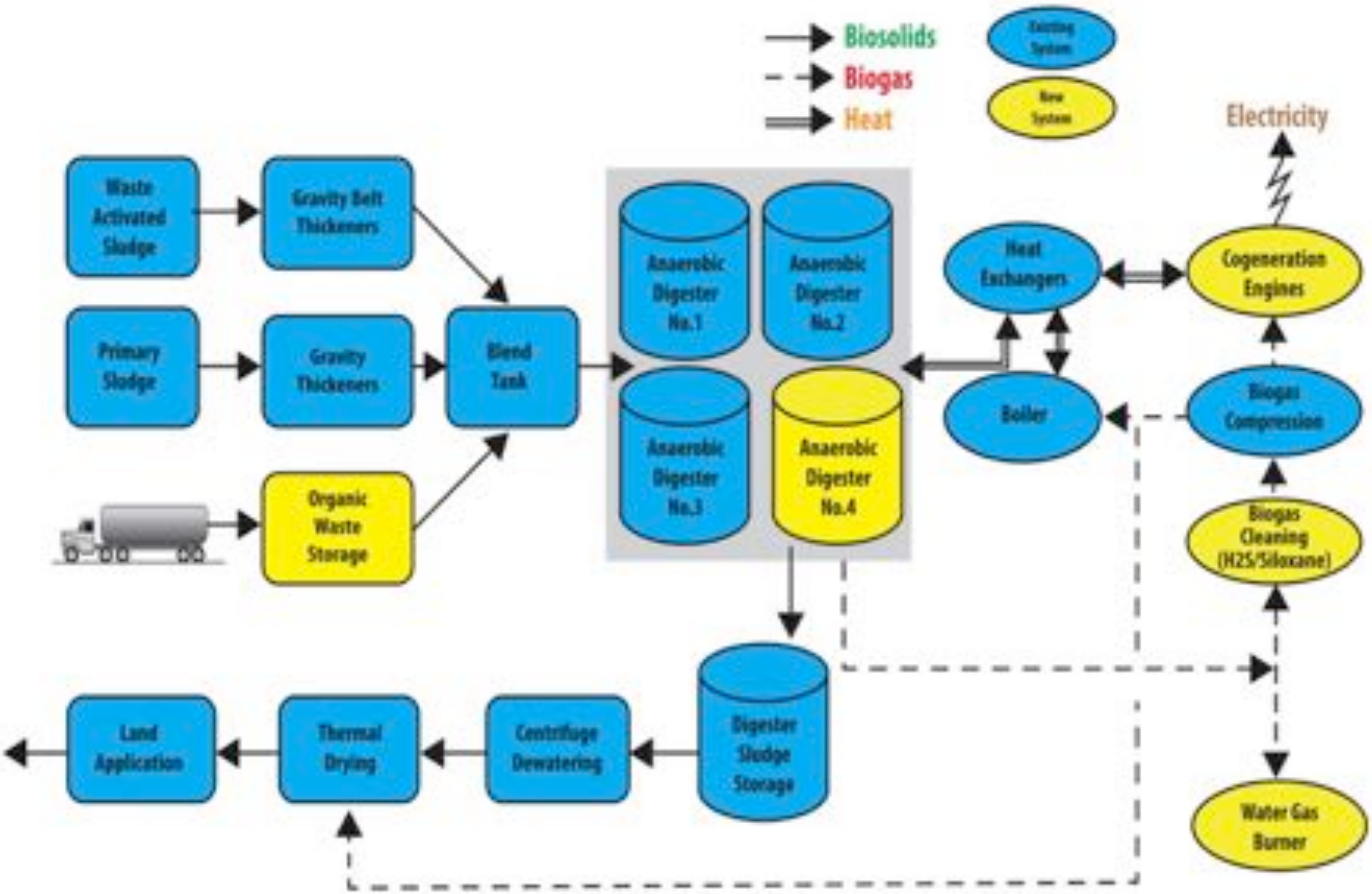
Technical Memorandum
Report
Greater Lawrence Sanitary District

