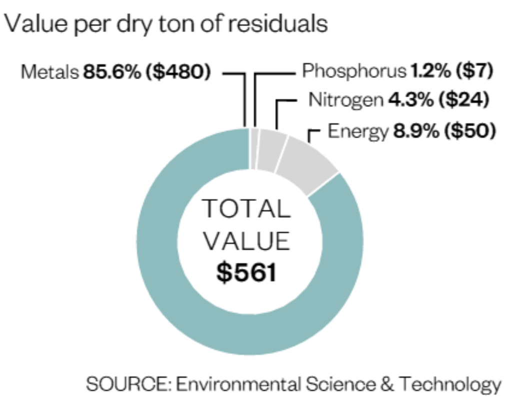


What is hot in biosolids processing?

Mohammad Abu-Orf, PhD, Residuals Group Practice Leader

Outline

- Overview of drivers for biosolids processing and trends
- Resource recovery
- Anaerobic Digestion Advances (THP, Pondus, Lystek)
- Dewatering (Bucher press, Dewatering/BioP, SLG-Orege)
- Thermal processing (Gasification, SCWO, Pyrolysis/biochar)
- Closing remarks

Overview of drivers and trends

Drivers for management of biosolids

- Main driver for managing continues to be federal and state regulations – usually stricter
- Public perception: increased scrutiny on all disposal/reuse routs
- Availability of disposal or reuse outlets
- Energy demand for management
- Cost of processing from production to end use and capital funding
- Paradigm shift, resource and not a waste

Processing and management ***trends*** in response to drivers

- Energy driven technologies:
  - Enhanced/advanced anaerobic digestion
  - Co-digestion of high strength waste – SSO, FOG, Whey, etc.
  - Increased beneficial use of biogas
  - Energy recovery from dried products through gasification/pyrolysis
  - Energy recovery from incineration

Processing and management ***<u>trends</u>*** in response to drivers

- High quality product technologies:
  - Sludge screens and finer influent screens
  - Thermal Hydrolysis prior to anaerobic digestion
- Side stream treatment technologies and nutrient recovery
- Metal recovery from biosolids
- Alternatives project delivery methods in response to high capital costs: DB, DBOOF, PPP

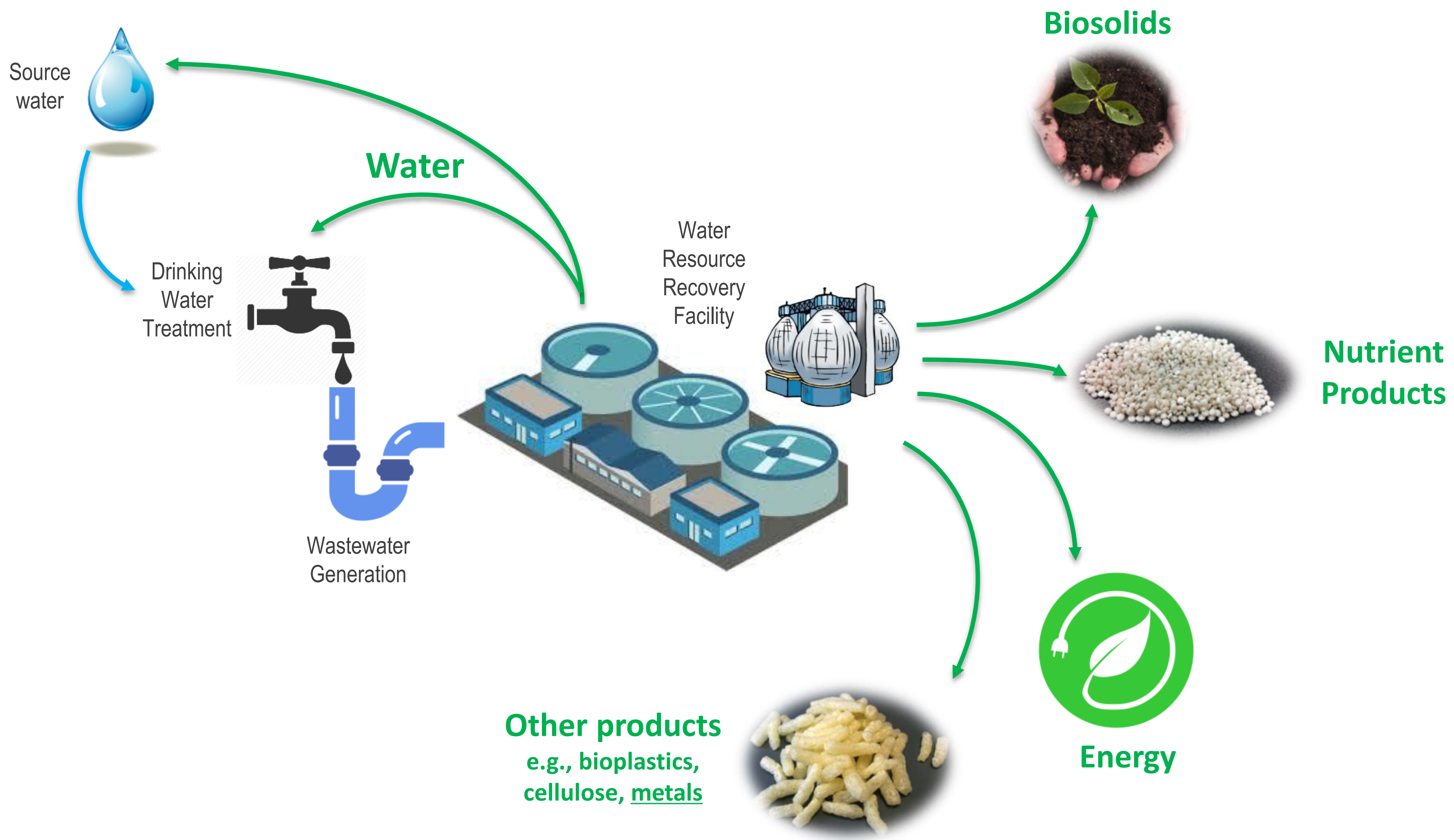
Resource recovery

Water Resource Recovery Facilities

NOT

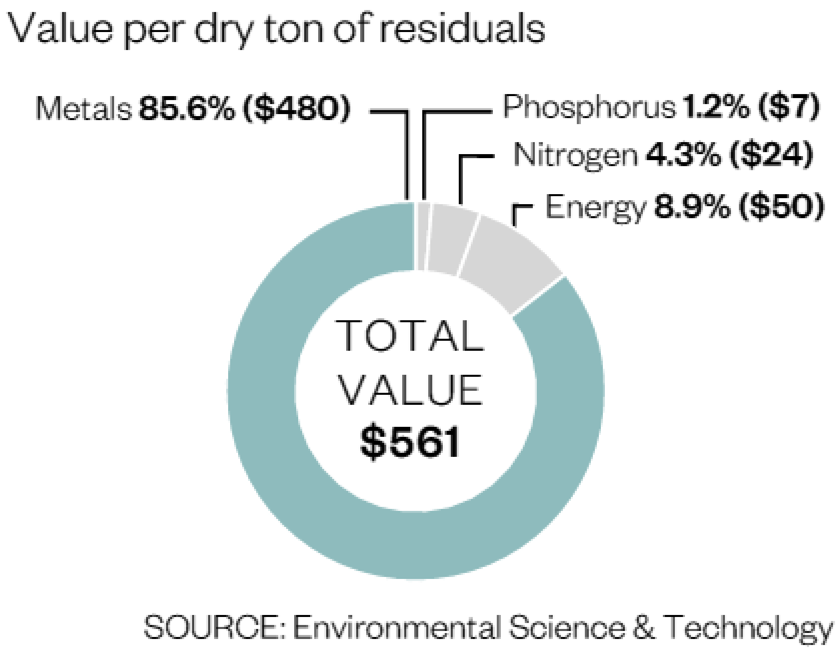
Wastewater Treatment Facilities

The Resource Management Paradigm for Utilities of the Future



Are we recovering the *proper* resources?

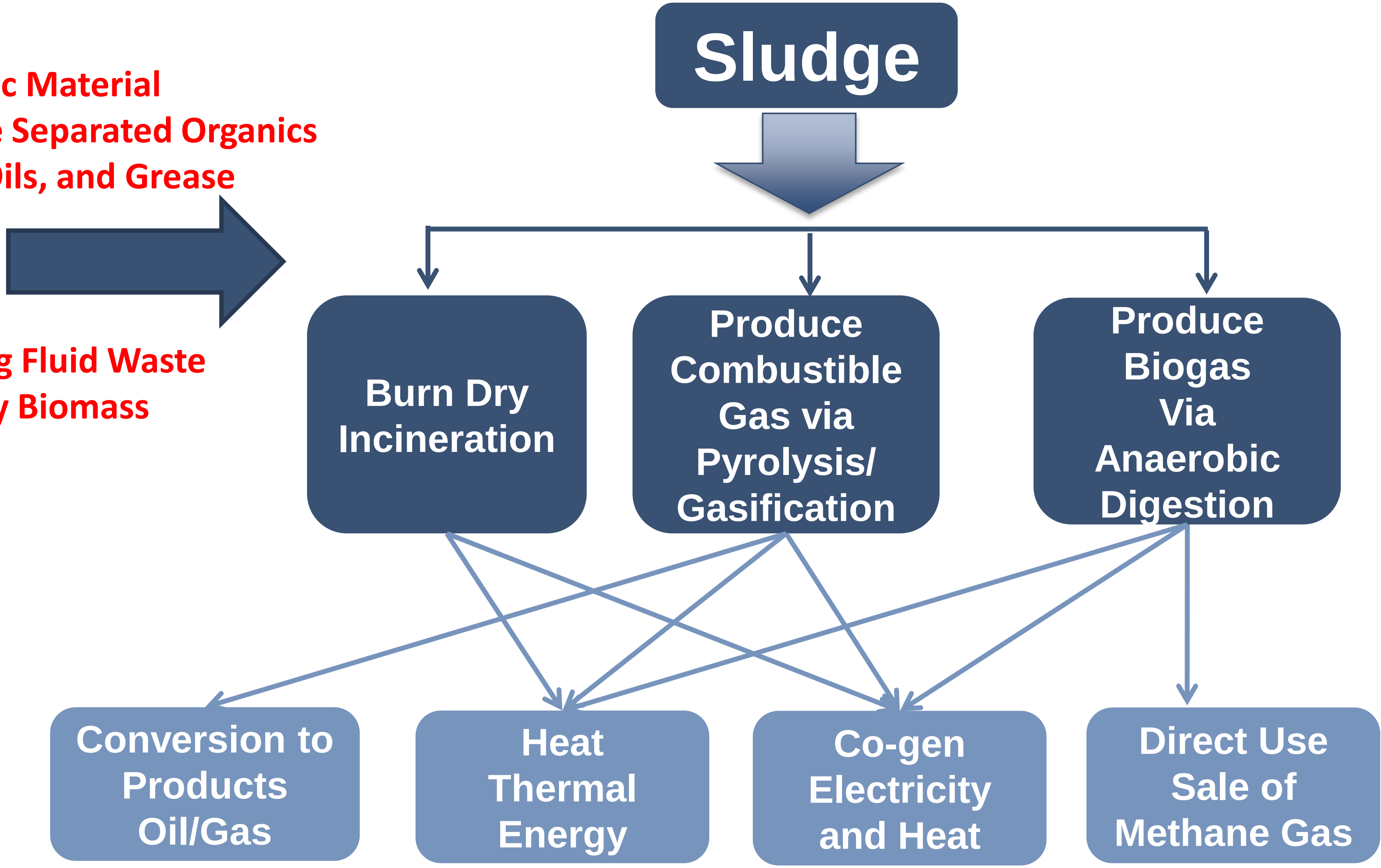
- Energy:
  - net zero energy facilities,
  - integrated waste management approach
- Nutrients:
  - marketable biosolids end-products,
  - increased value of soil amendments and fertilizers
  - struvite recovery
- Metal (Rare Earth Elements) recovery



