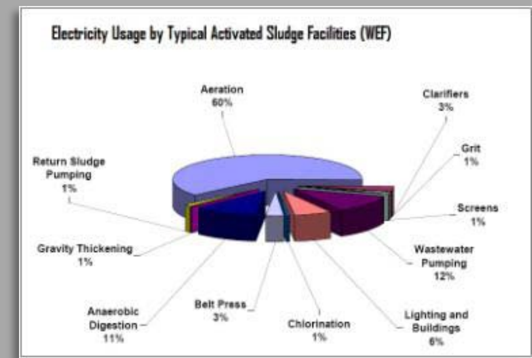
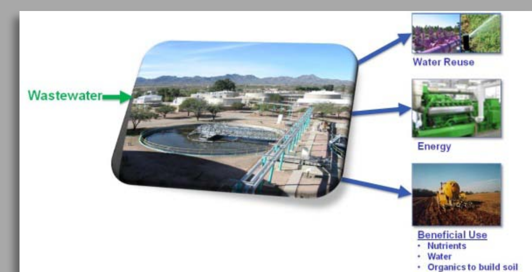
Energy Conservation and Recovery in Wastewater Treatment Facilities



OWEA 2010 Biosolids Specialty Workshop –

University Plaza Hotel & Conference Center

December 9th - Columbus, Ohio



J. E. Smith, Jr, DSc, BCEE

C. Dassanayake, PhD, PE

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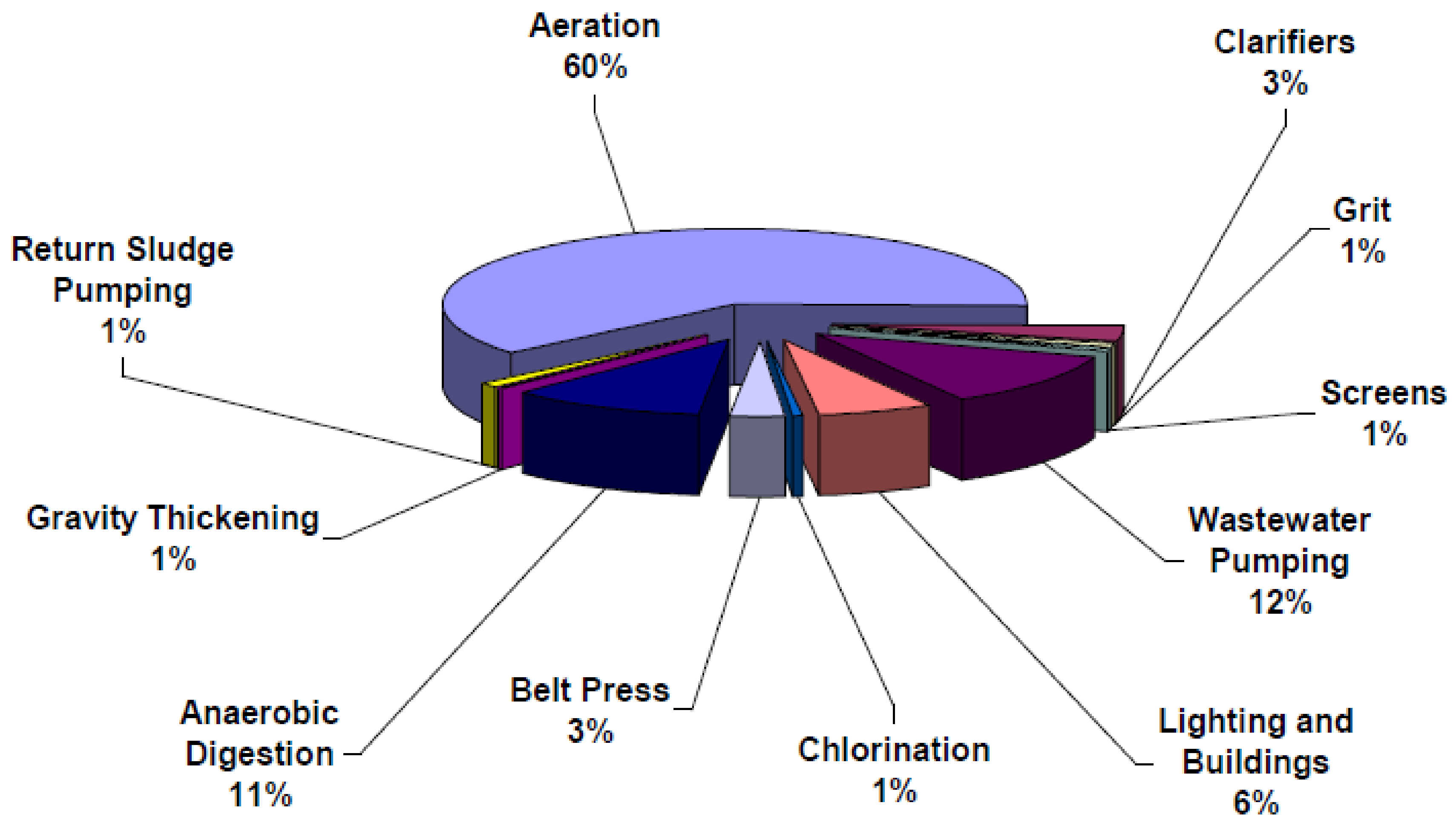
Presentation Overview

- Conserving the Energy Used in Treating Wastewater
- Transforming the Constituents in Wastewater into Valuable Products
- Production of Biogas
- Enhancing Gas Production
- Combined Heat and Power
  - ✓ Gas Cleanup
  - ✓ Power Production
  - ✓ Heat Recovery

Why is Energy an Important Consideration in Wastewater Treatment?

- Est W&WWT Electric Usage at 100 B KWH/yr and a cost of $7.5B/yr
- On average, wastewater treatment facilities spend ~ 25 % of their operating budgets on energy.
- Energy costs are second only to labor costs
- Average usage of electricity = 1,200 kWH/MG
- Average daily residential energy use is 31 kWh per home

Electricity Requirement for Typical Activated Sludge Facilities



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Resource Centers Convert Wastes into Valuable Products

