Anaerobic Digestion and Co-Digestion Optimization

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Outline

- Basics
- Mixing
- Preventing Digester Overflows
- Addition of FOG and HSW
- Case Studies

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Digester Basics

- The operator's work begins after the design and construction are completed. This discussion assumes that these steps were done correctly – not always the case.
- The basic information needed for digester start-up and operation is found in the Manuals of Practices of WEF (MOPs) for anaerobic digestion, starting with MOP 16, "*Anaerobic Digestion Manual of Practice", published in the late 1980s.*
- Co-digestion is an emerging practice, and there is no MOP available – yet – just experience.
- However there are the lessons learned at a number of facilities that can be applied. This is our focus today.

Co-Digester Basics

- Co-Digestion programs have evolved from the realization that some wastes are better introduced directly to the digester rather than via the sewer into the headworks.
- Such wastes can be piped directly to digestion, or more commonly as hauled wastes received via tankage for pre-treatment, blending and pre-heating with sludge as digester feedstock.
- The largest such programs are found in the mid-west USA at places such as Des Moines, IA, in operation over 20 years.
- Many other utilities have ventured into FOG/HSW waste handling including Johnson County, KS; Gwinnett County, GA; East Bay MUD, CA; Fresno, CA; Davenport, IA; Hershey, PA
- The waste receiving and handling practices used at these facilities provide many lessons learned for newer facilities.

Co-Digestion Lessons Learned:

- Knowledge of the individual wastes to be accepted – what are a waste's characteristics, variabilities and biomethane production potential.
- Contractual basis for acceptance – have a specification to describe the basis for acceptance or rejection of a load.
- Assay procedures – have a standard procedure to ensure that each load received is within specification.
- Outlet for the biogas – have established uses in place for the added biogas production.
- Receiving storage capacity – it is always cheaper to storage waste than to store gas.
- Additional gas hold-up in co-digestion will likely occur, reducing the density of the digesting liquid and increasing volume.

Most Existing Digestion Systems Are Not Designed for Co-Digestion:

- The scale of a co-digestion program will change over time as the viability and reliability of a program is built.
- Multiple categories of wastes to be received may require multiple waste storage tanks.
- Waste receiving, blending and pre-heating operations must be scaled to the size of the program, often a guess, so phasing is often a consideration.
- Digester design should but often doesn't provide additional head space and overflow capacity for when the unexpected happens.
- Secondary digester capacity is useful/essential for balancing flows to dewatering.
- Other examples are provided later in this presentation.

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Digester Mixing

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Digester Mixing Concepts

- Too little mixing can allow pockets of gas to accumulate, *creating density gradients*
- Too much mixing can entrain gas on a wider scale, *creating density gradients*
- Temperature gradients and variability in feeding, *increasing density gradients*
- Rapid rise foam formation results from excessive and rapid *lowering of density*

Digester Mixing Concepts (continued…)

- There will be some foaming in a digester under *the best of circumstances*
- Co-digestates like FOG and food wastes add to the potential for *nuisance foaming*
- Digesters should be designed to *accommodate some nuisance foaming*
- Increasing mixing energy input has been a ***tempting panacea*** for digester designers

Hydraulic Mixing Systems

Pump Mixing or Nozzle (Jet-Mix) Mixing

Advantages of Hydraulic Mixing

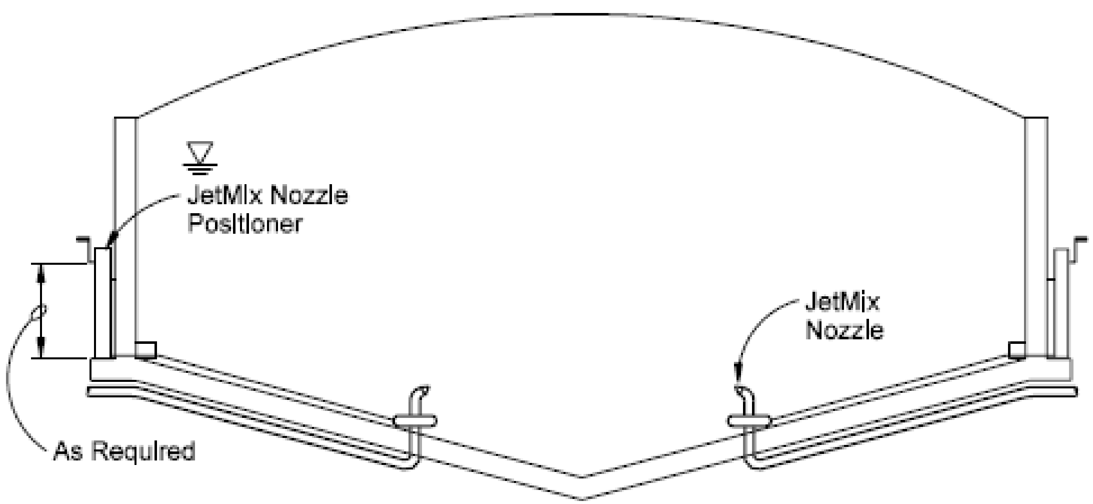
- Provides sufficient mixing energy (eliminates dead spots)
- Maintains solids in suspension and re-suspension
- Chopper pumps macerate rags and debris accumulation (Vaughn Chopper Pump)
- Controls foam problems more effectively than gas mixing systems
- Reduces routine cleaning (minimal solids accumulation on digester bottom)
- Easy retrofit of existing digester tanks (equipment located outside of digester)
- Special ventilation or electrical requirements not required
- Rotatable nozzles (adjust according to scour locations, Jet-Mix only)
- System requires least amount of submerged equipment (except for submersible mixers)
- Low explosive hazard during system maintenance (compared to gas mixing)