1. Energy recovery opportunities from sludges

Organic Material
Source Separated Organics
Fats, Oils, and Grease

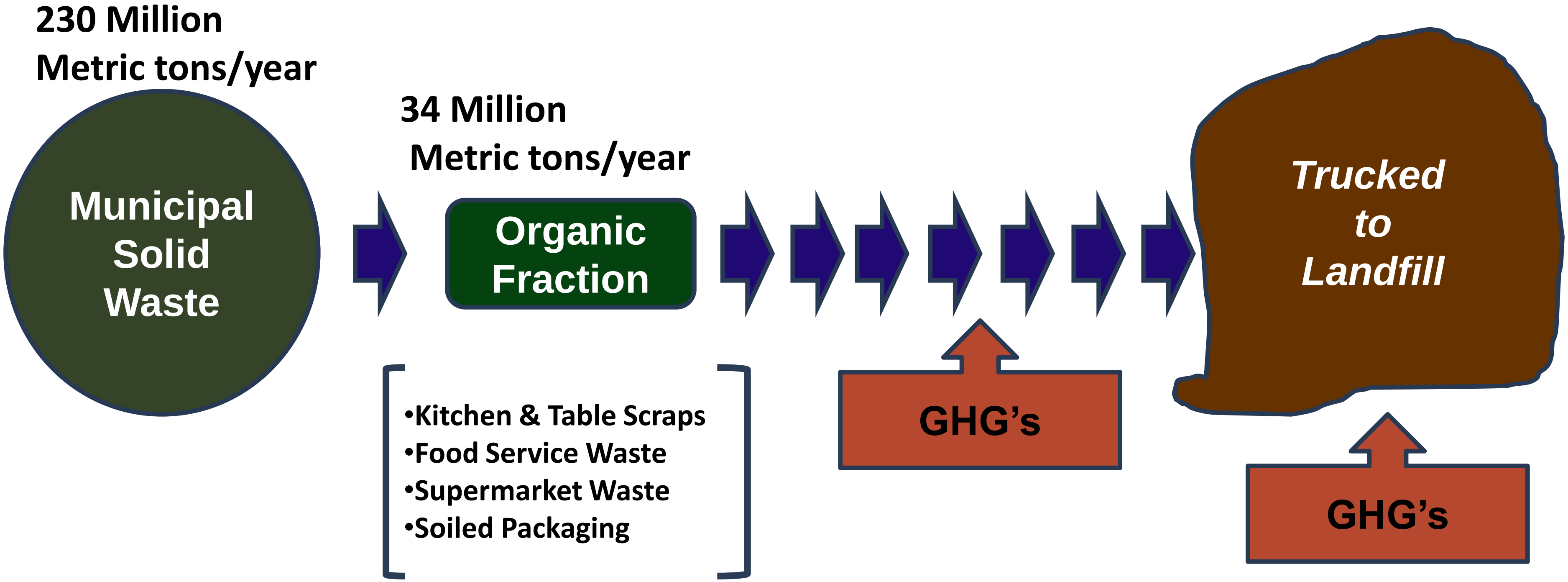
Whey
Deicing Fluid Waste
Woody Biomass



Food waste is 14 % of country’s total waste (2010)

Less than 3% of food waste recovered

America wastes enough food to fill the Rose Bowl daily!



Food waste decomposes in landfills: produces leachate, methane

Europe Converts SSO to Renewable Energy North America is Catching Up

If 50% of the food waste generated each year in the U.S. was anaerobically digested, enough electricity would be generated to power over 2.5 million homes for a year.

Laura Moreno, EPA, 2012

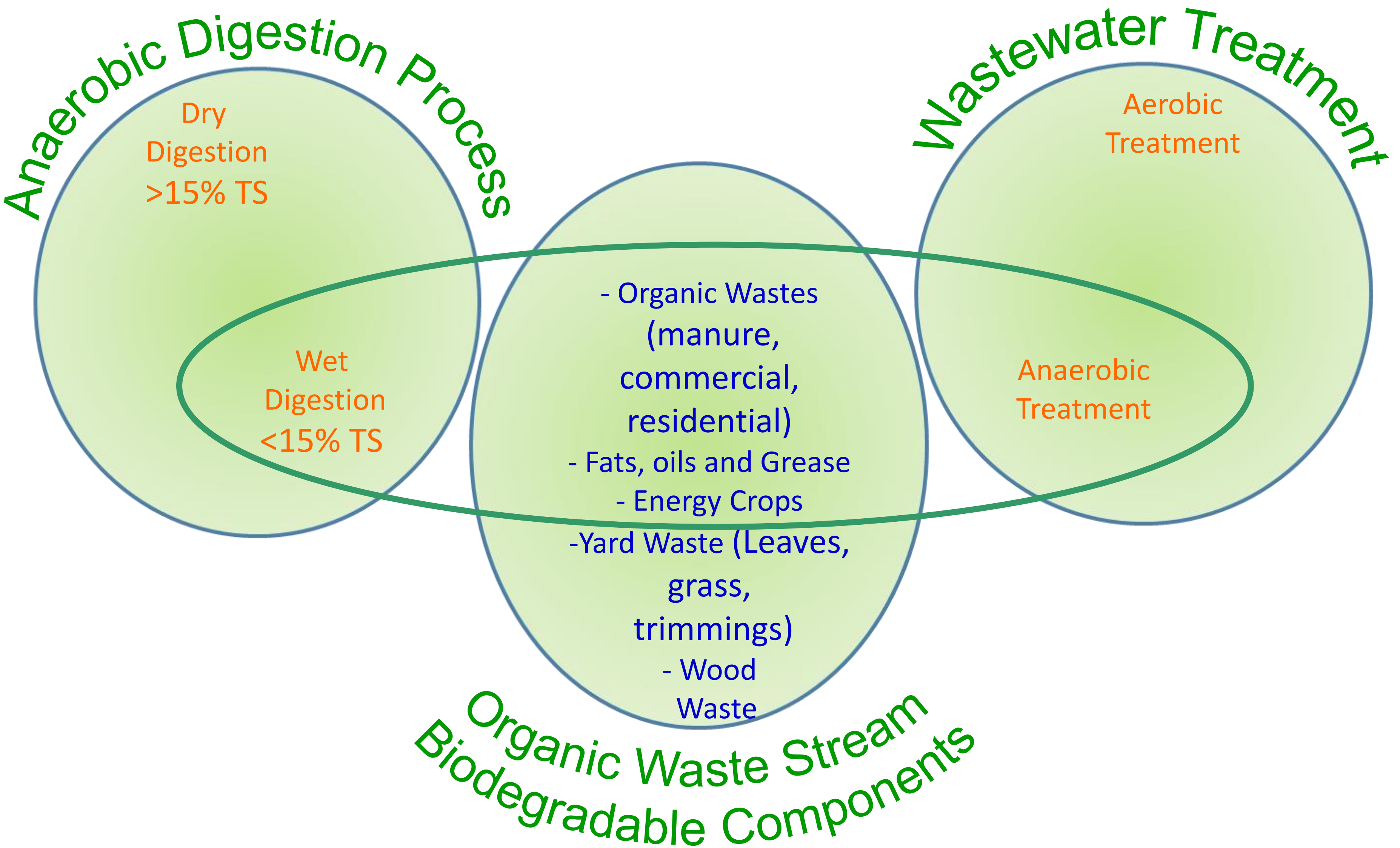
230 Million Metric tons/year

34 Million Metric tons/year

Municipal Solid Waste → Organic Fraction → Source Separated Organics → *Trucked to Landfill*

- Kitchen & Table Scraps
- Food Service Waste
- Supermarket Waste
- Soiled Packaging