Wastewater

Water Reuse

Energy

<u>Beneficial Use</u>
- Nutrients
- Water
- Organics to Build soil

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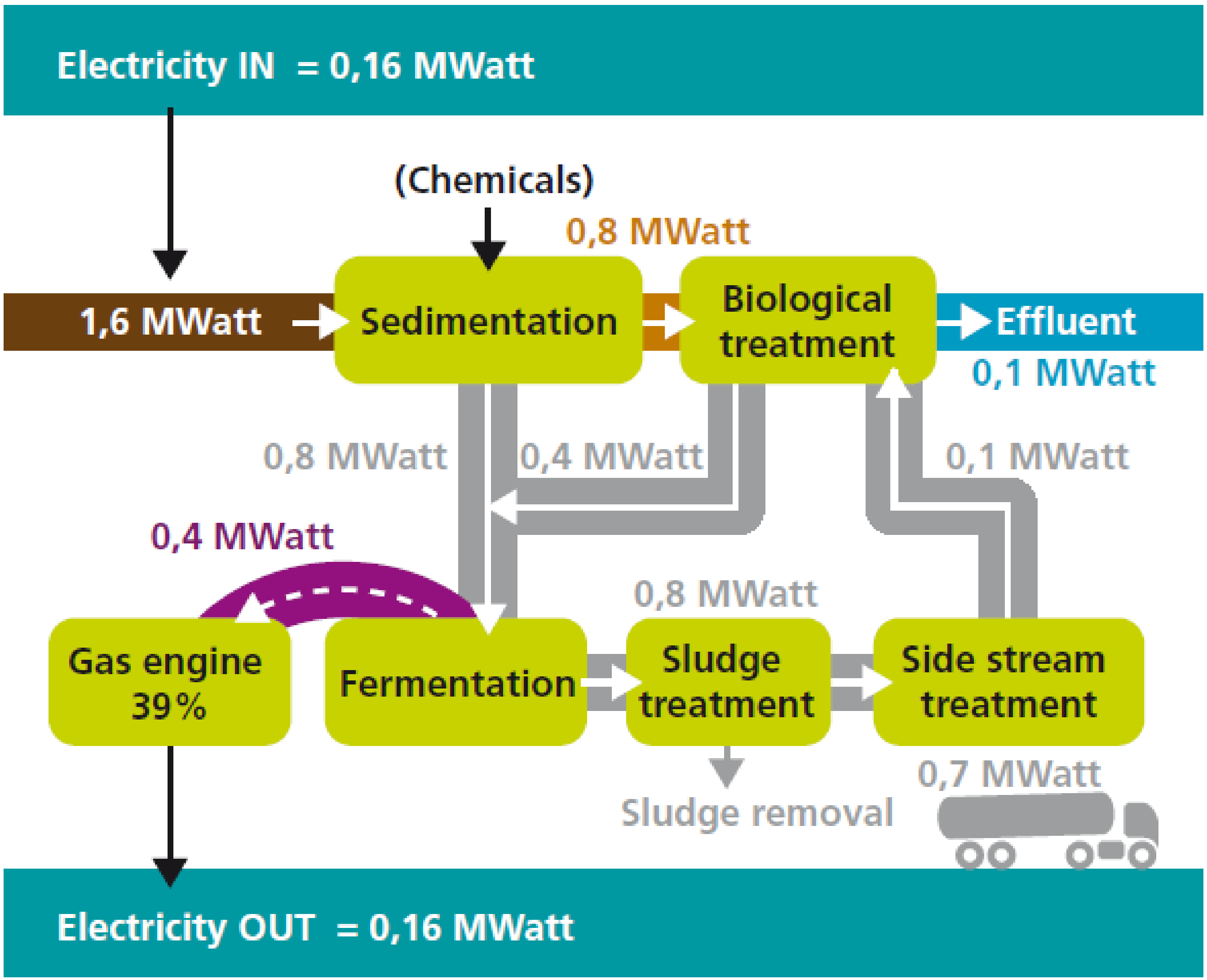
ENERGY FACTORY



Aeration Tank

The Major Place to Save Energy

Some Considerations:

- Can the loading on the aeration tank be lowered?
  - ✓ Can primary clarification be improved?
- Do I have the most efficient aeration equipment?
- Air Delivery Mechanism
  - ✓ Ratchet delivery up or down-5:1
  - ✓ Monitor DO in Basin(s)
  - ✓ Automatic Controls

Aeration Efficiency

Aerator Type	Aeration Efficiency, kg O_2/kWh (lb O_2/hp hr)	
	Standard Conditions	Field Conditions
Fine-pore aeration[1]	5.0 – 6.5 (8.2 – 10.7)	2.5 – 3.5 (4.1 – 5.8)
Course bubble aeration[1]	2.5 – 3.5	1.0 – 2.0
Surface centrifugal (low speed)	1.2 – 3.0	0.7 – 1.4
Surface centrifugal (draft tube)	1.2 - 2.8	0.7 – 1.3
Surface axial (high speed)	1.2 – 2.2	0.7 – 1.2
Downdraft open turbine	1.2 – 2.4	0.6 – 1.2
Downdraft closed turbine	1.2 – 2.4	0.7 – 1.3
Submerged turbine, sparger[1]	1.2 – 2.0	0.7 – 1.1
Submerged impeller	1.2 – 2.4	0.7 – 1.1
Surface Brush and blade	0.0 – 2.2	0.5 – 1.1