Hydraulic Mixing Systems

Pump Mixing or Nozzle (Jet-Mix) Mixing

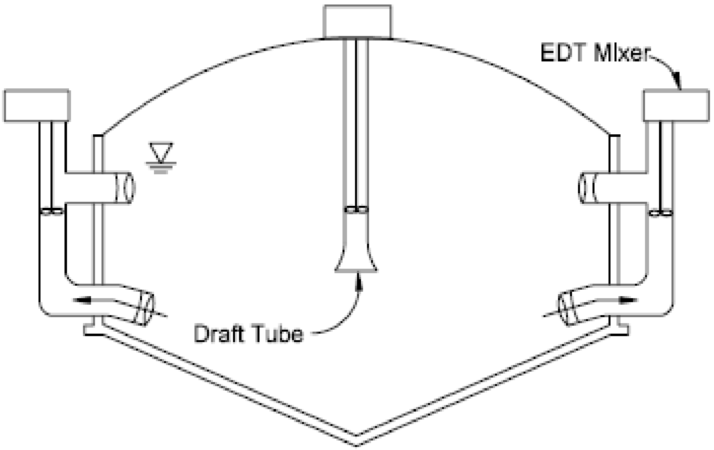
Disadvantages of Hydraulic Mixing

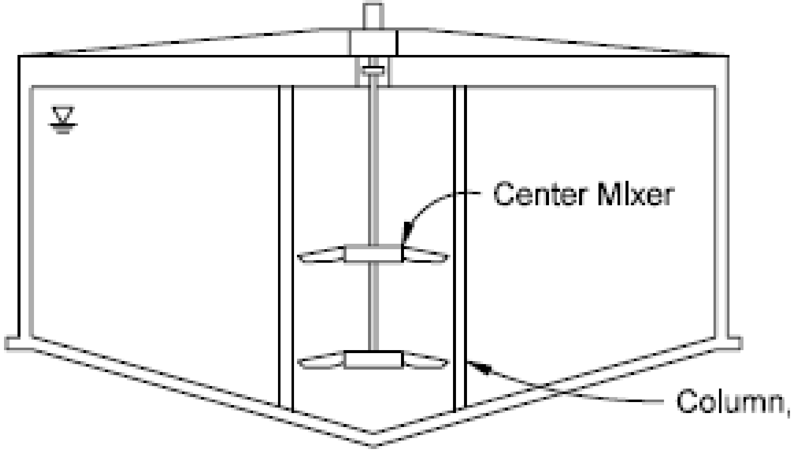
- Limited history in digesters; excellent history in mixing sludge tanks
- Nozzle cranks penetrating walls of digester (Jet-Mix only)
- Slightly higher energy usage than confined gas systems



Mechanical Mixing Systems

- Draft Tube Mixers (Eimco and WesTech)
- Center Mixers (Lightning/Philadelphia)
- Peripheral Mixers (Omnivore)
- Linear Motion Mixers (Ovivo)





Mechanical Mixing Systems

Advantages of Mechanical Mixing

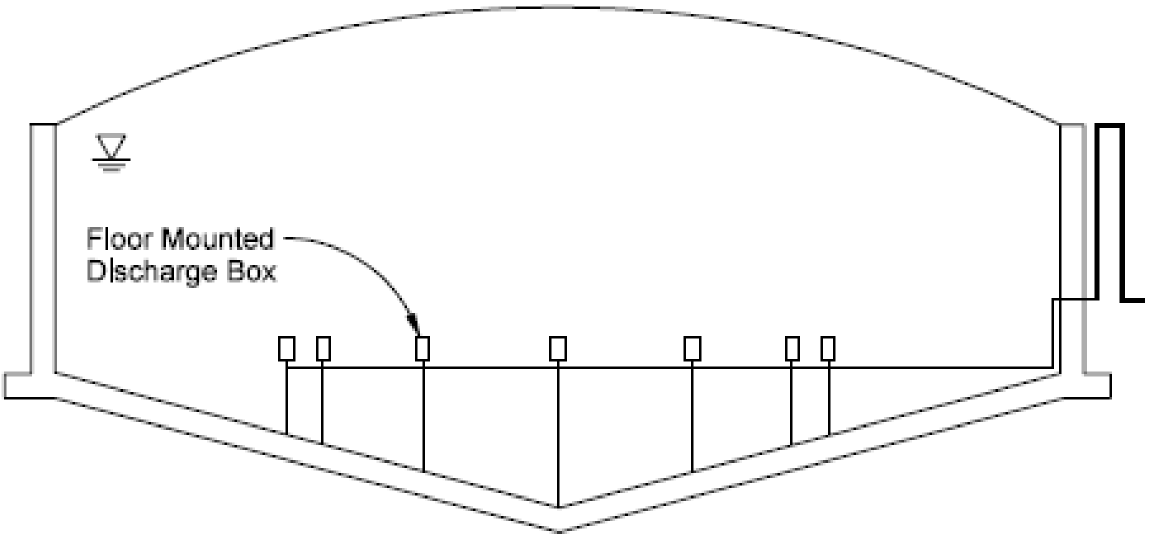
- System provides a less explosive-hazard environment compared to gas mixing
- Provides sufficient mixing energy for various tank sizes and configurations
- VFD pumps can alternate speed according to digester solids contents

Disadvantages of Mechanical Mixing

- More prone to clogging with rags and other large debris
- Formation of rag balls clog downstream pumps and piping
- Sensitive to liquid level in tank (mixing not as effective)
- Replacement of digester covers required to retrofit existing system (center mixer system)
- Reinforcement of digester cover required to handle heavy weight and forces generated by mixer (center mixer and roof-mounted draft tubes)

Gas Mixing Systems

- Bubble Gun System (IDI Atara)
- Perth (Envirex)
- Draft Tube (Walker)
- CRP System (Chicago Pump Co.)