Organics to Energy
Feasibility Study
June 2013

CDM Smith

Organics to Energy Project

Combined Heat and Power and Anaerobic Digestion Upgrades



Biosolids
Biogas
Heat

Existing System
New System

Electricity

Waste Activated Sludge
Gravity Belt Thickeners
Primary Sludge
Gravity Thickeners
Blend Tank
Organic Waste Storage

Anaerobic Digester No.1
Anaerobic Digester No.2
Anaerobic Digester No.3
Anaerobic Digester No.4

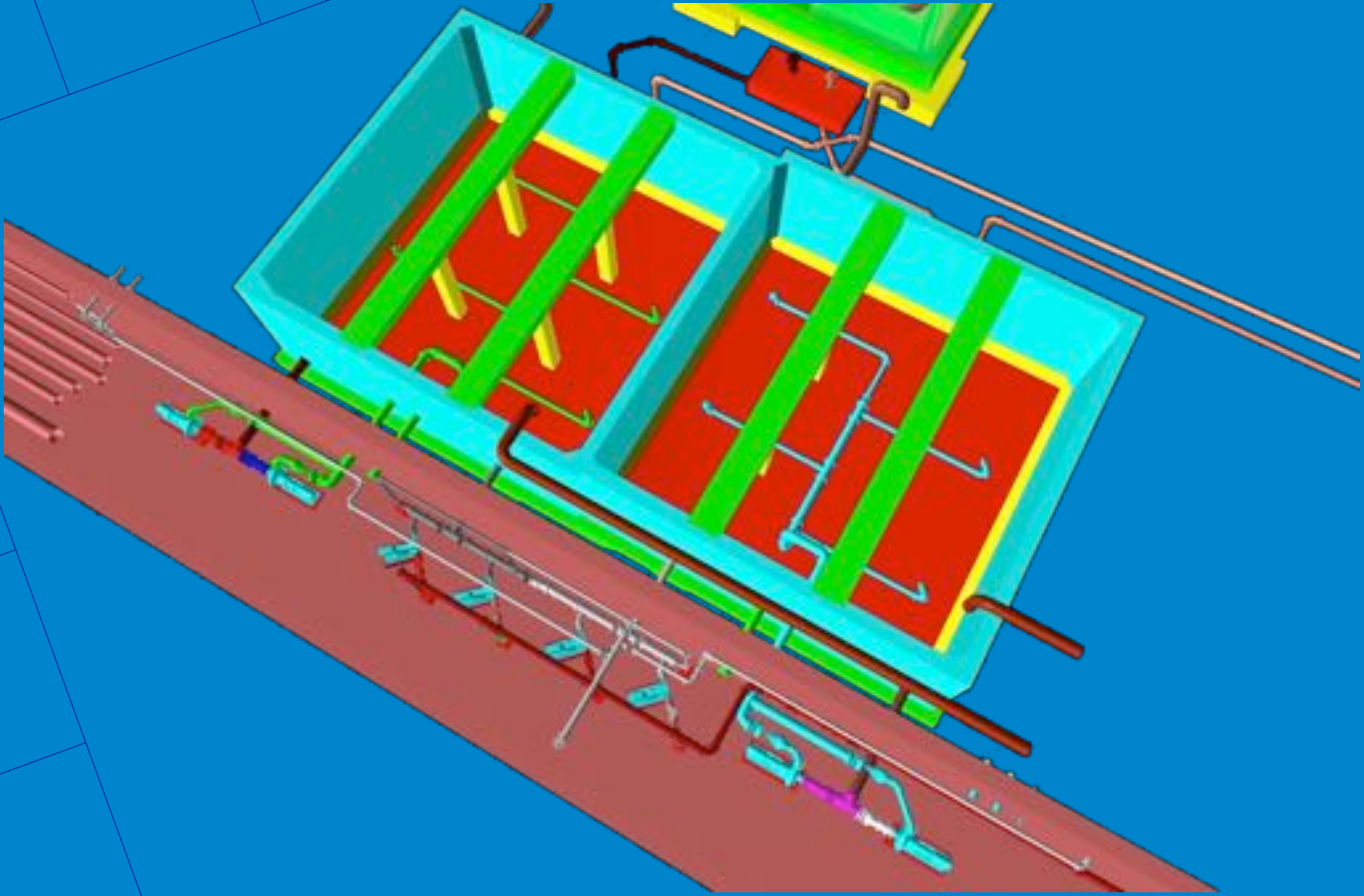
Heat Exchangers
Cogeneration Engines
Boiler
Biogas Compression
Biogas Cleaning (H2S/Siloxane)
Water Gas Burner