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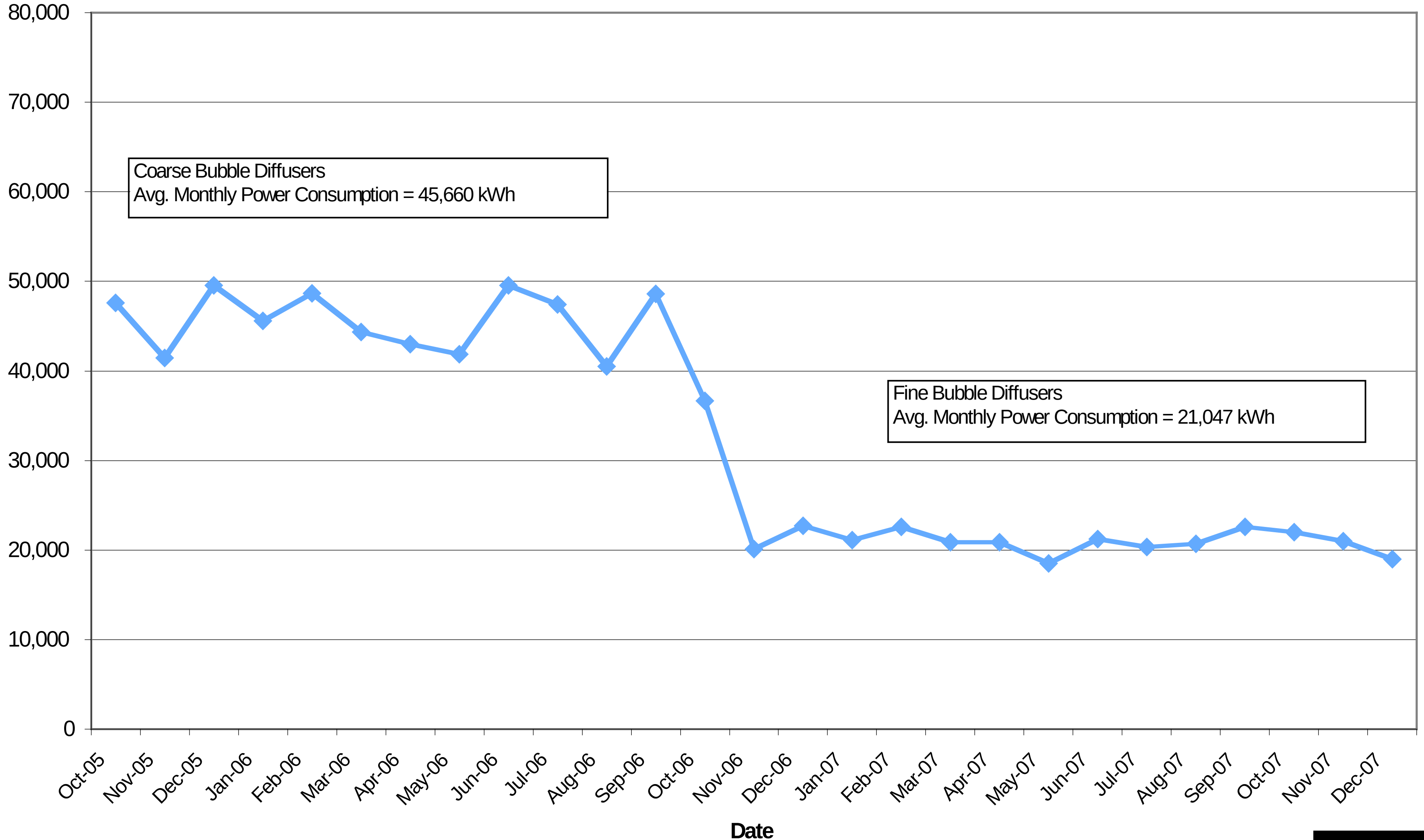
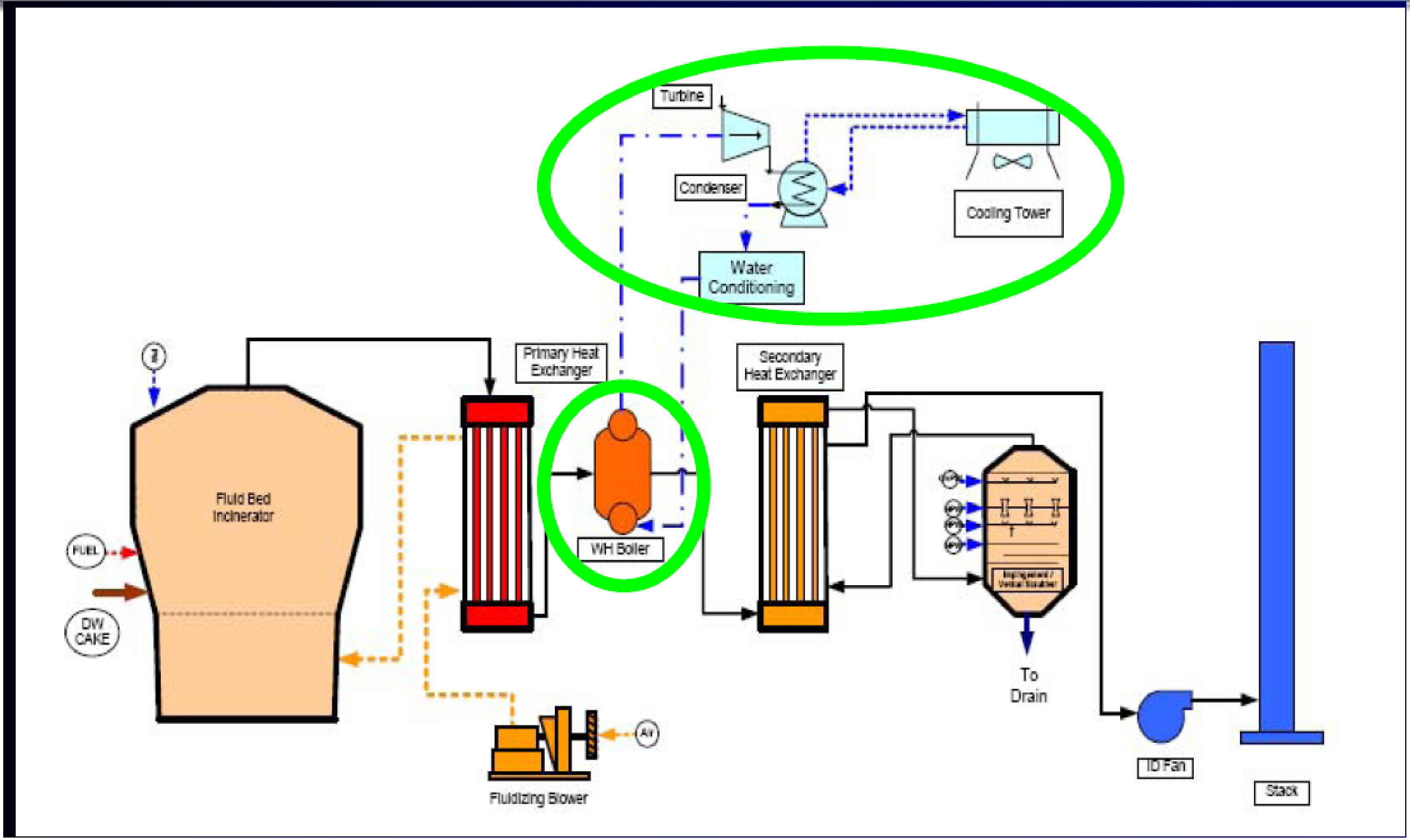
Village of Palmyra WWTF



Courtesy of Joe Cantwell, SAIC


Milorganite

Fluidized Bed Incineration with Energy Recovery



Courtesy Bob Dominak, NORSD

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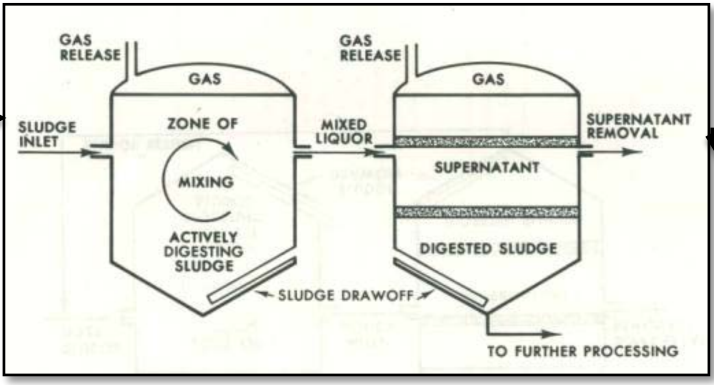
Utilize Materials in Wastewater to Create Valuable Products like Energy