Gas Mixing Systems

Advantages of Gas Mixing

- Most commonly used mixing system
- Mixing intensity regulated by throttling gas flow
- Complete mixing possible with unconfined gas mixing systems, but only IDI Atara will guarantee performance
- Potentially less power consumption than mechanical mixing systems

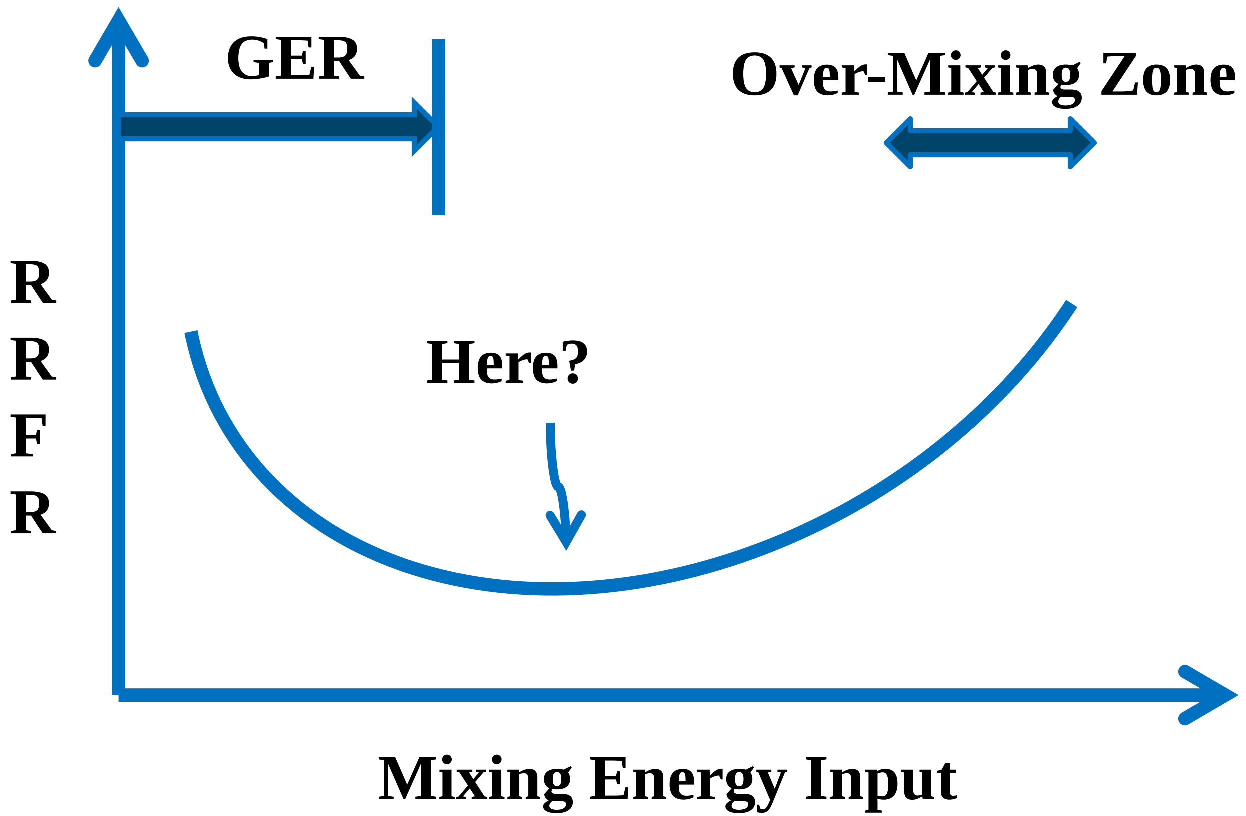
Disadvantages of Gas Mixing

- Gas compressors, nozzles, and diffusers prone to plugging
- Excessive foaming and grit accumulation experienced
- Explosive characteristics of digester gas (O&M more difficult)
- Costly retrofit for existing digesters (addition of gas compressors and piping)
- Inefficient mixing below gas injection level prevents grit from remaining in suspension
- System requires maintenance of "different" types of equipment – compressors, etc.
- Proprietary mixing systems

Mixing Parameters in Digesters

- GER (Gas Evolution Rate) – is driven by microbiological activity:
  - Area-specific as gas always rises (Mixing Energy/area-time)
  - Increases with greater height to diameter ratio
- RRFR (Rapid Rise Foam Formation Rate) is driven by
  - GER (Gas Evolution Rate)
  - Mechanical MEI (Mixing Energy input)
- Each sludge and digester design is a unique combination and present a unique set of circumstances.

Where’s the Mixing Energy Sweet Spot?