Digester Sludge Storage
Centrifuge Dewatering
Thermal Drying
Land Application

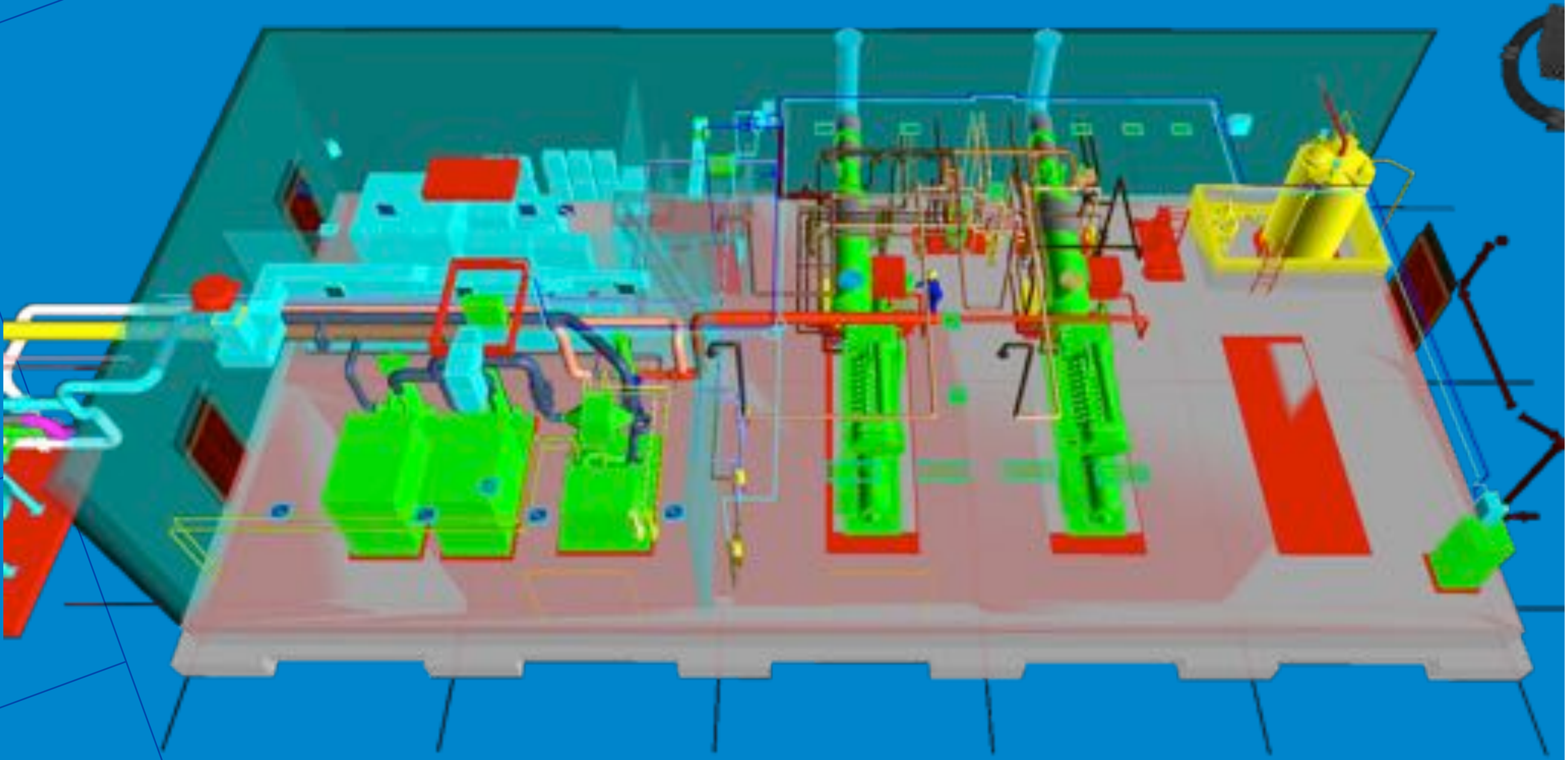
Proposed GLSD Biosolids Process

CDM Smith

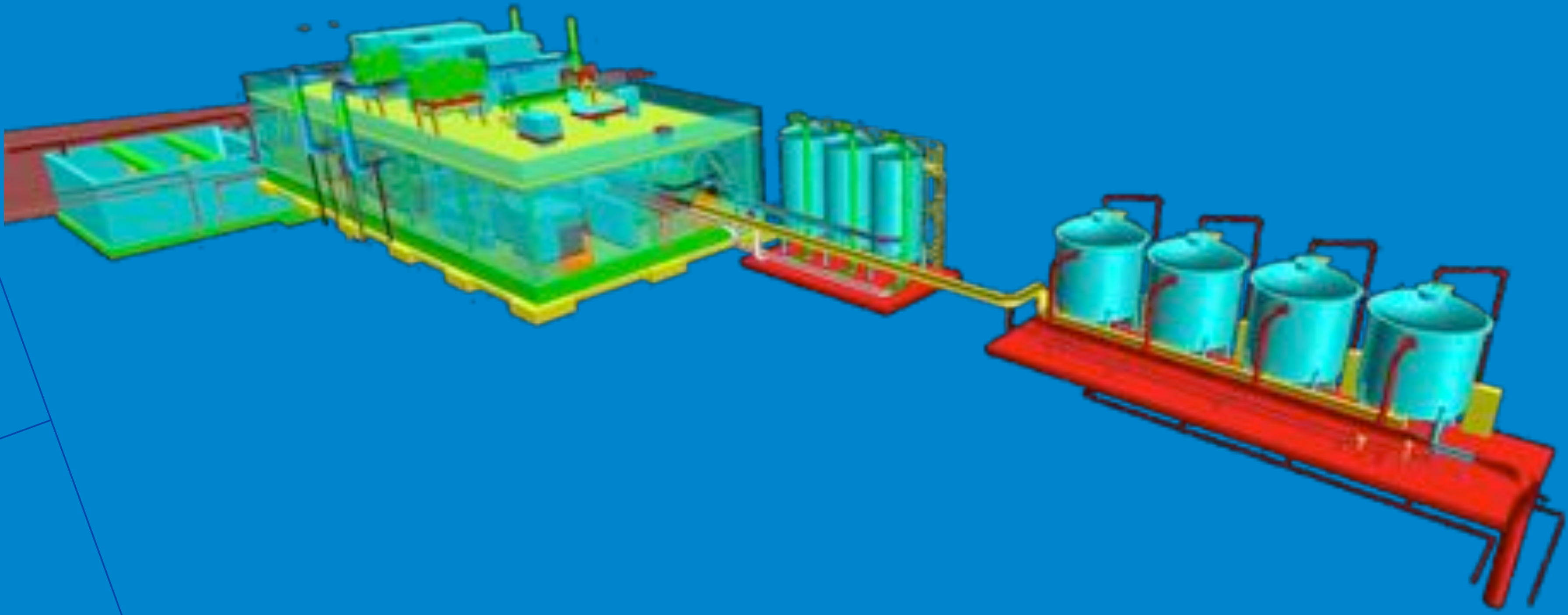
Underground Organic Receiving Tanks



CHP Building