Transformation
Like Anaerobic Digestion

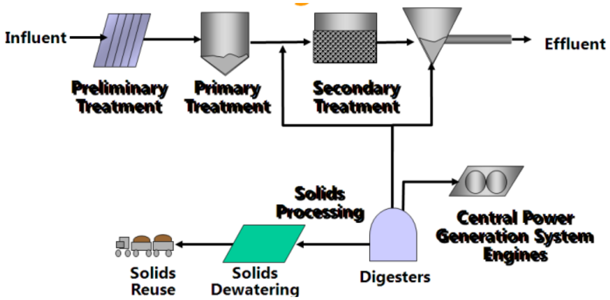
Organics in Wastewater



Energy
- **Biogas**
- **Other Product**

Biosolids for Beneficial Use

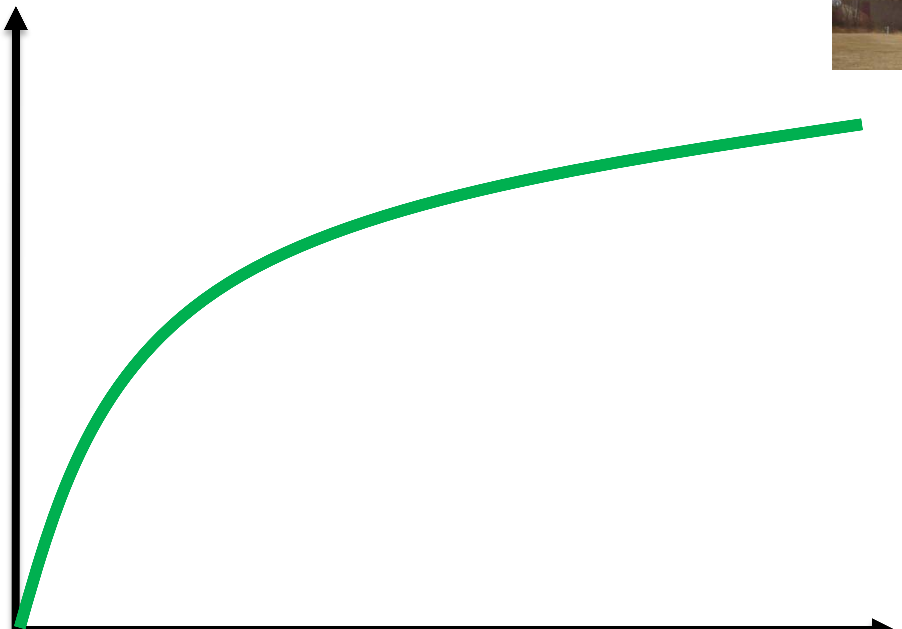
US Wastewater Treatment Facilities (WWTFs) with Anaerobic Digestion & Off Gas Utilization



- **# WWTFs in USA is 16,583**
- **# WWTFs in USA treating a wastewater flow > 5 MGD is 1,066 or ~ 6 % of total number**
  - ✓ **# of these with anaerobic digesters is 544**
  - ✓ **# of facilities with anaerobic digesters that utilize biogas is 106**

Source: 2004 Clean Watersheds Needs Survey

Relationship Between the Organics in Wastewater / Residuals and Biogas



12 cf gas/lb VS consumed

600 BTUs/cf gas

Requirements for Anaerobic Digestion

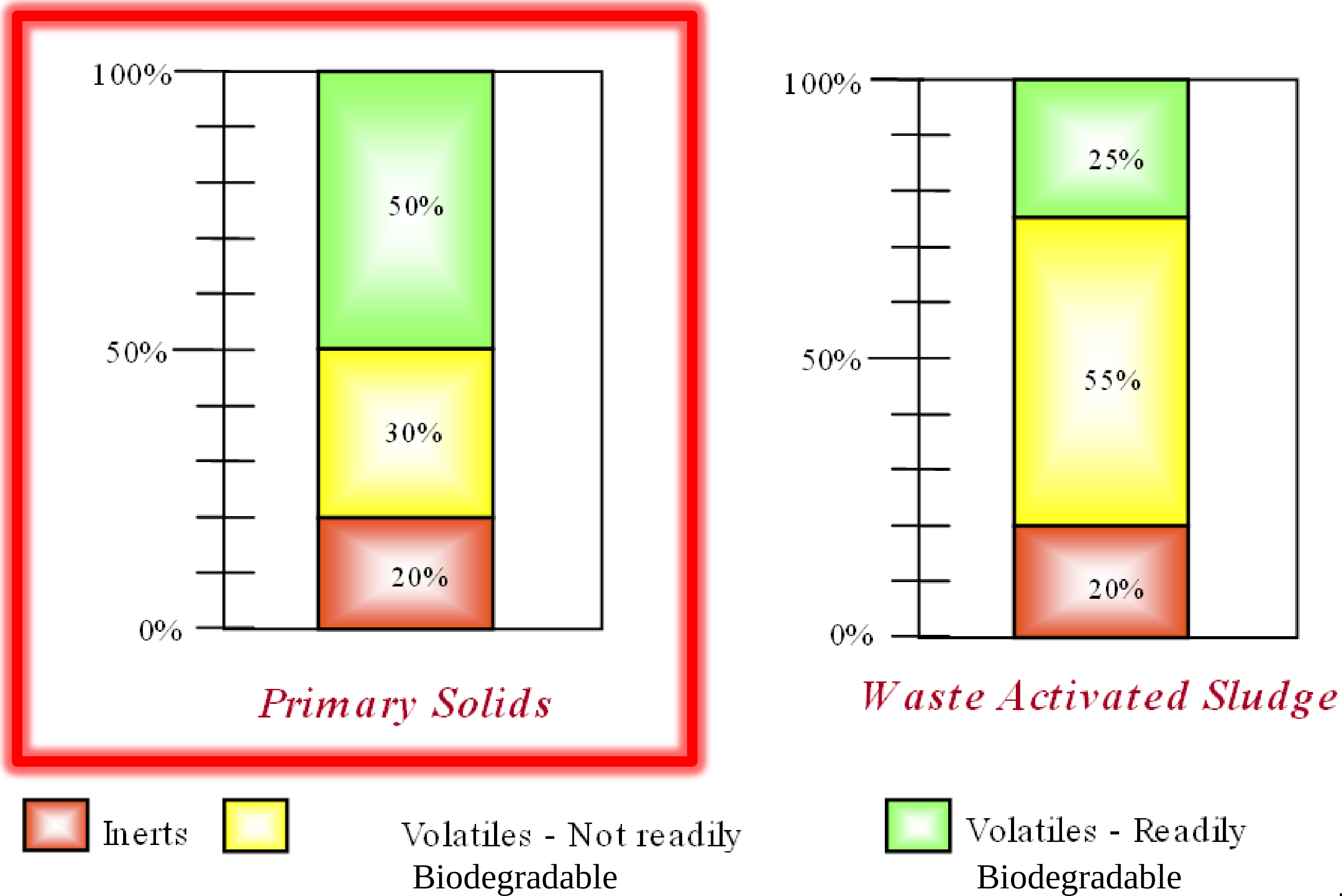
Process Conditions

- temperature
- retention time
- organic loading rates
- chemical environment (pH, volatile fatty acids, ammonia, etc.)