RRFR = Rapid Rise Foam Formation Rate

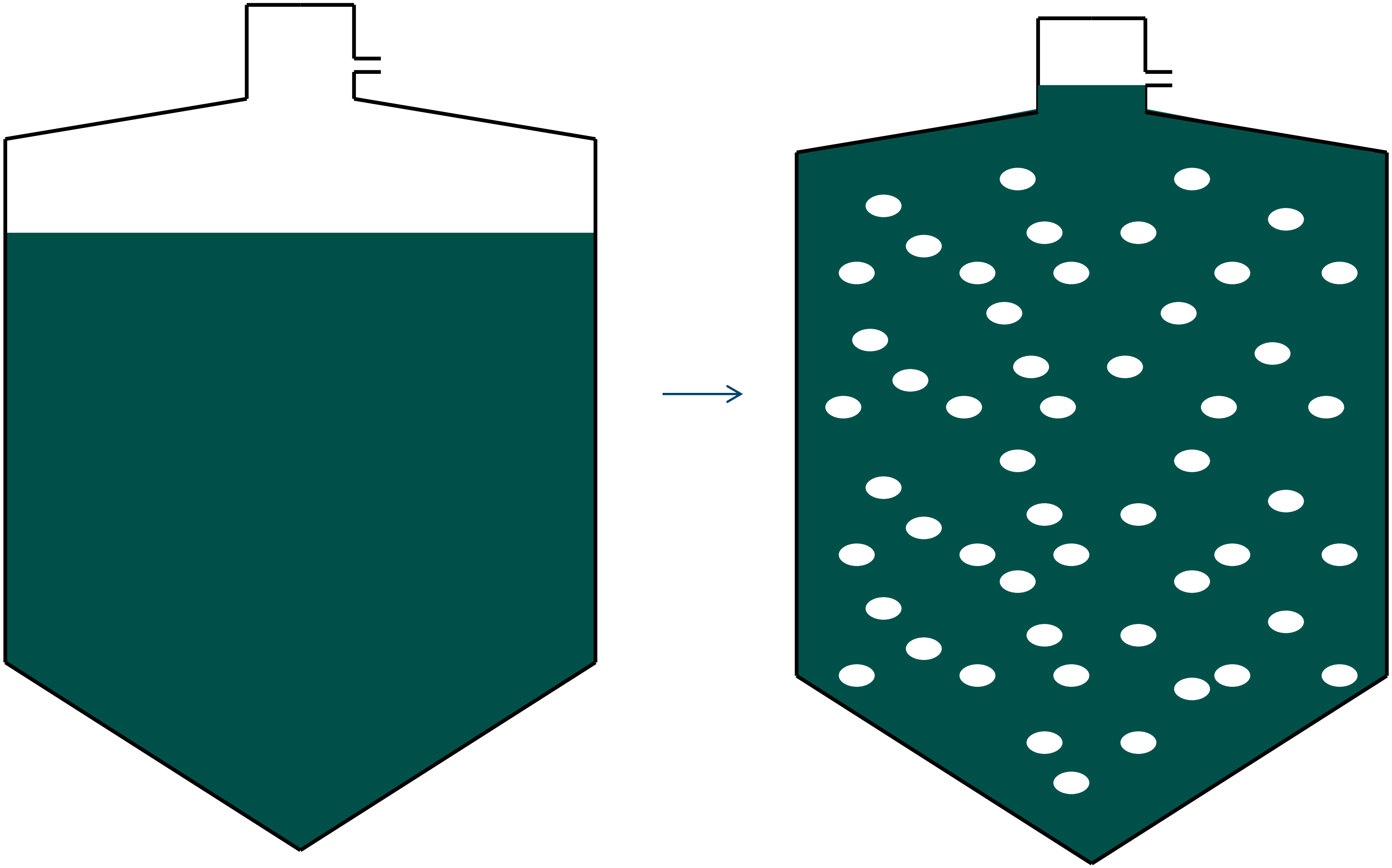
GER = Gas Evolution Rate

Key Points on Digester Mixing

- Gas evolution rate increases in proportion to mixing energy input
- Digester over-mixing is a wide-spread concern and contributes to foam production.
- More work and more detailed information required to select appropriate digester mixing systems.
- Better performance results from feeding digesters as continuous as possible, especially with FOG and high-strength organic wastes added to the feed.
- Can expect to see
  - More pumped hydraulic jet mixing systems with VFDs (variable frequency drives)
  - LMMs as a path forward.
  - Different energy for process needs with grit suspension. Grit removal + LMM may become more common.

Digester Overflows – Causes and Control Measures

Volume Expansion & Density Reduction from Gas Holdup



… Can Lead to Scenes Like This!

Why?