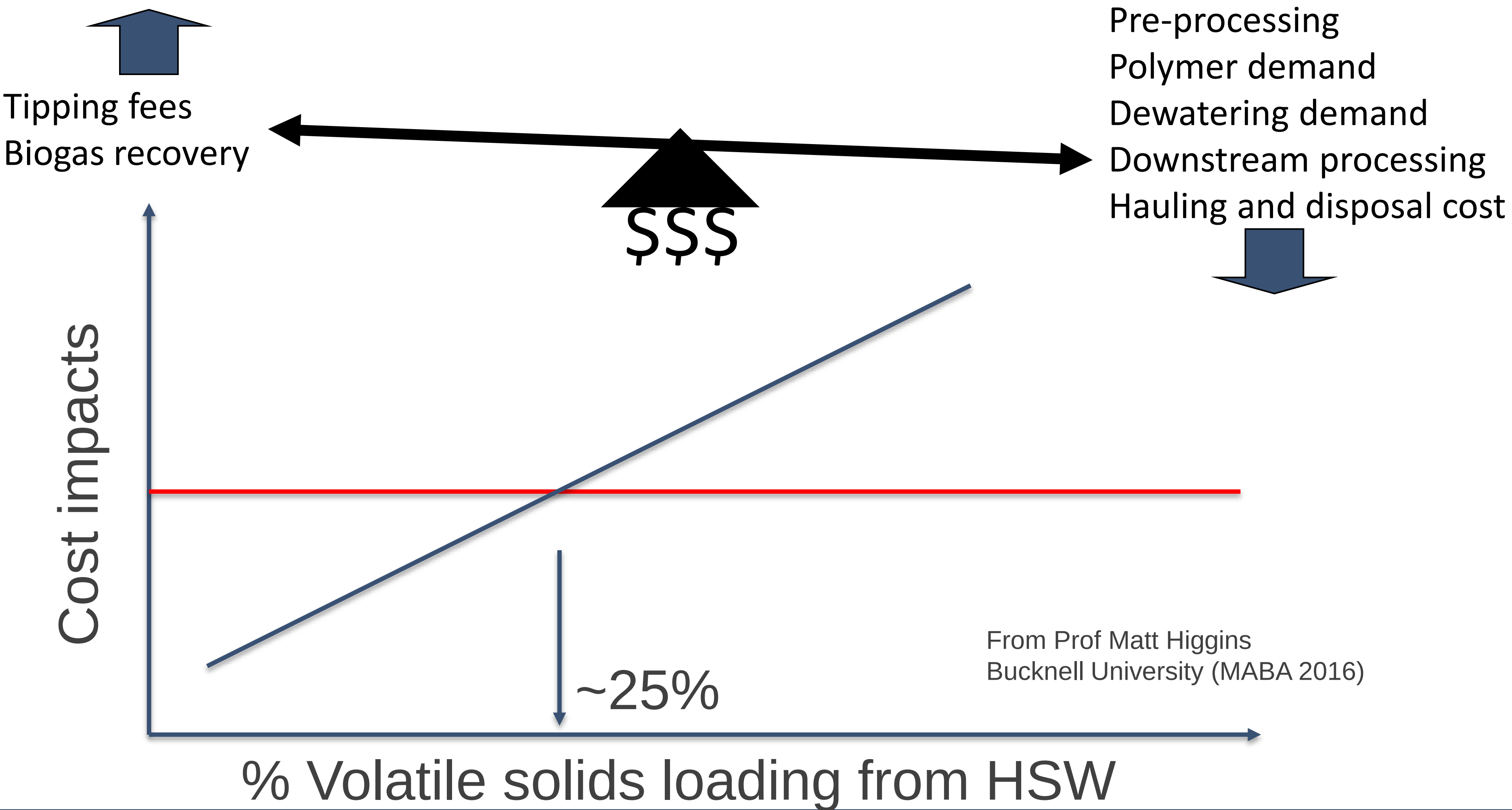
Combine with Water Resource Recovery Facilities



Why Water Resource Recovery Facilities

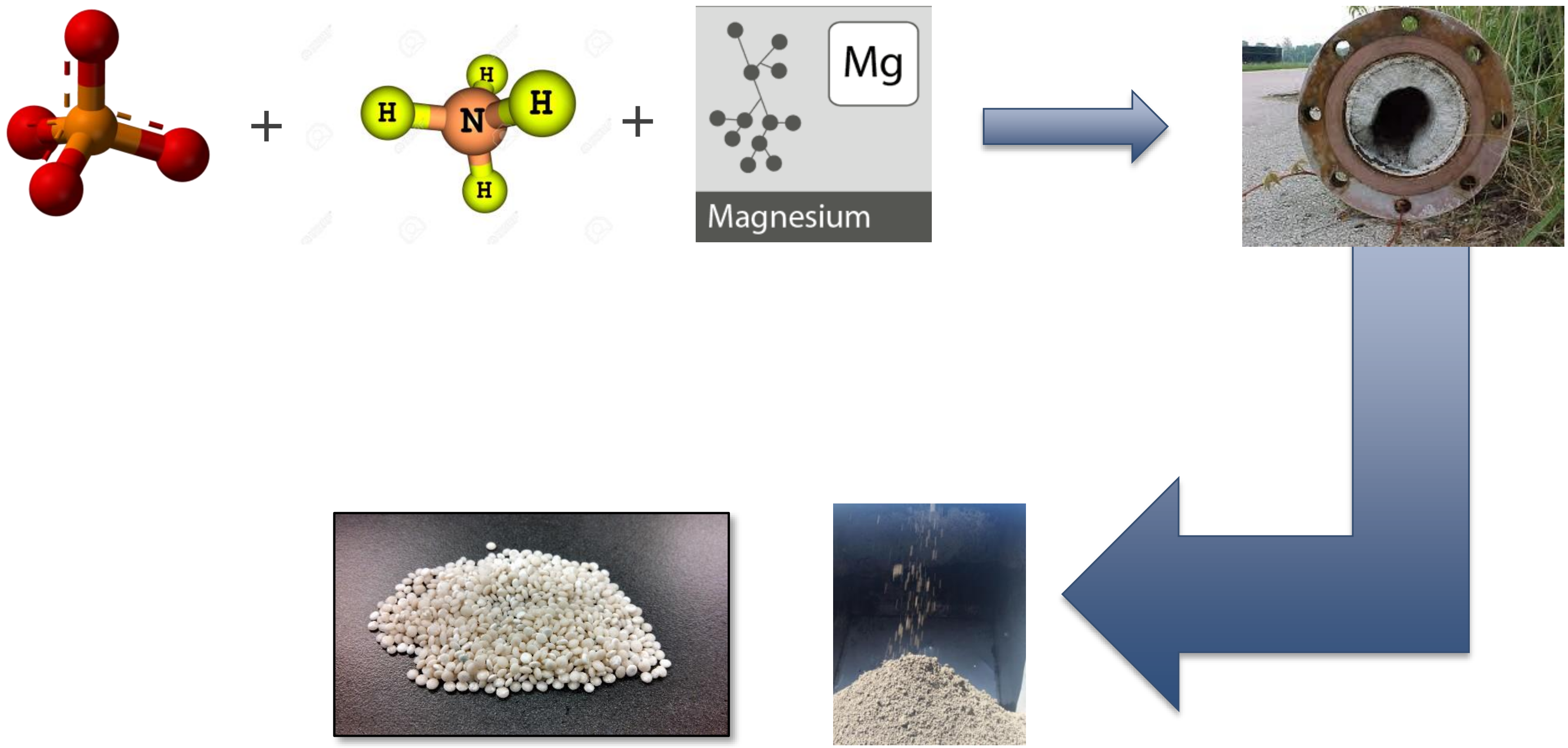
- Infrastructure already in place
- ~15-30% excess digestion capacity nationwide
- Energy demand on the rise
- Located in populated areas: proximity to waste streams
- Still, need to be economically viable!

Economic balance is important to the practice



From Prof Matt Higgins
Bucknell University (MABA 2016)

Struvite: from nuisance to resource recovery



Example technologies to recover struvite (PAM)

Pearl®

AirPrex®

Multiform™

- Recovery can be practiced from
  - Digested biosolids: positive impact on dewatering
  - Centrate/filtrate

Rare Earth Elements

REUTERS: Nearly 2 kilograms of gold in every metric ton of ash left from burning sludge

ES&T (2015): There's as much as $13 million worth of metals in the sludge produced every year by a million-person city - ~2.6M is Gold and Silver

Metal recovery (Rare Earth Elements, REE)

- Free ion concentrations are low
- Readily form complexes with CO_3^{-2} and PO_4^{-3}
- Complexation with organic compounds
- Adsorption onto sediments and biological material

How do REEs in wastewater behave in WRRFs?

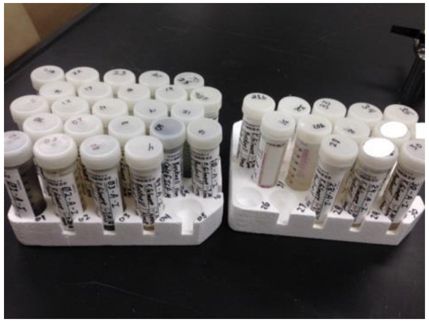
Is there economic incentive to recover and reuse REEs present at WRRFs?

Value drives recovery potential

Element (Abbr.)	Commodity Price ($/lb)
Silver (Ag)	$242/lb[(4)]
Aluminum (Al)	$0.91/lb[(4)]
Gold (Au)	$17,700/lb[(4)]
Cadmium (Cd)	$0.91/lb[(5)]
Chromium (Cr)	$5/lb[(5)]
Copper (Cu)	$2.72/lb[(4)]
Iron (Fe)	$0.05/lb[(4)]
Gallium (Ga)	$165/lb[(5)]
Iridium (Ir)	$8,475/lb[(4)]
Manganese (Mn)	$0.91/lb[(4)]
Molybdenum (Mo)	$7.75/lb[(4)]
Nickel (Ni)	$6.35/lb[(4)]
Palladium (Pd)	$11,350/lb[(4)]
Titanium (Ti)	$2.75/lb[(4)]
Zinc (Zn)	$0.91/lb[(4)]

North American REE Sampling Campaign (WE&RF)

Goal – A better understanding of the abundance of REE entering North American WRRFs, and a preliminary look at speciation through selected WRRFs with significant REE input



<u>28 Participating WRRFs</u>

- 2MGD – hundreds of MGD
- Influents ranging from residential to heavily industrial

<u>Sampling Regime</u>

- Influent, Secondary Effluent, and Biosolids Samples
- Influents to be analyzed first to identify facilities with highest occurrences

Anaerobic digestion advances

Thermal Hydrolysis

Pondus

Lystek

Desired performance from anaerobic digestion

1. **Class A biosolids:** sustainability and reuse cost
2. **Less digestion volume: footprint, cost (**water content of the feed sludge)
3. **High digestibility, more volatile solids reduction:** more gas, more energy
4. **Good dewaterability after digestion:** less hauling and cost
5. **Minimize FC reactivation/regrowth potential and odors:** sustainability for land application
6. **High digester loading rate: more throughput, less digestion volume, cost**
7. **Good mixing efficiency, less energy input: Better Digestion, more VSR, more energy recovery and**

Pre-treatment technologies to conventional digestion (ultrasonic, shear, etc.)