Feedstock

- biodegradability
- moisture content and particle size
- C/N ratio
- presence of inhibitory or toxic compounds

Composition of Raw Primary and Waste Activated Sludge Solids



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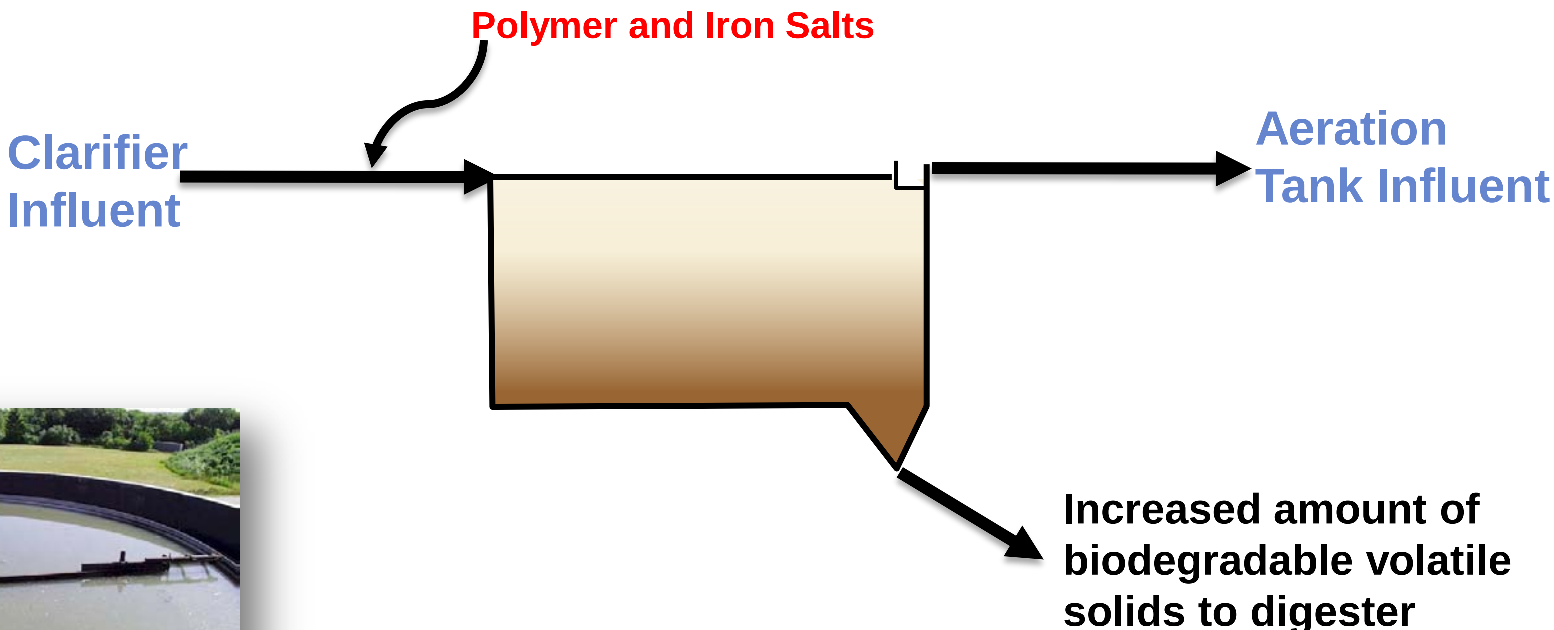
Enhance Primary Clarification

- Polymer addition
- Get other benefits (p-removal)



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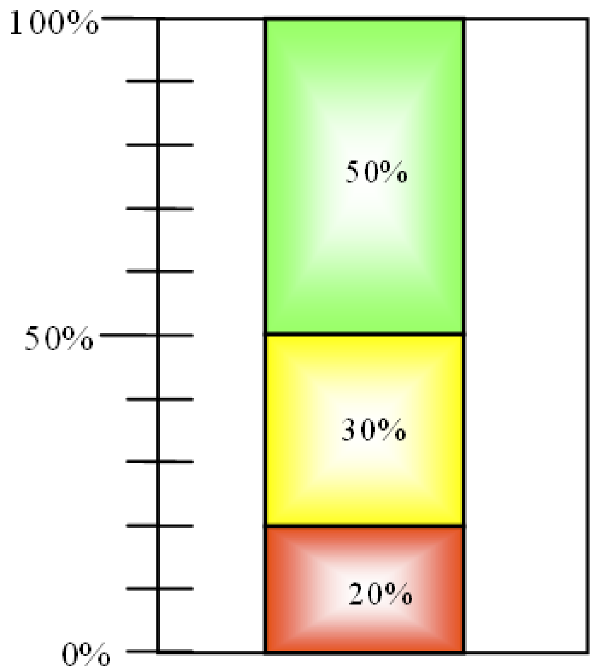
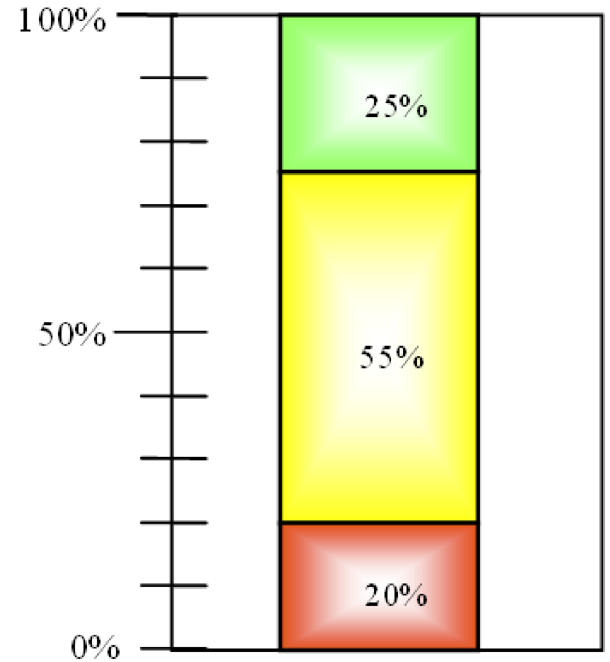