Overview of Biogas Treatment and CHP Building



WM CORe® Inbound Source Separated Organic Food Waste

WM CORe® Processing Capability

Typical Inbound Food Waste

Contaminants Removed

WM CORe®

Processing System and EBS™ Production

WM CORe® NYC Varick Ave. Tip Floor, Processing Area and EBS™ Production

WM CORe®
Organics to EBS™

CORe® SSO Receipt Hopper & Bioseparator

EBS™ Mixing & Storage Tank

EBS™ Product

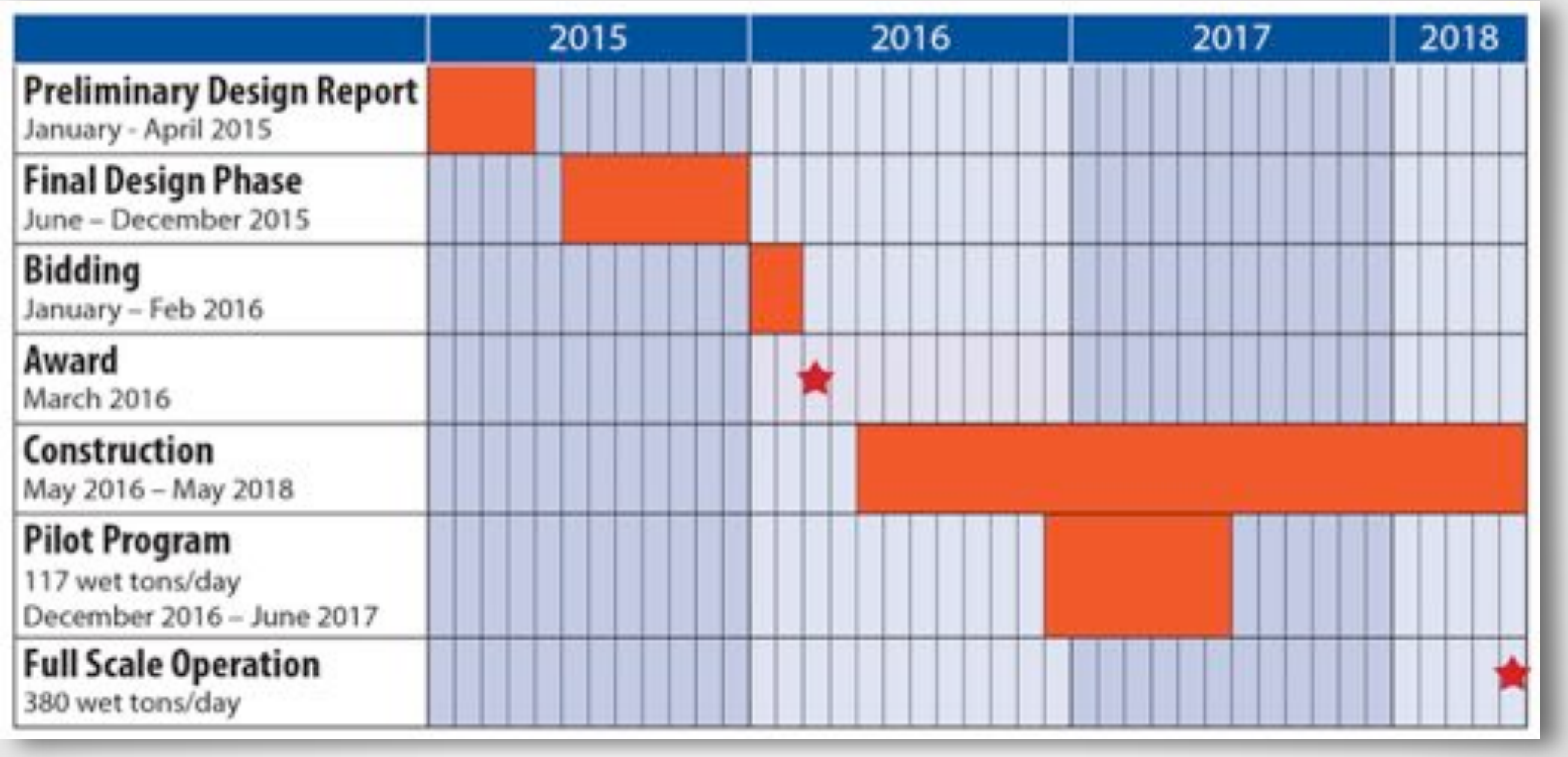
WM Engineered BioSlurry

EBS™ Characteristics:

- Characterization of WM EBS™
  - pH: 3.5 – 9.0
  - Volatile Acids (Acetic Acid Equivalents): Less than 15,000 mg/L
  - Total Solids: 12.0 – 16.0%
  - Volatile Solids (% of Total Solids): 85 – 95%
  - Total COD: Greater than 180,000 mg/L
  - Total BOD: Greater than 80,000 mg/L
  - Screening 2 stage (15mm to 6mm)

- Energy Potential
  - 1 ton of Source Separated Organics ~2.5 to 3.0 MMBTU/d

SCHEDULE



Preliminary Design Report
January - April 2015

Final Design Phase
June – December 2015

Bidding
January – Feb 2016

Award
March 2016

Construction
May 2016 – May 2018

Pilot Program
117 wet tons/day
December 2016 – June 2017

Full Scale Operation
380 wet tons/day

QUESTIONS

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Capital Projects Manager
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Nashua, NH

Some slides courtesy of Anastasia Rudenko PE, ENV SP | GHD

Nashua WWTP

- 16 MGD Secondary Treatment Facility
- 1.25 MG egg-shaped digester
- Minimum HRT = 15 days for Class B biosolids
- Facility currently has 3 tanks available to store substrates (~67,000 gallon capacity) – unheated
- Economic analysis of source separated organics

Biogas production

Measurement

- Unreliable in past
- Project to install new digester gas flow meters

2012 Estimate

- 335 kW

Uses:

- Digester gas-fired boiler
- Dual fuel boiler
- Engine generator
- Flare

HRT capacity

- Current HRT = 17.1 days
- Factor of Safety – 1 days storage
- Excess Capacity (~ 5%)

2012 Influent Stream	Daily Quantity (gpd)
Primary Sludge (PS)	56,500
Waste Activated Sludge (WAS)	16,800
Septage	Negligible
Total	**73,300**

Volatile solids capacity

- Traditional Circular Tanks with Vertical Walls = 50% reduction
- Egg Shaped Digester = 55 – 60%
- Excess Capacity = 2,000 lb/day VS

Options

Additional Substrate	gpd	Electrical Energy (kW)
Low Strength	4,800	35 – 45
Septage (to head of plant)	12,000	15 – 25
Waste Grease or Vegetable Oil	4,800	80 – 110
Glycerol	400 - 800	135 - 145

Liquid unloading station

- 4,800 gpd = 1 tanker truck per day
- Transfer pump and quick disconnect station
- Truck piped directly to storage tank – no odor control needed
- Storage tank vent piping to facilities existing odor control
- Unloading control panel – view tank levels
- Construction costs = $150,000 to $200,000

Solids unloading

- 2,000 lb VS = 3 to 4 tons of food scraps per day
- Typically delivered in roll-off containers or dump trucks (1 to 2 trucks/day)
- Dump pit or Hopper
- Large screen
- Chopper/macerator
- Dilution system to add liquid and slurry to 5-7% solids
- Need odor control
- Construction costs
  - $400,000 to $500,000 if in existing building
  - $1.0 to $1.5 mil incl. new building

Substrate potential

	Annual Tipping Fees Possible	Electrical Generation Potential (kW)	Annual Value of Electrical Generation	Annual Sludge Disposal Costs	Annual Net Benefit	Construction Costs	Simple Payback (years)
Yogurt waste	$87,600	41	$27,200	$35,900	$78,900	$175,000	2.2
Cheese waste	$87,600	41	$27,200	$35,900	$78,900	$175,000	2.2
Food processing byproducts	$87,600	64	$42,400	$35,900	$94,100	$450,000	4.8
Waste vegetable oil	$87,600	110	$72,600	$0	$160,200	$175,000	1.1
Source-separated organics (curbside pickup)	$0	69	$45,400	$35,900	$9,500	$450,000	47
Apple juice/vinegar waste	$87,600	14	$9,100	$35,900	$60,800	$175,000	2.9
Yellow grease	$0	110	$72,600	$0	$72,600	$175,000	2.4
Brown grease	$0	80	$53,000	$0	$53,000	$175,000	3.3
Glycerol	$0	138	$90,800	$0	$90,800	$175,000	1.9
Septage	$346,000	21	$13,600	$35,900	$323,700	$1,750,000	5.4