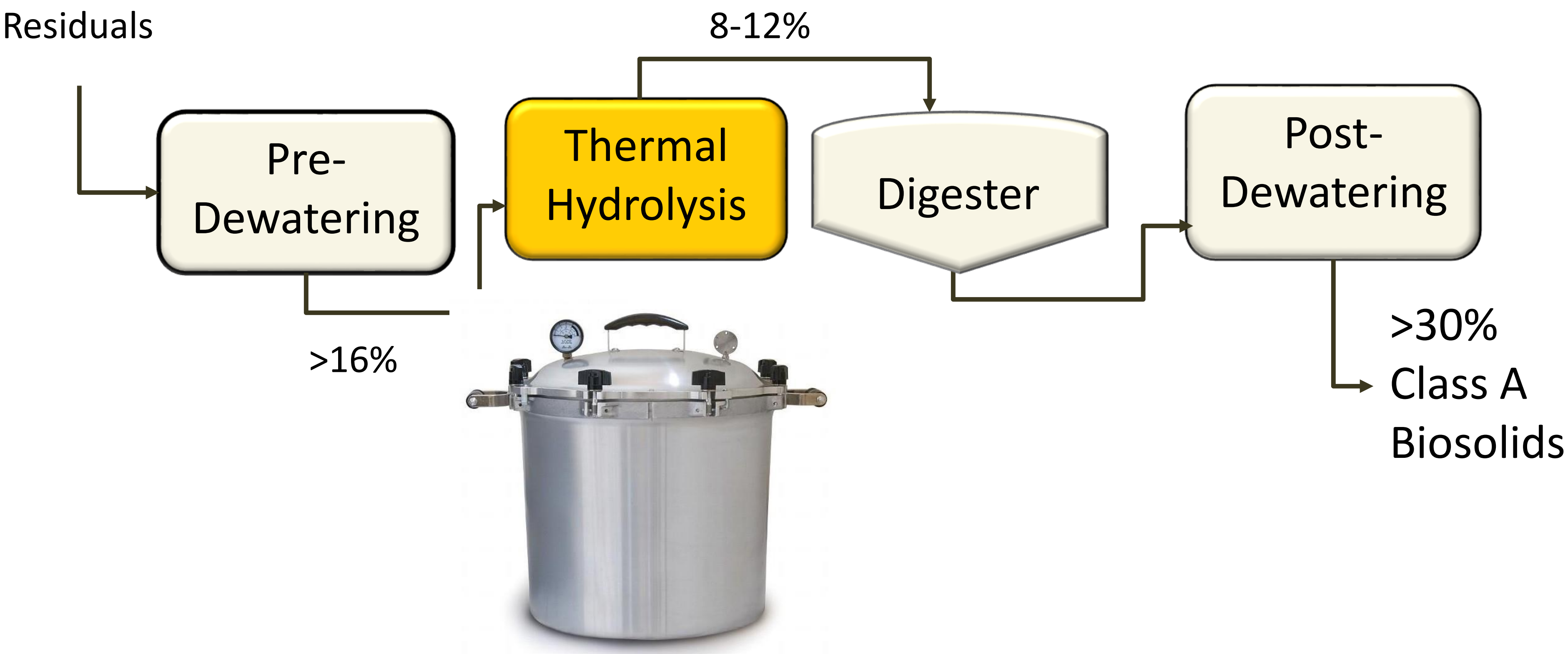
Acid/Gas Digestion

Temperature Phase Anaerobic Digestion

Staged Thermophilic Anaerobic Digestion

Thermal Hydrolysis prior to anaerobic digestion

Thermal Hydrolysis – Advanced Anaerobic Digestion Pretreatment Process



A sludge "pressure cooker" operating at about 330F/165C (90 psig)

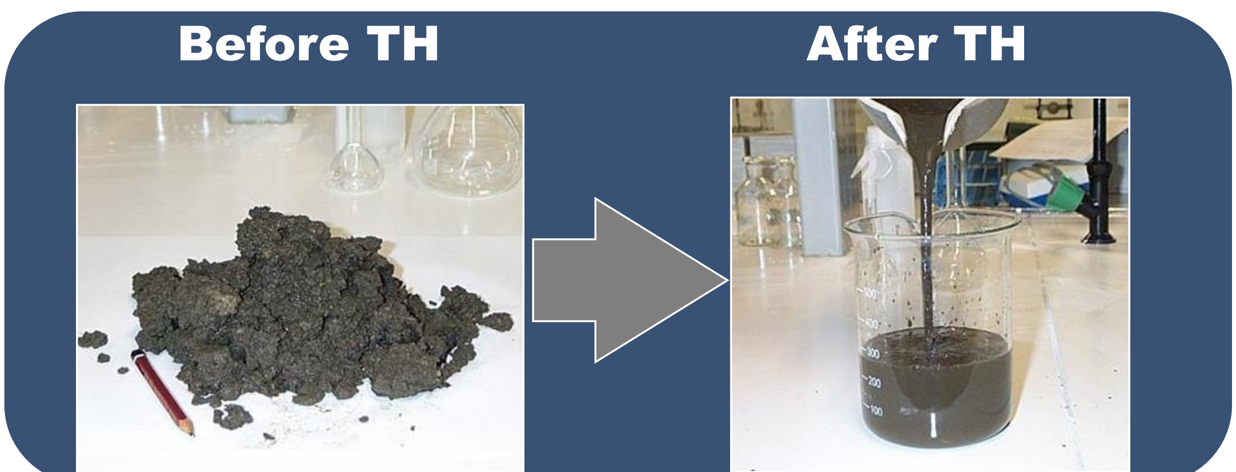
Thermal Hydrolysis Process (THP)

Process

- Treats dewatered sludge (from 14 to 17%) prior to anaerobic digestion, under the following conditions:
  - High temperature of 150 - 170° C (300 – 340° F)
  - Under pressure of 6 to 9 bars (90 – 130 psi)
  - Reaction time 22 to 30 min
- Dewatered sludge Input to digestion 8 to 11%

Result

- Decrease viscosity
  - Allows sludge mixing at higher concentration
  - Decrease digestion volume
- Sterilized sludge (Class A)
- Improves anaerobic digestion
  - Increase VS reduction
  - Improve biogas production
  - Reduce mass for further processing
- Improve final dewatering



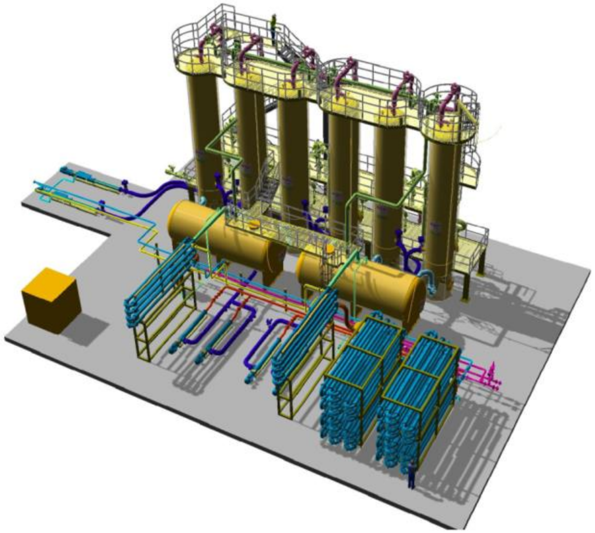
Thermal hydrolysis achieves ALL desired requirements from anaerobic digestion

- Pasteurized solids, Class A
- Digester is fed at 8-12% total solids, half the volume
- Volatile solids destruction is high 55- 65%
- Dewatered cake ~30%
- Proven to not have problem with FC reactivation/regrowth, better odor quality
- 50% more solids loading compared to conventional digestion
- Power required to mix digester is less

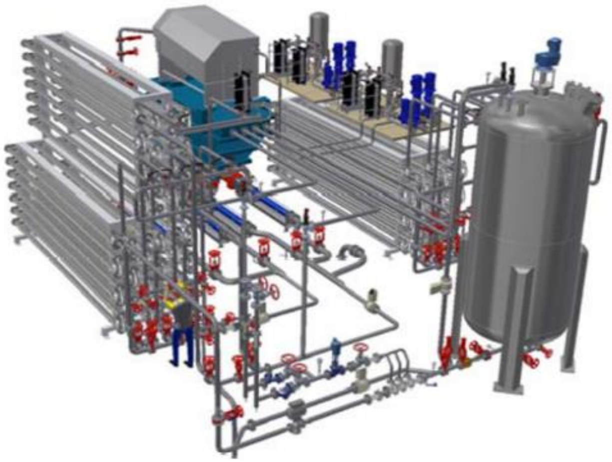
Thermal hydrolysis technology providers

Cambi > 50 facilities

Veolia ~ 12 facilities

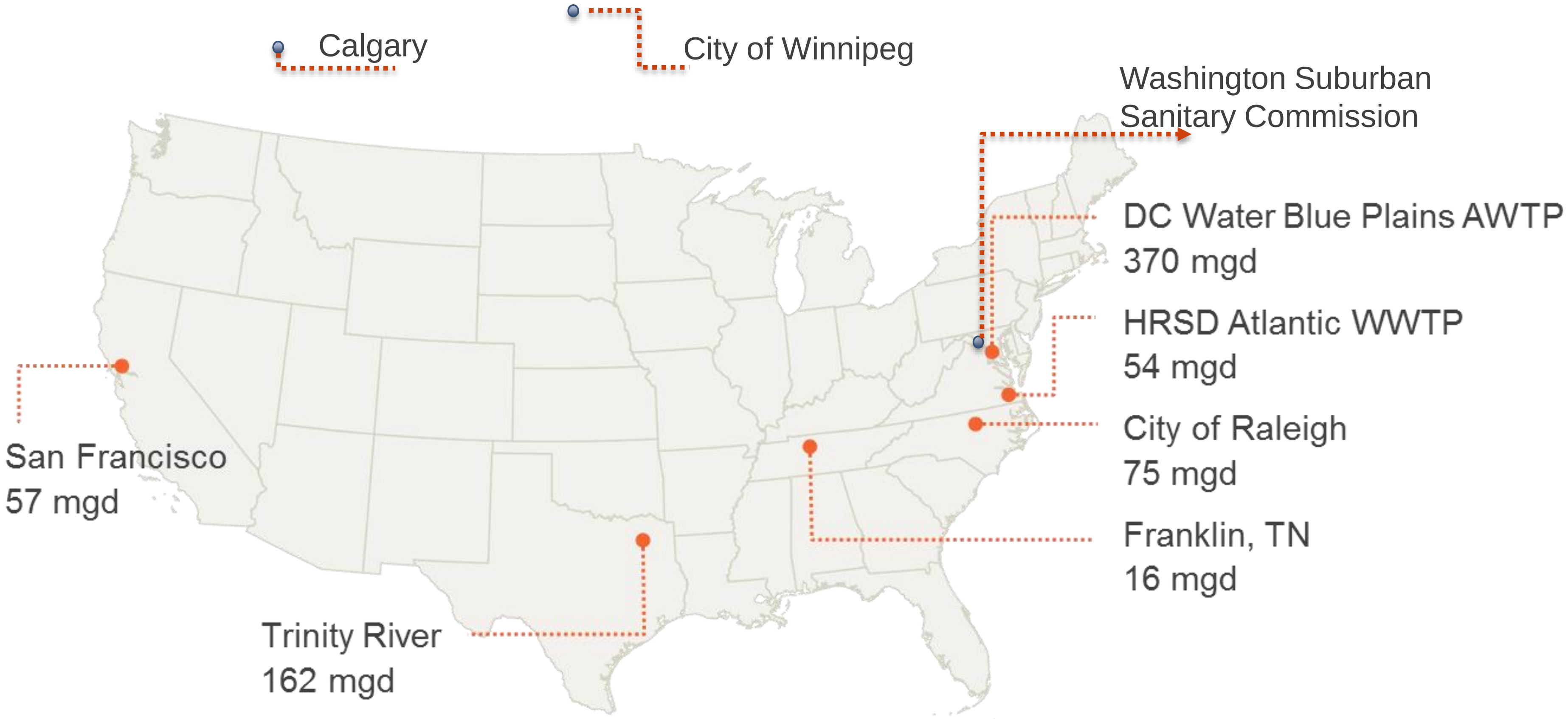


Sustec: 2 facilities



Haarslev: 2 facilities

THP may be coming to a utility near you in the near future…



Thermal Hydrolysis – “no free lunch”