Primary Solids



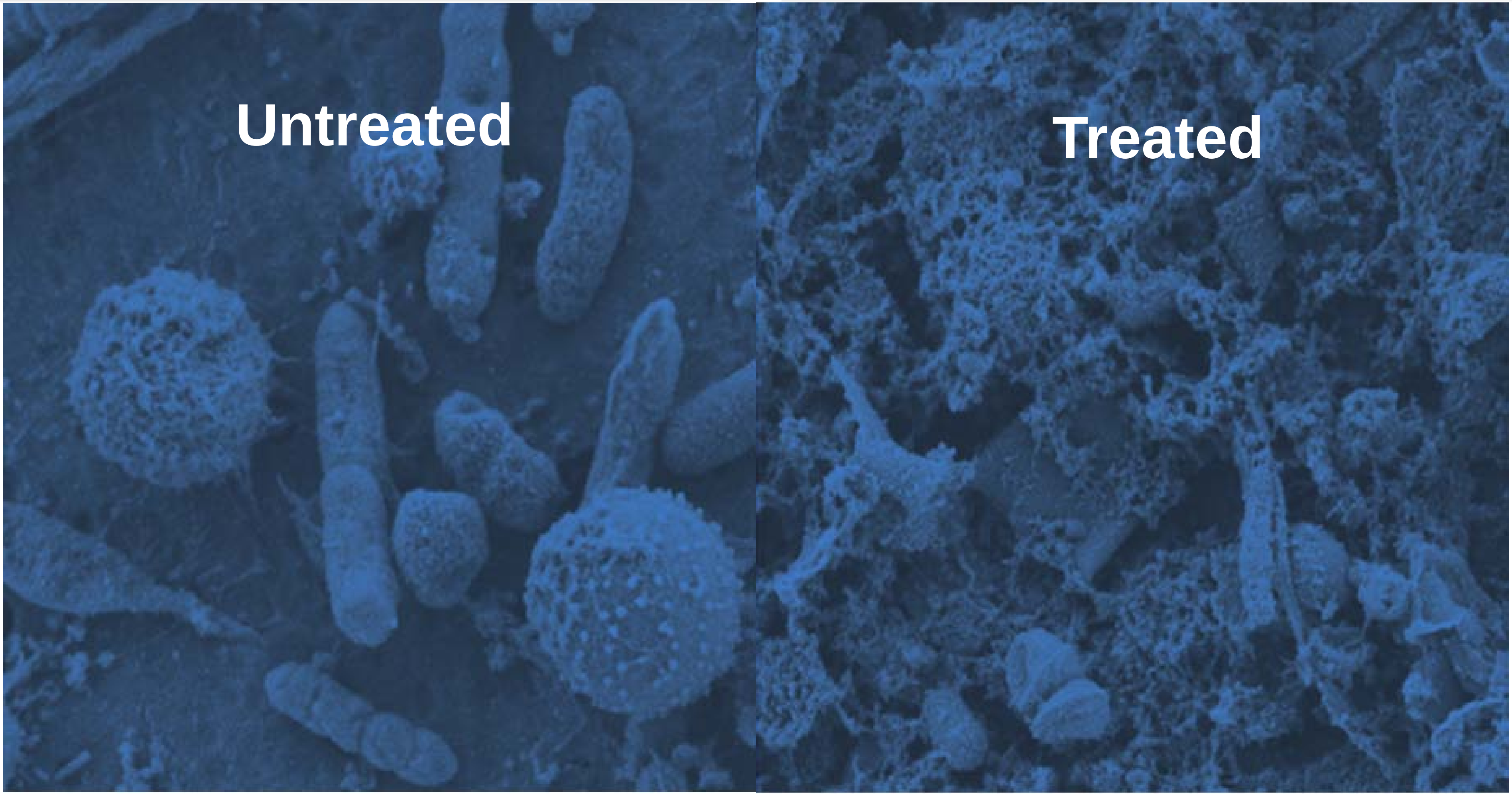
Waste Activated Sludge

Inerts

Volatiles - Not readily Biodegradable

Volatiles - Readily Biodegradable

Can Waste Activated Sludge Be Made More Biodegradable?



Processes for Pre-Treating WAS

- Thermal hydrolysis
  - ✓Cambi (13 installations), Ve
- Pressure release
  - ✓Crown Biogest (17 installatio
- Electrical
  - ✓OpenCEL (1 installation)

Cambi

Crown

OpenCEL

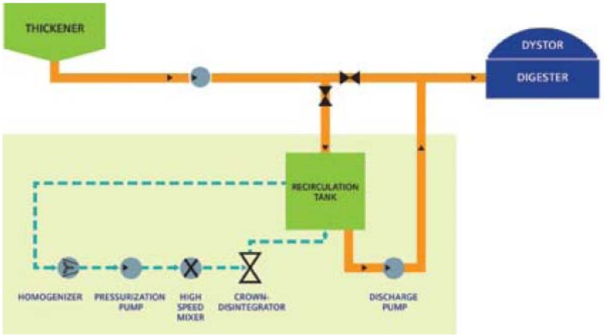
CAMBI's Performance Claims

Parameter	Mesophilic AD	CAMBI + Meso AD
Digester Feed (%TS)	4 – 6	12 – 15
VSLR (kg VS/m^3/d)	1.5	3.5
VS Destruction (%)	40 – 55	55 – 65
Pathogen Content	Class B	Class A
Dewatered Cake TS (%)	20 – 25	30 - 35

Sludge Disintegration Processes

- Macerate sludge to homogenize
- Increase pressure (12 Bar) with PC pump
- High pressure mixer, flow into disintegration nozzle
- As the flow exits the nozzle, cavitation occurs rupturing cell structure
- Sludge can be passed through system three times before discharge to the digesters

Crown Disintegrator
Wiesbaden WWTP - 60m3/hr

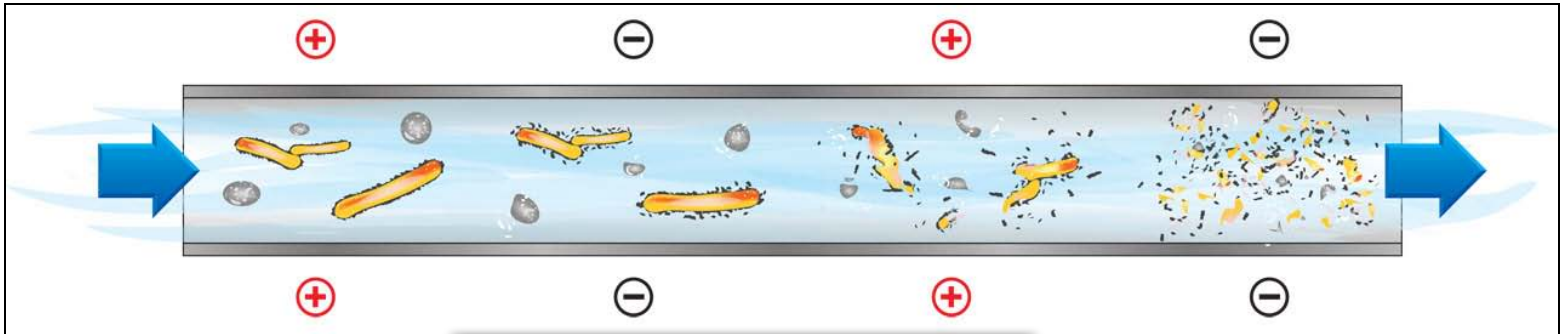


Performance Data by Crown

Site Name	VSr %			Biogas production cf/lb VS des		
	Before	After	% inc	Before	After	% inc
Wiesbaden Biebrich	32%	38%	20.0%	25.1	24.7	-1.7%
Taunusstein	32%	44%	38.9%	22.6	20.8	-7.8%
Ingelheim	36%	49%	34.1%	17.0	17.7	4.4%
Ginsheim	45%	54%	19.9%	14.7	14.3	-3.1%
Münchwilen	32%	43%	32.0%	20.2	19.1	-5.3%
Rosedale WWTP	51%	62%	21.6%	18.2	17.9	-1.8%
Average	**38.1%**	**48.3%**	**27.7%**	**19.6**	**19.1**	**-2.6%**