Factors with Volume Expansion

Potential Causes

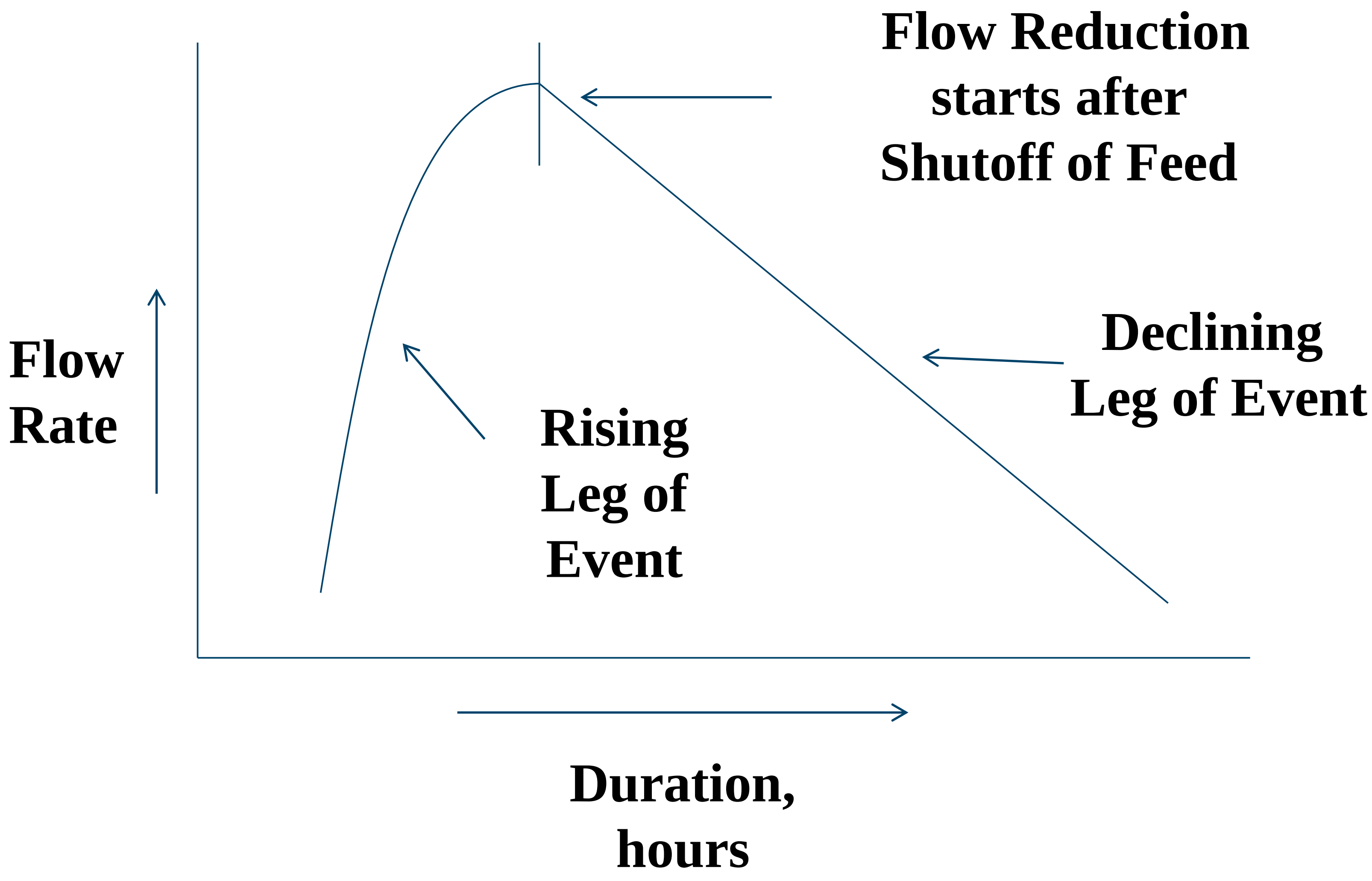
- Changes in rate or composition of feed
- Changes in mixing regimen
- Power outage/shutoff of mixing
- Inadequate or excessive heating
- Rapid pressure drops

Potential Safeguards

- Pressure relief valves
- Emergency surface overflows
- Foam suppression sprays
- Increased headspace in gas plenum
- Rapid transfer piping to lower liquid level

Note that some of the safeguards are nonfunctional at reduced liquid density

Rapid Rise Foam Formation Event



Rapid Rise vs. Chronic Foaming

- **Rapid-rise foaming:**
  - Frothy sludge with high gas holdup can reduce the density to half that of sludge.
  - Rapid increase in flow rate (as much as 10-fold more than inflow)
  - Rapid increase signals operation reaction
  - Extended decrease in the flow rate that can last as long as a day
  - Digesters usually not designed to accommodate

- **Chronic or normal foaming:**
  - A relatively continuous phenomenon
  - Digesters are typically designed to handle chronic or normal foaming using such measures as foam breakers with scum nozzles

Foam Breaker with Scum Nozzle

Vaughan Foambuster (Above) and Scum Nozzle (Below) for control of surface scum and foam buildup

Foam Management Begins with Start-Up

- Start-up is a time of transition
- Transitions are the most critical periods for foam formation generating gas hold-up
- A proven example start-up protocol is found in the WPCF (now WEF) MOP 16 “Anaerobic Digestion Manual of Practice No. 16”.
- This document addresses the start-up procedures and is crystal clear on what is required.

Digestion Process Start-Up

- MOP 16 and common sense dictate that all systems and equipment must be operational before startup.
- The monitoring program and laboratory capacity must be ready to go.
- The staff must be fully trained.
- A contingency plan must be in place.
- One person must be in charge
- Everyone must buy in to the challenges.

The alternative outlets for gas & liquid ..

Pressure Relief Valve & Flame Arrester

Emergency Overflow

Can be rendered non-functional due to frothy sludge

Gas Draw-Off Pipe

Can be part of the cause of an imbalanced loading

Frothy Sludge Over the Digester Wall …

… And Onto the Ground

Control Measures

- Have an approved start-up plan with buy-ins
- Have a start-up team with a chain of command that means business
- Avoid premature start-up at all cost.
- Avoid complacency at all cost
- Visit other sites where start-ups have been done and capture the lessons learned.