- More complex than standard digestion, steam with high pressure and temp
  - –Will need to train staff on pressure and steam systems
- Greater performance at higher dry solids means more ammonia
  - –Centrate/filtrate need to be treated
- Needs energy (steam)
  - –Energy demand dependent on dry solids input and temperature of recycle
- Production of refractory compounds
  - –Color, refractory COD greater at higher temperatures
- Need to dump heat

Each facility needs own evaluation

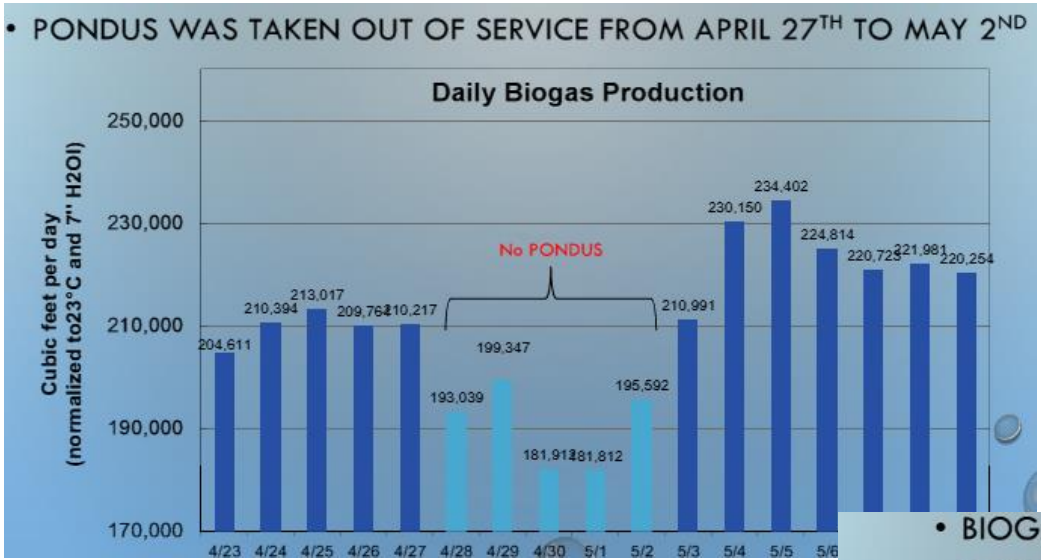
Facility	Feasibility study	Status
Blue Plains DC Water	✓ 2008	Operating 2014, DB
CRWS (TRA)	✓ 2011	Under construction, DB
Piscataway (WSSC)	✓ 2012	In planning, DB
Honouliuli CCH	✓ 2013	Not recommended
Central District Miami	✓ 2014	Not recommended

Avoiding construction of new digesters and reduced biosolids for beneficial use are NOT outweighed by pre-dewatering, THP cost and beneficial use costs

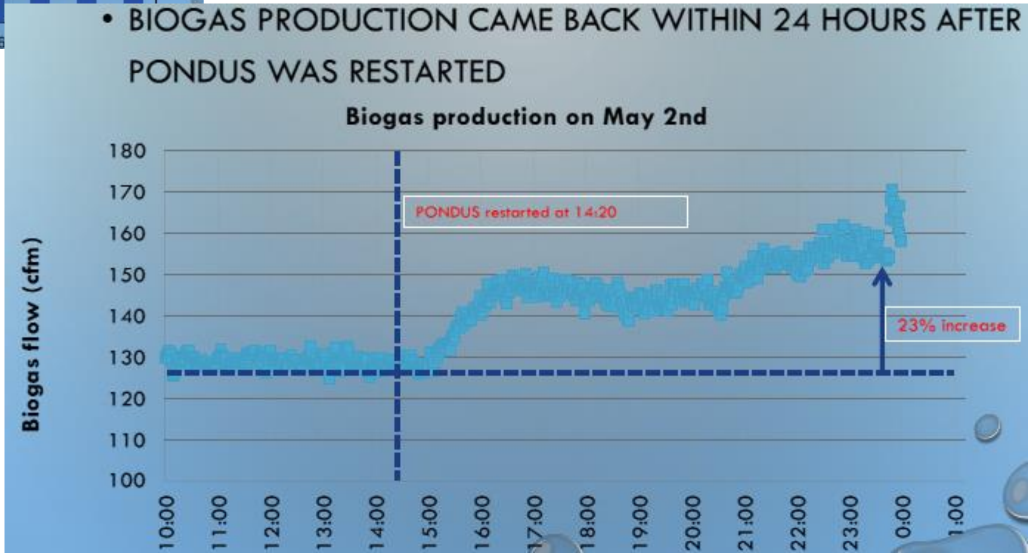
Thermo-Chemical Hydrolysis Pondus, CNP – Technology

- Applied only to thickened WAS
- TWAS is heated to 65-70 (150-160)
- Caustic soda (50% concentration) added to TWAS: 1.5-2.0 liter per 1 m3
  → pH ~11
- Detention time: circulation through reactor and HEX 2.0-2.5 hrs
- Hydrolysis increased COD to ~ 170%, brings down the pH to 6.8-7.0
- Decreased viscosity, enhanced mixing
- Increased digester solids loading rate

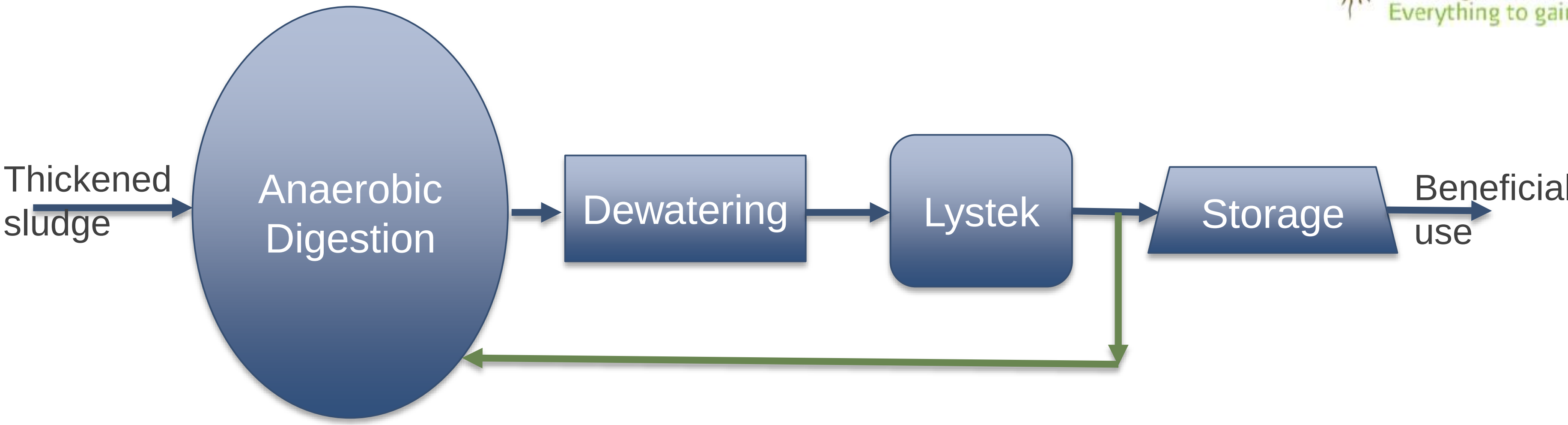
First USA installation, Kenosha Water Utilities ~22 MGD



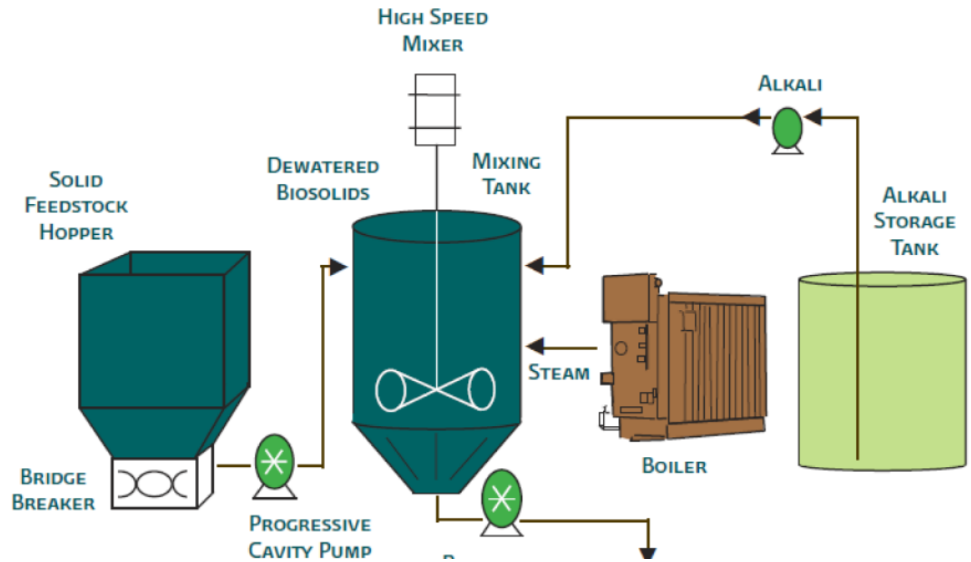
Courtesy of Central States WEA
May, 2016