Pulsed Electric Field

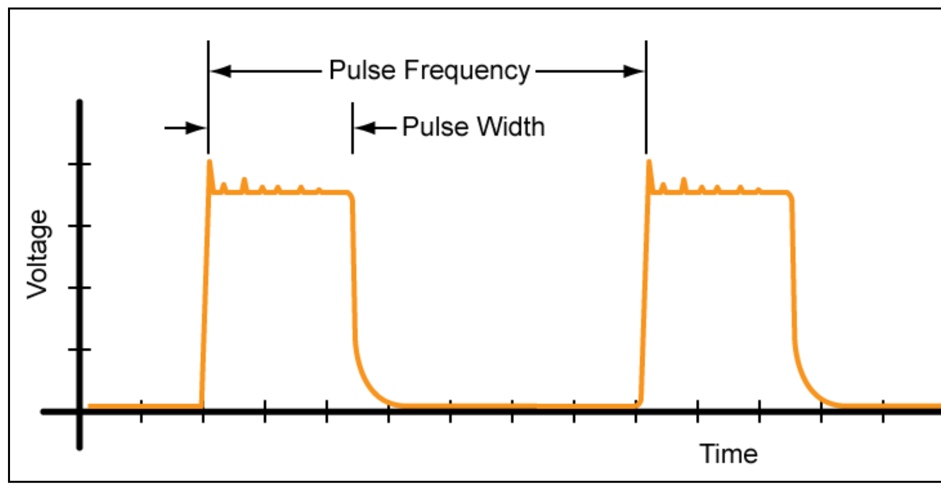
How it Works



Key operating parameters

Field Strength	Pulse Duration	Pulse Interval
15 to 100 kV/cm	2 to 15 μs	2 to 10 kHz

Mono or bipolar pulse



Full-Scale Installation at Mesa, AZ

Performance Data:

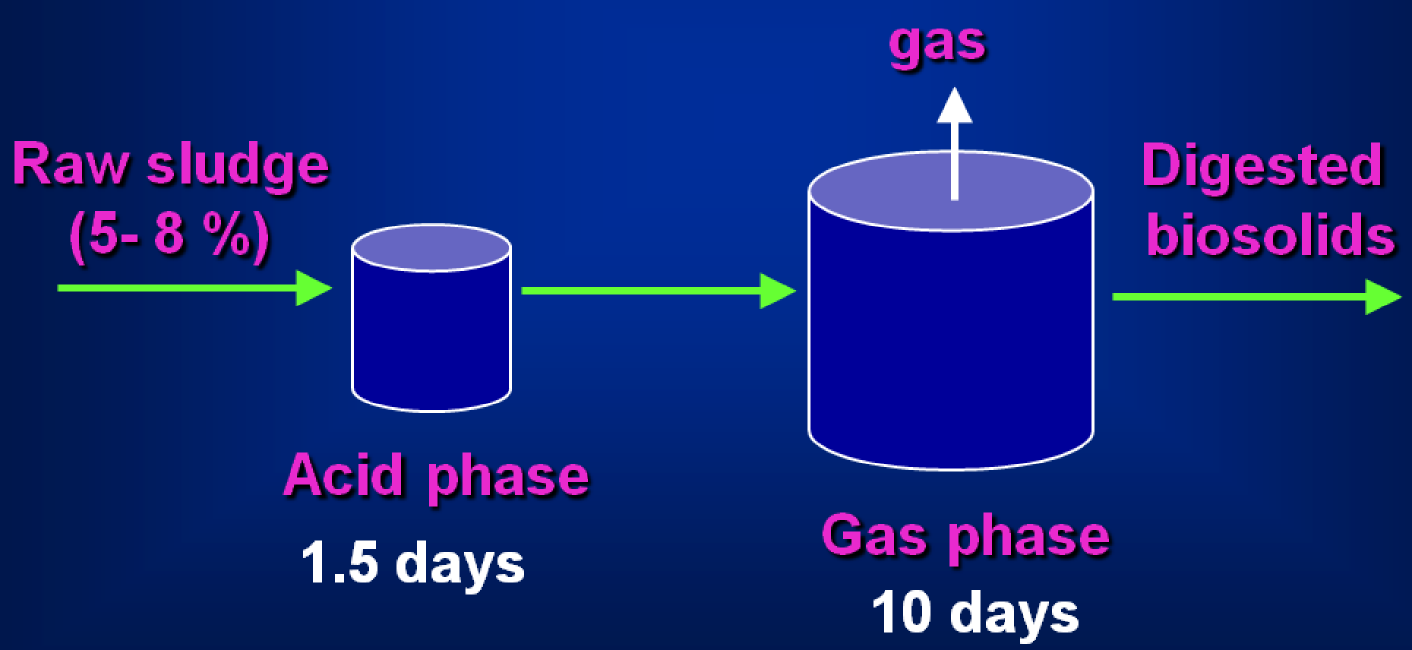
- Greater than 10% increase in VSr
- Increase in methane by 55-60%
- Sludge treated with pulsed electric field is a potential carbon source for denitrification

Operating Data:

- Plant flow: 10-12 MGD
- Thickened PS/WAs mixture 50,000 - 60,000 gpd
- Solids content: 4 - 6%
- In operation since Sept. 2007

Favorable gas production configurations

2-phase AG (Acid/Gas) Anaerobic Digestion



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Increase Biogas Production by Addition of Other Feedstocks