Notes:

1. Tipping fees based on $0.05 per gallon, which is typical of the New England market.
2. Tipping fees based on 4,800 gpd for 365 days per year.
3. Septage tipping fee based on $79 per 1,000 gallons
4. Value of electricity estimated at $0.11 per kWh, 6000 hours per year
5. Annual net benefit = Tipping Fee + Value of Electricy – Sludge Disposal Cost

Case Study: LAWPCA

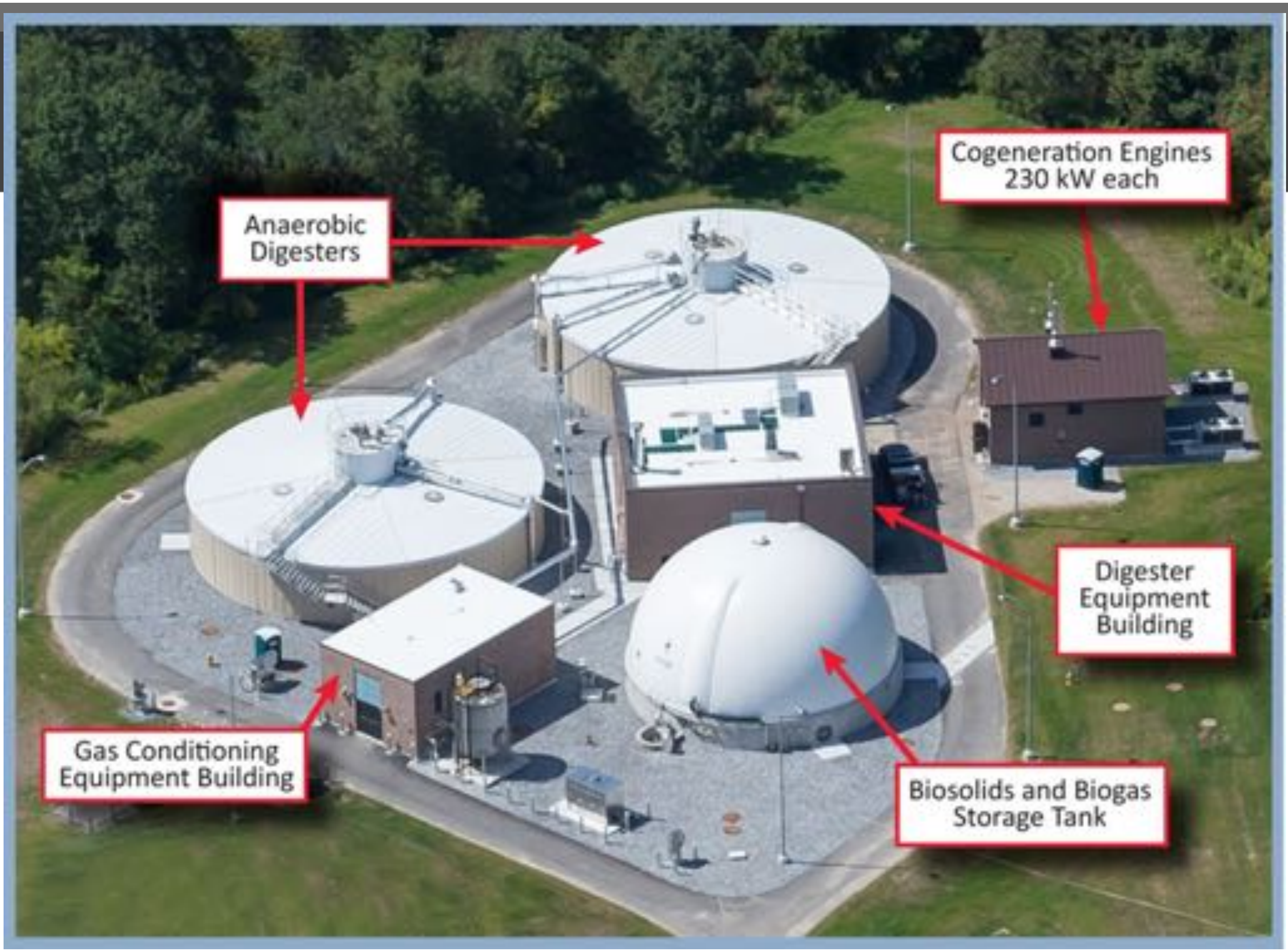
Lewiston-Auburn WPCA

Water cleaned & returned to river.