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Addition of FOG and HSW Considerations

FOG and HSW Addition Considerations

- Overall Benefits of Use of FOG as a Resource
  - Improve sewer and WRRF performance
  - Provides revenue stream from tip fees
  - Will generate significant amounts of biogas at low hydraulic loading in anaerobic digestion
  - Biogas production when coupled with co-generation can result in significant cost savings
  - Biogas use from FOG addition in CHP can reduce GHG footprint and energy dependence
- Other Considerations
  - Get a handle on quantities and characteristics available
  - Start slow
  - Modeling digester performance/biogas production can easily be done
  - Consider impact on entire wwtp process train during design

Key Considerations for Utilizing FOG Resources

- Characteristics and form of FOG or high strength wastes to be received for co-digestion
- Reliability, consistency and availability of each material supply as a feedstock
- Collection network to move the FOG to a receiving station at the WRRF
- Special requirements for receiving, holding and transferring FOG on a continuous basis

Key Considerations for Utilizing FOG Resources

- Capacity available or required in each supporting system of the solids train
- Additional return liquor loadings
- Excess capacity in the liquid treatment train or separate side stream treatment system to handle the additional return liquor loadings
- Synergistic sludge degradation with FOG addition can potentially increase the recycled nutrients load
- There can be significant net cost savings despite the extra cost of treating the higher strength recycle streams

Key Considerations for Utilizing FOG Resources

- Using digester gas to fuel CHP projects is a rapidly growing practice to reduce energy demand at WRRFs with anaerobic digestion systems.
- Receiving FOG and HSW into WRRFs with spare digestion capacity can create revenue by tipping fees and boost gas production, thereby making CHP more economically attractive than digesting biosolids alone.
- The manner in which FOG and HSW are received at a WRRF and fed to digesters is critical to avoid digestion upsets.
- Heated storage tanks for blending and leveling out FOG/HSW feed rates to digesters are critical elements of any FOG/HSW receiving facility.

Summary (continued)

- There is little in the way of standard operating procedures for these types of facilities to date, but the practice is growing sufficiently that development of standard procedures and best practices is warranted.
- Procedures are being implemented at many facilities that will be useful to operators of other FOG/HSW receiving facilities, and will contribute to industry standards as they are developed
- The construction of CHP systems along with FOG and HSW receiving and handling systems can offer attractive payback periods in the range of 4 to 9 years, even in locations with relatively low unit power rates. Site-specific issues such as tipping fees and power-rate structure will affect lifecycle costs and payback period.

Summary of Means to Avoid Problems

- Feed consistently (hourly at least)
- Ramp up feed loading slowly based on solids/COD load
- Make sure characteristics of FOG/HSW feed materials are known
  - COD
  - pH
  - Nutrient content
- Monitor digester conditions daily
  - Alkalinity
  - pH
  - VFA's
- Consider adding fixed covers with gas collection bonnet in the dome with foam suppression
- Consider pre-heating FOG/HSW before feeding to digester
- Consider pre-blending FOG/HSW with thickened primary solids and WAS before feeding to the digester

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FOG and HSW Addition to Digesters with Combined heat and Power System Case Studies

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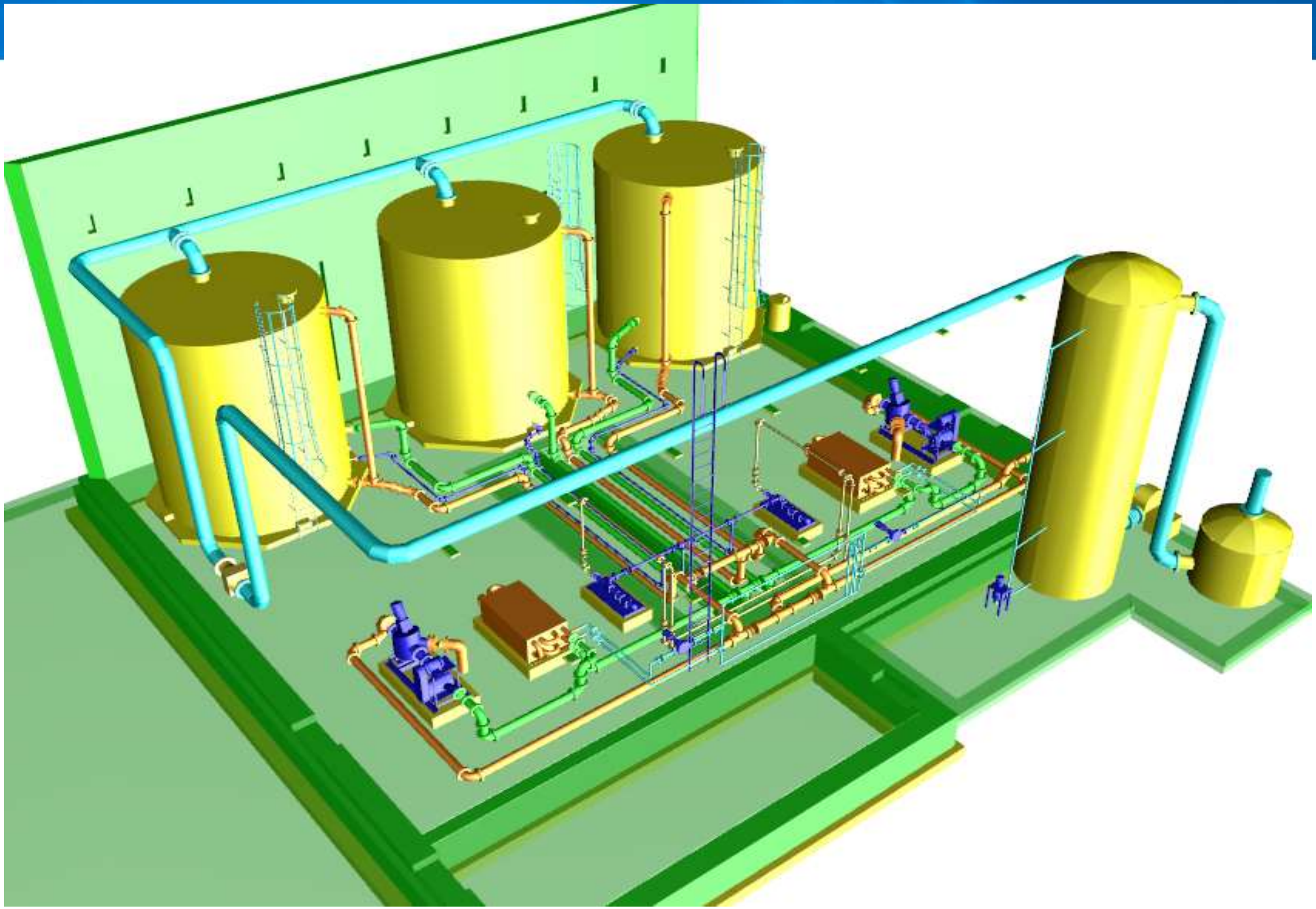
Facilities