Lystek in solids treatment scheme



Lystek Process



Thermo-Chemical Hydrolysis: Lystek

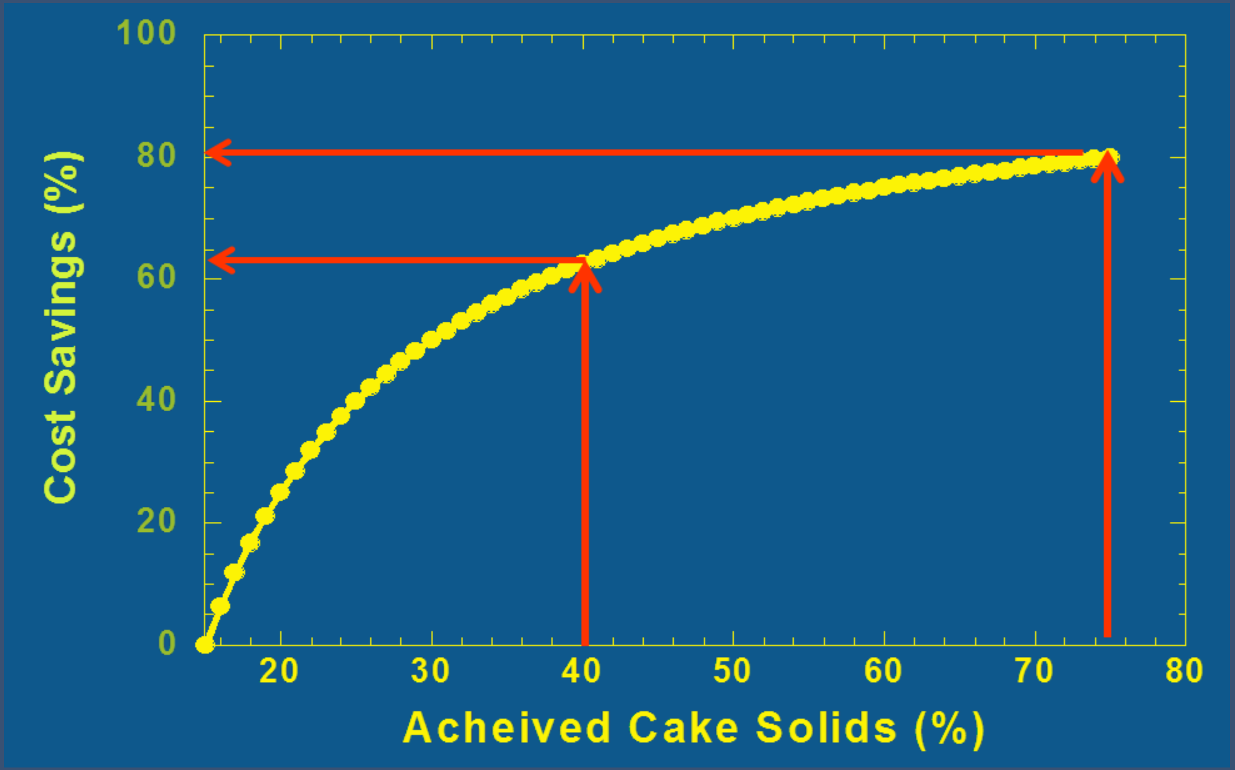
- Applied to dewatered solids/biosolids
  - Low pressure steam (165oF)
  - High shear mixer
  - Alkaline addition 9.5-10 pH
- Class A EQ, ~15% flow-able product
- 6 facilities in Canada
- First facility in USA: Fairfield Suisun Water District (October 2016 as part of the BAB2E)
- On-site, off-site
- DB, DBT, DBOOF

Advances in dewatering

Bucker Press

SLG, Orege

BioP impacts

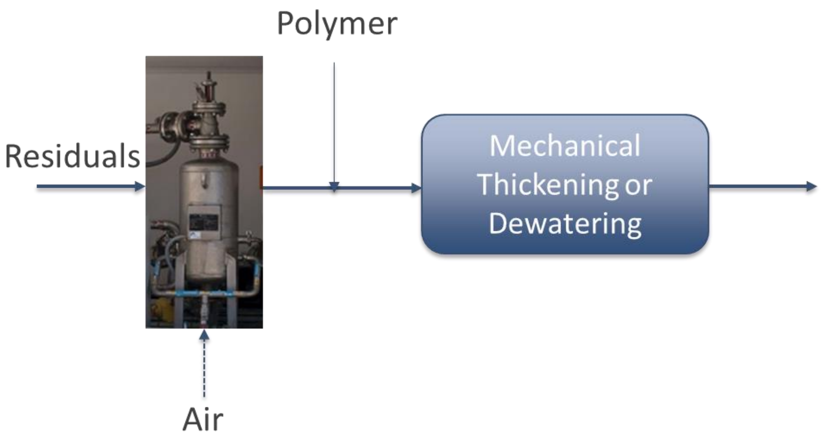


Bucher Press, Suez

- Technology from fruit pressing industry
- High capital
- ~ cake solids by up to 5 pts
- In UK recently practiced on THP, ~ 40% DS
- 15 to 18 kg/TDS polymer
- serious consideration when hauling and use tipping fees are high

SLG Process, Orege France

- Adds pressurized air to the sludge line in vessel prior to polymer addition
- Proposed theory on conditioning mechanism:
  - Air bubbles get enmeshed in the sludge floc
  - Less dense flocs
  - Under compression, air bubbles collapse leaving behind passages/cracks that allow water to be easily squeezed out
  - Technology is expected to work better for BFP type technologies as compared to centrifuges



First USA installation: Lehigh County WWTP, PA

- 7 MGD, Anaerobic digestion
- 3 BFP
- Demonstrate to purchase agreement
- Side by side
- ~2 yrs payback
- Demonstration at Welsh Water and University of South Wales

	Control BFP	SLG/BFP	Improvement
Cake Dryness	15%	18-18.5%	20-30%
Polymer Usage (lb/dt)	60	45	25%
% solids recovery	98%	≥ 98%	Same or better

BioP and dewatering impacts

~ 4pts decrease of cake solids

Mainly due to PO4-P

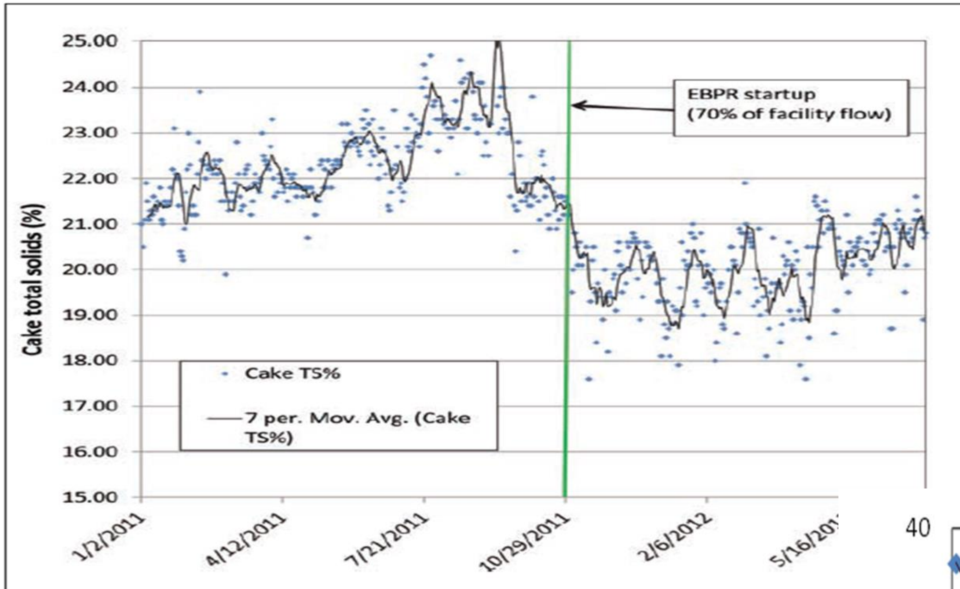
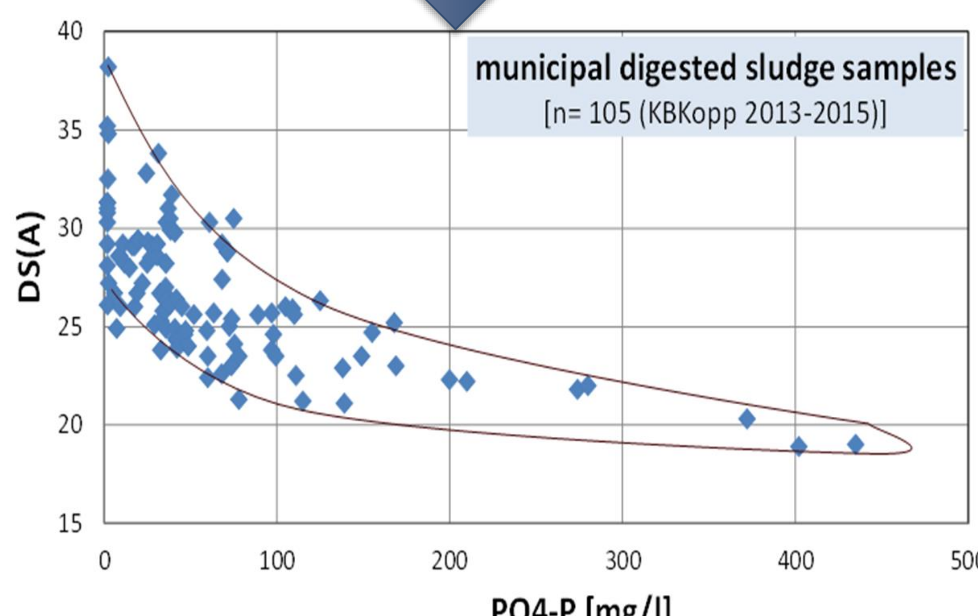


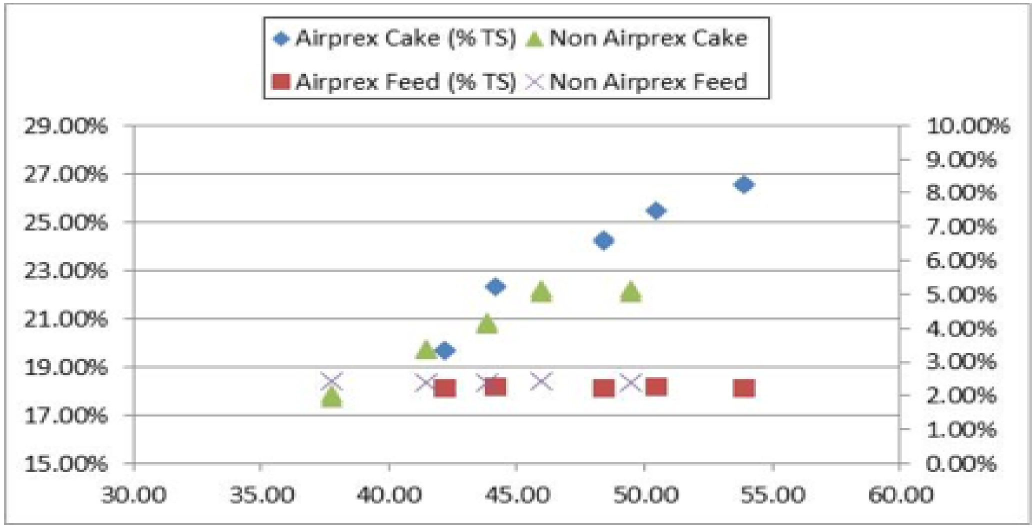
Figure from Cavanaugh, L., K. Carson, C. Lynch, H. Phillips, J. Barnard, and J. McQu
(2012). "A Small Footprint Approach for Enhanced Biological Phosphorus: Remov
Results from a 95 MGD Full-Scale Demonstration," WEFTEC 2012 Proceedings (O