Energy extracted = renewable fuel.

Lewiston-Auburn, ME

Solids recycled as soil amendment.


Cogeneration Engines
230 kW each
Anaerobic Digesters
Digester Equipment Building
Gas Conditioning Equipment Building
Biosolids and Biogas Storage Tank

Gas storage

Approximate Annual Savings from AD

Item	Amount
Reduction in Land Application Program	$310,000
Reduction in Composting and Compost Revenues	170,000
Elimination of Contract Disposal	150,000
Reduced Plant Energy Costs	130,000
Co-Digestion of Other Organics	20,000
Composting of Other Biosolids	180,000
Total	**$960,000**

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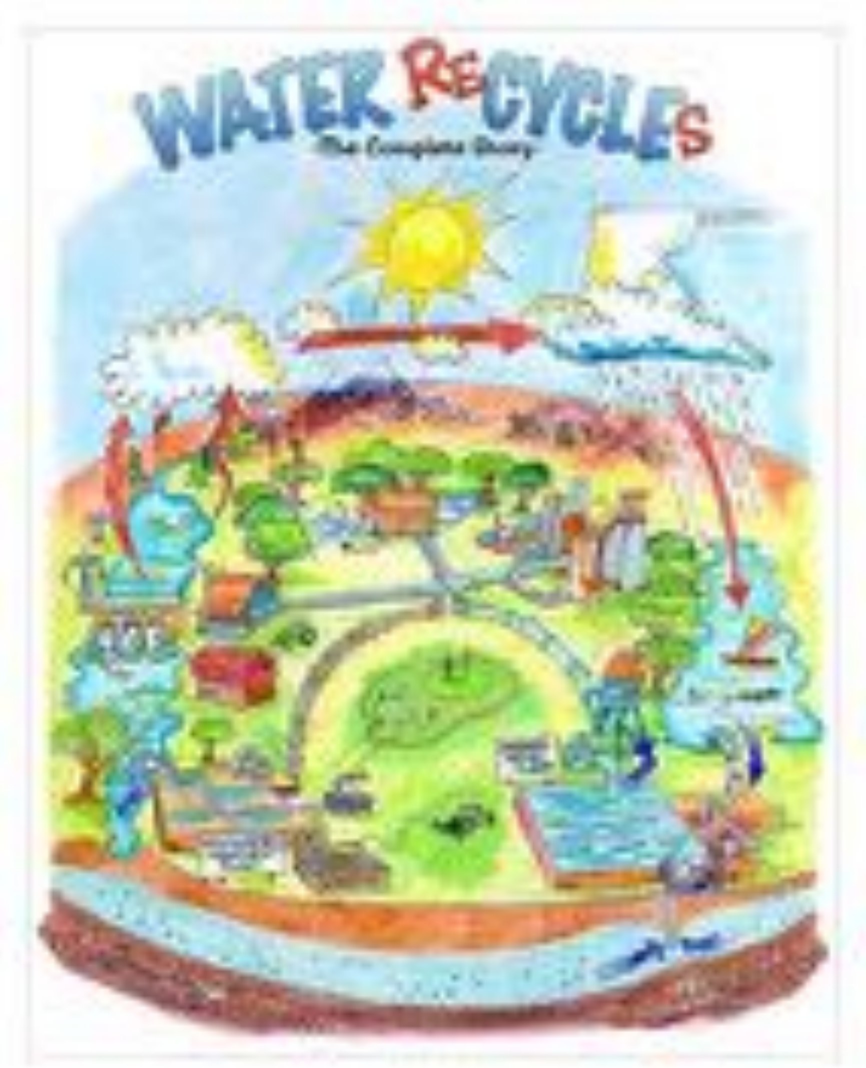

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603-323-7654