Smith Middle Basin WRRF

- 35-mgd (132,000 m^3/day) capacity WRRF
- FOG/HSW receiving facility to process 14,500 gal/day (55 m^3/day) on average
- Cold winter & snow requires building enclosure & heated tanks
- Multiple day tanks, heating and equalization systems
- Two 1.06 megawatt (MW) internal combustion engines (ICE)

Facilities



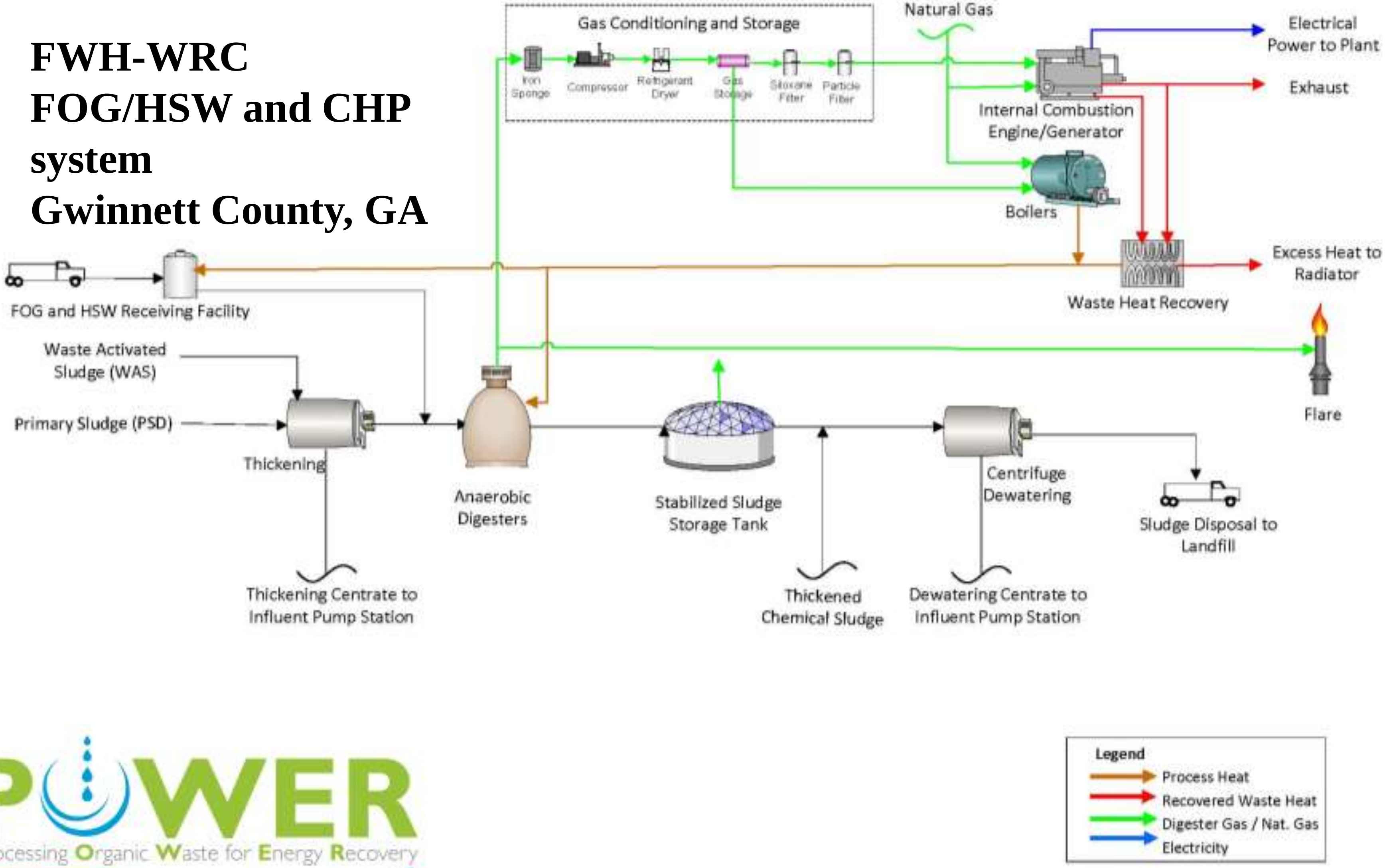
Facilities

F. Wayne Hill WRC

- 60-mgd (227,000 m^3/day design capacity)
- Receives combined sludge from Yellow River WRRF
- 300-400 cfm (8.5-11.3 m^3/day) biogas production
- Less than half of biogas utilized prior to CHP
- 2.5 megawatt (MW) GE-Jenbacher engine
- Up to 75,000 gal/day (280 m^3/day FOG/HSW receiving capacity