(Kopp, 2016)

Recover dewaterability by removal of PO4

AirPrex Piloting at SDWWTP, Miami Dade, March 2016



- Precipitation and/or recovery of struvite from biosolids enhanced dewatering performance
- Working with Metro Water Reclamation District to further understand and pilot
- WE&RF research project (Matt Higgins, Bucknell) is looking to shed more light

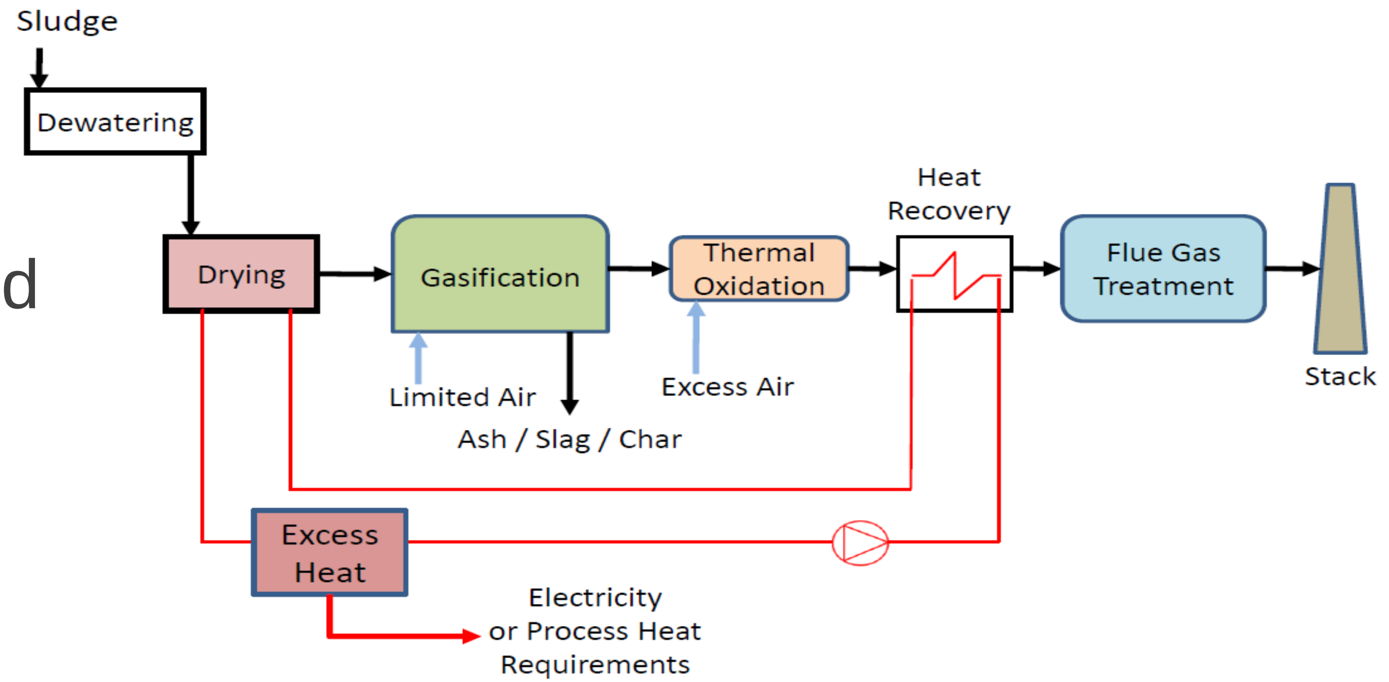
Advances in thermal processing

- **Gasification**
- **Pyrolysis/biochar**
- **Super Critical Water Oxidation**

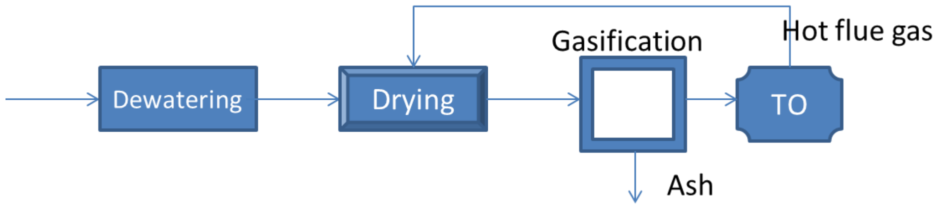
Thermal processes

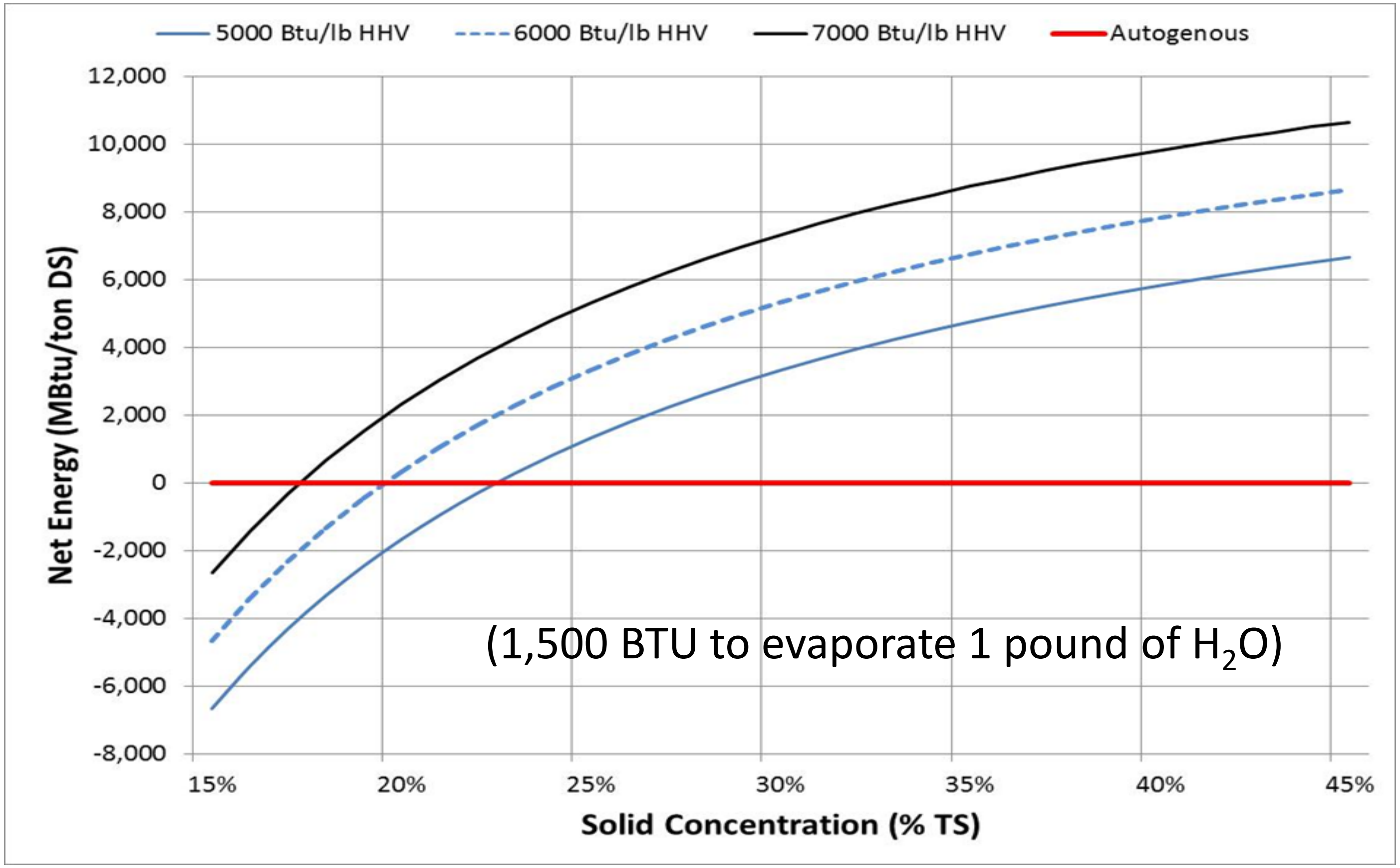
	Combustion	Gasification	Pyrolysis
Temperature (F)	1,650 – 2,000	1,100-1,800	390 – 1,100
O_2 Supplied	> Stoichiometric (Excess Air)	< Stoichiometric (Limited Air)	None
Products	Flue Gas (CO_2, H_2O) & ash	Syngas (CO, H_2) & ash	PyroGas, Oils, Tars & Char

Close-coupled gasification

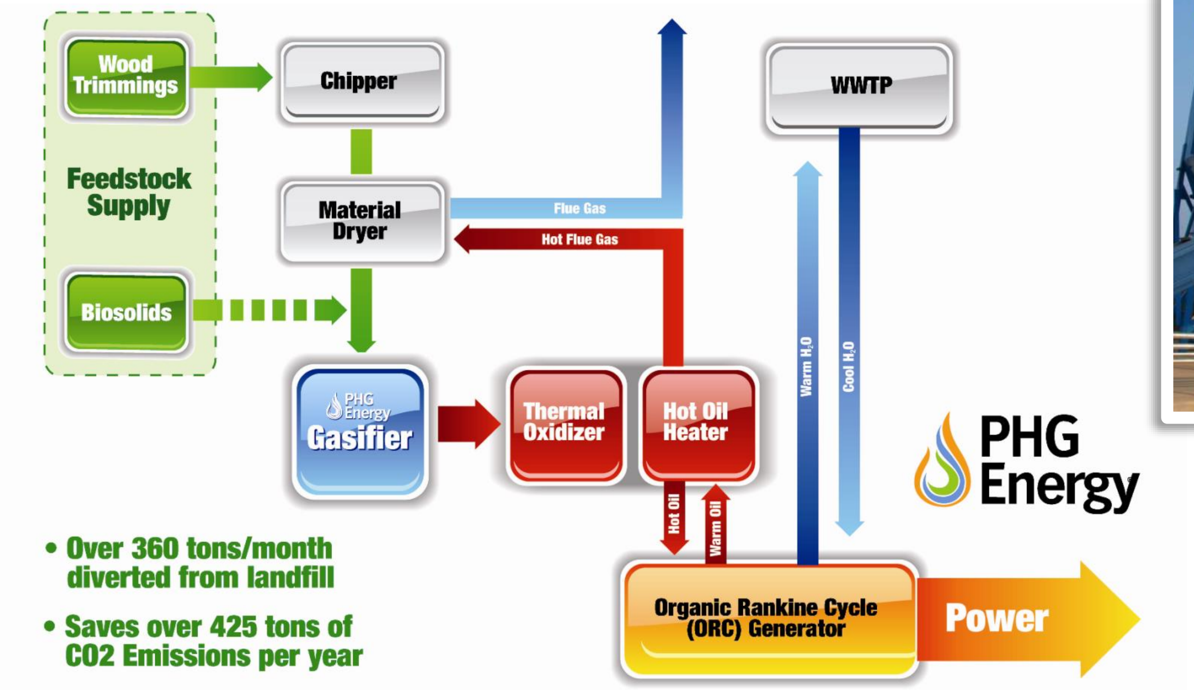


Net energy vs. solids type and concentration





City of Covington, TN



- Small facility 1 MGD plant
- Started October, 2013
- 80:20 wood to biosolids, wood ~1 inch
- PHG operating now, 5 days/wk, 10 hrs day
- 120 kW energy, more than average (100kW)