Facilities

FWH-WRC
FOG/HSW and CHP system
Gwinnett County, GA



gwinnett POWER
Processing Organic Waste for Energy Recovery

Biogas with Addition of Fats, Oil & Grease (FOG)

F. Wayne Hill WRC, Gwinnett County, Georgia

50 dry tons/day solids ≥ 600,000 ft^3/day of biogas → $4,800/day energy value

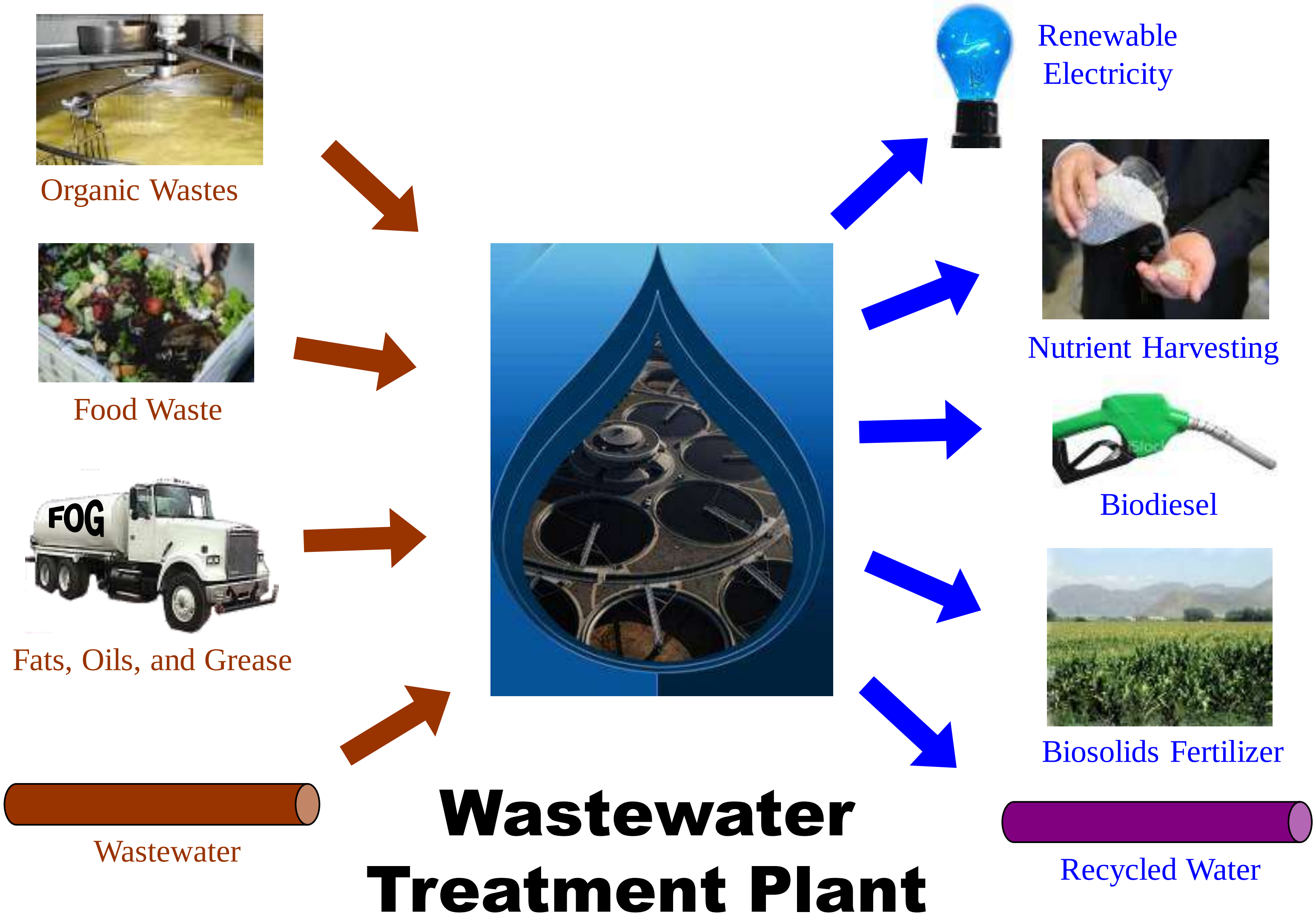
55,000 gal/day FOG @ 5% solids + 50 dry tons/day solids ≥ 952,000 ft^3/day of biogas → $7,600/day energy value

+ $1,022,000/yr energy value with FOG

50% of Plant Power Needs Met

Douglas L. Smith Middle Basin Facility
Johnson County, Kansas

The Resource Recovery Model



Renewable Energy Expansion

Original Facility (3 engines)

- Installed in 1985
- Meet 40-50% of demand (2-2.5 MW net gen)
- Frequent flaring of excess biogas

Expansion (+1 turbine)

- Meet 100-200% of demand (5-10 MW net gen)
- Sell excess green energy
- Reduce air and GHG emissions
- Increase operational reliability

First WWTP in U.S. to Become a Net Electricity Provider

Net Electricity Provider

Electrical Grid

Wastewater Treatment Plant

2013 to-date

Generation:	6MW
Demand:	5MW
Net Sales =	1MW

Resource Recovery Opportunities Remember 3-3-6!

- 3 Times as many WRRF’s are without AD as those with AD
- 3 Times as many WRRF’s with AD do not generate power or drive plant equipment as those that do
- 6 Times as many WRRF’s do not import FOG or high strength waste to feed digesters as those that do

Anaerobic Digestion and Co-Digestion Optimization

QUESTIONS?

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