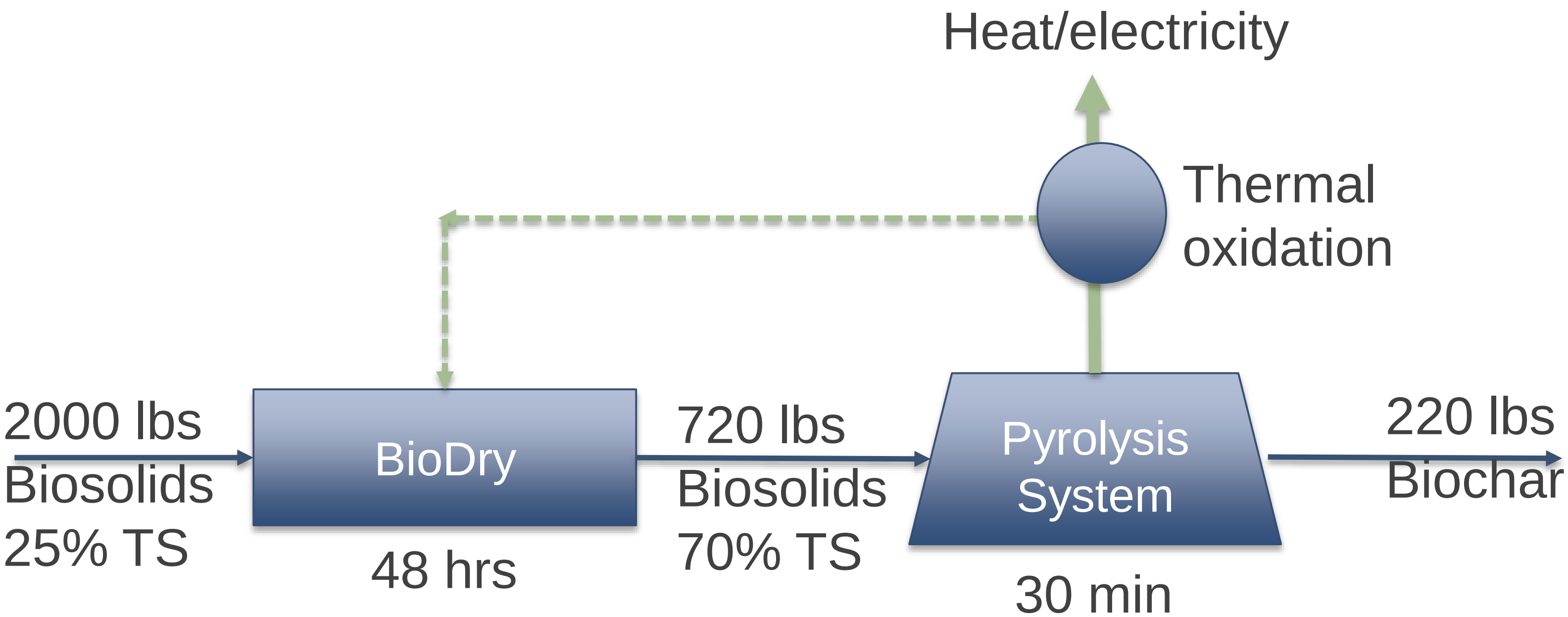
Lebanon, TN Facility

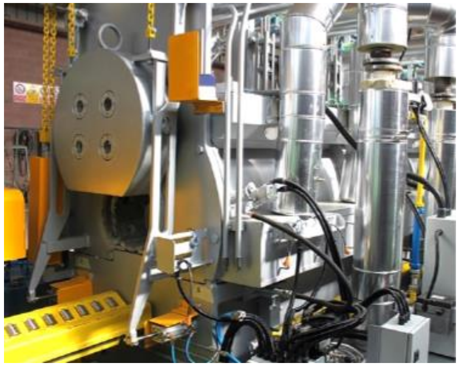
- 5 MGD WWTF
- Started October 2016, finished end of 2016
- 32 tons per day: 3 tons sludge, 3 tons tires, 26 tons wood waste
- Generate 420 kW, ~ 60% of average use
- $100k/yr cash flow

Delta Diablo, BAB2E program

- In planning phase
- ~ $10 M project, 25% of Delta Diablo biosolids, 467 KW
- 1 truck/day yard waste + 2480 wet tons/yr biosolids @ 25%TS
- 60% from anaerobic digestion + 40% gasification → off the grid!

Biodry and Pyrolysis (BIOFORCETECH)





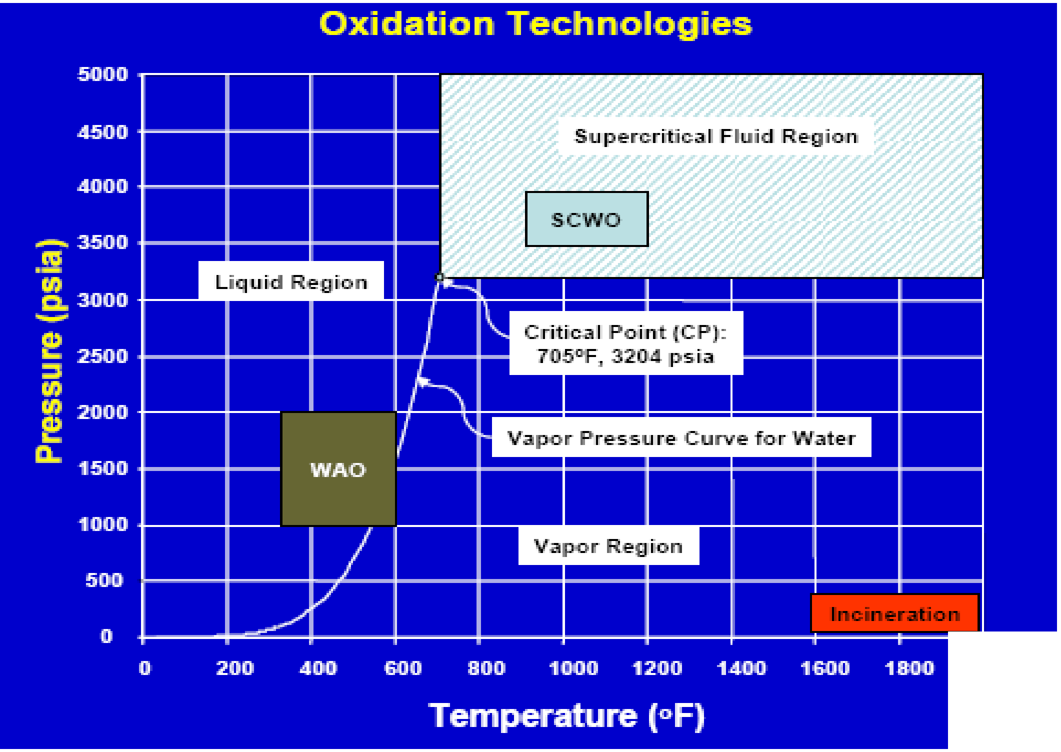
Silicon Valley Clean Water Demonstration BAB2E Program

- Under construction
- ~$10 M project
- 6 biodryers and one pyrolysis unit
- 8,000 tons biosolids/yr
- Pyrogas and bio-oil burned for energy, supplement bio-drying
- ~700 tons/yr biochar

Innovations could reduce the process from a multi-step system…

…to a single step process

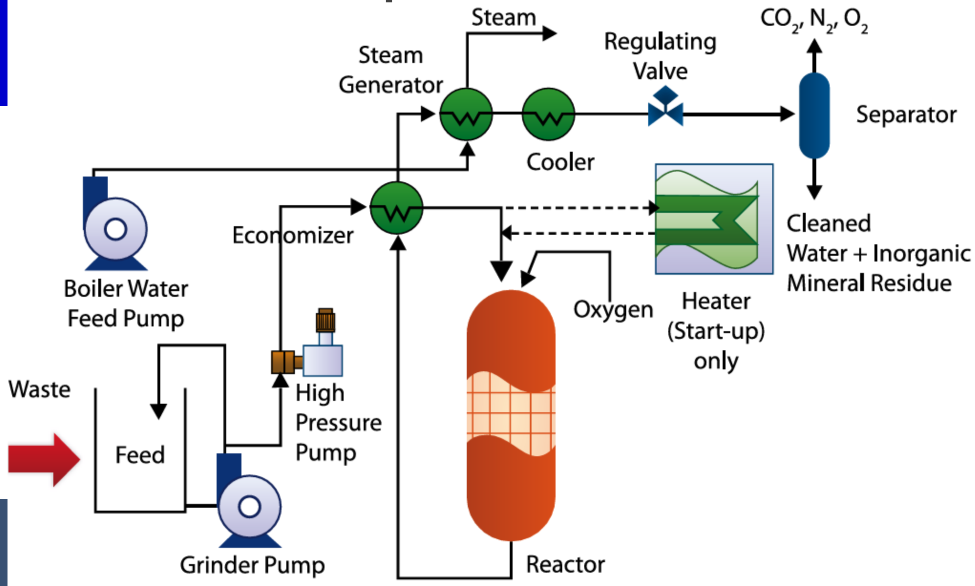
Supercritical Water Oxidation – SCFI Group



Aqueous Sludge
+
O_2

H_2O, Liquid CO_2,
Metal Oxides/Salts
energy

AquaCritox®



- Spain demonstration site
- Still working to process ~16% input

USA demonstration sites

- BAB2E Program
  - Dublin San Ramon Services District – SCFI/Synagro
  - West County Wastewater District – SCFI/Synagro
- Orange County Sanitation District, CA

Closing remarks

- Processing and managing residuals will remain a challenge: no single or standard solution.
- Drivers will focus on preserving the earth resources and sustainable practice require adapting to these pressures and drivers.
- Economic sustainability and resource scarcity will dictate the resources we need to recover from residuals
- Expect to see a place in the future for most existing technologies with gradual shift to more untraditional technologies such as gasification/pyrolysis, SCWO and HTML

Questions?