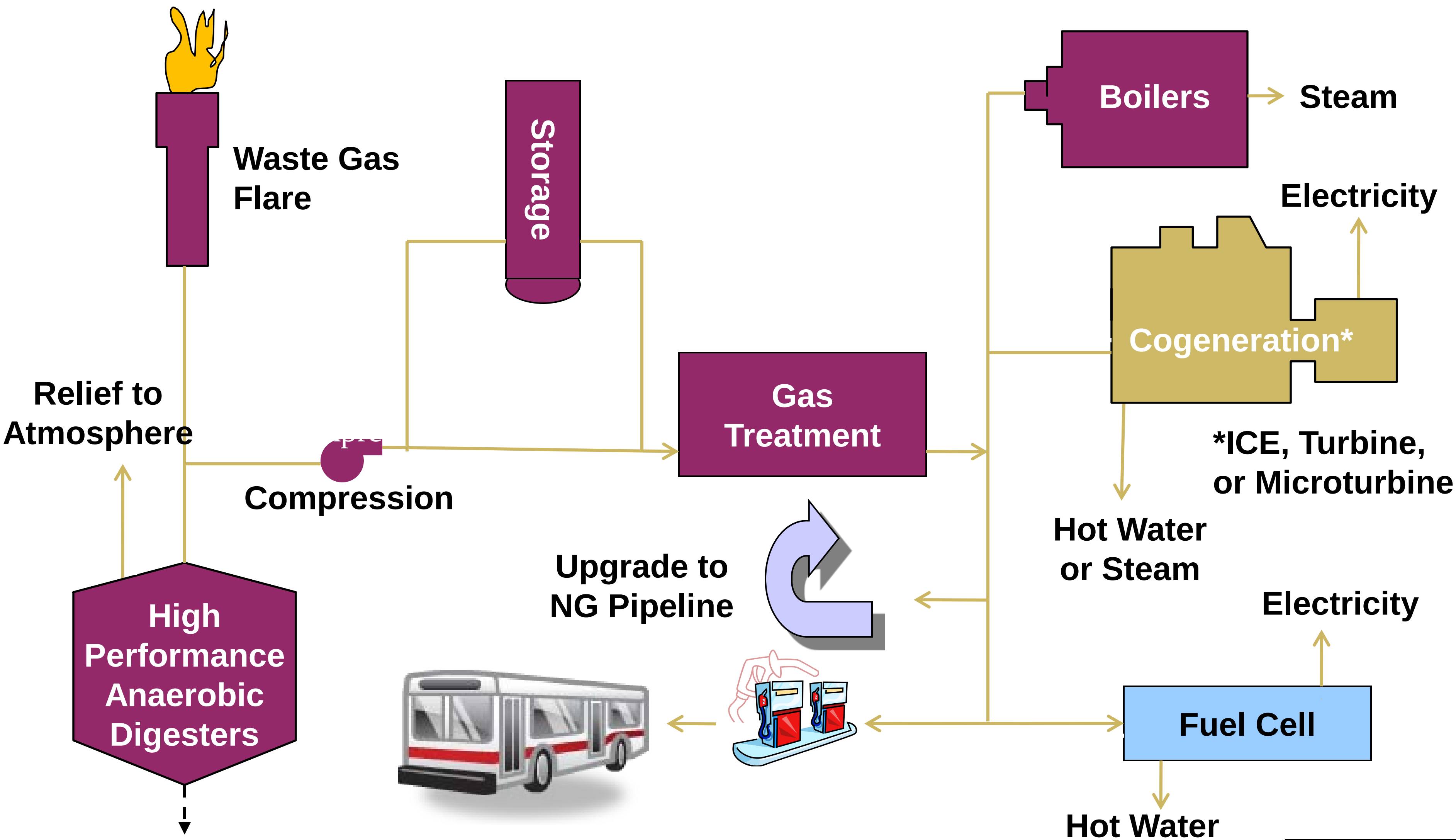
- High strength organic wastes that are easily degradable
- Examples:
  - ✓ Fats, oils, and grease (FOG)
  - ✓ Restaurant wastes
  - ✓ Food processing wastes
  - ✓ Solid wastes

Example of Innovative Approach EBMUD, CA

Food Waste vs. Wastewater Solids Comparison

Parameter	Food Waste Pulp	Wastewater Solids
Volatile Solids in Feed (%)	85-90	70-80
Volatile Solids Loading (lbs/ft3-day)	0.60 +	0.20 max
COD Loading (lbs/ft3-day)	1.25 +	0.06-0.30
Total Solid Fed (%)	10+	4
Volatile Solids Reduction (%)	80	56
Hydraulic Detention Time (days)	10	15
Methane Gas Produced ($meter^3$/ton)	367	120
Gas Produced (liters/liter of feed)	58	17
Biosolids Produced (lbs/lbs fed)	0.28	0.55

Biogas Utilization Alternatives



Courtesy of Tim Shea of CH2M Hill

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Problems from Contaminants

- Moisture
  - ✓ causes corrosion, together with acid gases
- H_2S
  - ✓ causes corrosion in mechanical moving parts of prime movers
  - ✓ causes breakdown of lubricants, leading to bearing, piston ring and seal failures
- Siloxanes
  - ✓ causes scaling leading to failure of mechanical components
  - ✓ causes breakdown of lubricants, leading to bearing, piston ring and seal failures

H2S – Impact on Gas Utilization

- 3,100 ppmv is high (200 ppmv acceptable in lean-burn engines)
- Biogas H2S will be <200 ppmv when ferric is added for sulfide and struvite control
- Sulfide removal to very low levels is needed to protect and extend life of activated carbon if used
- If ferric is not used for struvite control, one can compare the benefits and costs of ferric addition vs. gas treatment for sulfide removal

Siloxanes – Impact on Gas Treatment

- GE Jenbacher says, "…only reliable way to monitor siloxanes is to measure rate of siloxane buildup in engine oil..."
- GE Jenbacher uses the following guidelines as preliminary indicators for siloxane removal:
  - ***No gas treatment is needed*** if total siloxane concentration (as Si) in biogas is below 5 ppmv
  - ***Increased maintenance to be expected*** with no gas treatment if total siloxanes in biogas are 5 -10 ppmv (as Si)
  - ***Siloxane removal is strongly recommended*** if total siloxanes >10 ppmv (as Si) in biogas

Tradeoffs between conservative design and maintenance effort are apparent

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Problems with Siloxane

The sand-like material is SiO_2 produced through oxidation (burning) of the volatized siloxanes contained in the digester gas. Figure shows siloxane deposition on boiler tubes.

Methods of Gas Conditioning

- Moisture Removal
  - ✓ Refrigerant: Dewpoint of 40 ^{o}F
  - ✓ Adsorption by Dessicant: Dewpoint of -40 ^{o}F
- H_2S Removal
  - ✓ Precipitation (liquid): Iron Salts to digester
  - ✓ Precipitation/Scavenging: Iron Sponge, Sulfa Treat
  - ✓ NaOH Scrubbing/Biological Oxidation: THIOPAC
  - ✓ NaOH Scrubbing/Chemical Oxidation: Lo Cat, Apollo
- Siloxane
  - ✓ Activated Carbon: Applied Filter Technology
  - ✓ Refrigeration: Dewpoint of -10 ^{o}F to -20 ^{o}F

Comparison of Treatments for Biogas Contaminant Removal

Treatment	Technologies & Sample Vendors	Typical Removal Rates	Estimated Installed Equipment cost for 100 scfm of Biogas flow[1,2]
Drying	Desiccant : Van-Air Refrigerated Dryer : Van-Air Cyclic Refrigeration/Deep Dryer: Pioneer	Desiccant: 10-20 °F below ambient dewpoint (pressurized). Refrig. Dryer: down to 35-50 °F final pressurized dewpoint Deep Dryer: -20 °F final dewpoint	Desiccant: $3,500 – 5,500 Refrig. Dryer: $30,000 – 40,000 Deep Dryer: [3] $85,000 – 100,000
H2S Removal	Iron Sponge: Various Sulfa Treat: Sulfa Treat Activated Carbon: Various Liquid Catalyst: Apollo Biological: NIRAS	Iron Sponge, Sulfa Treat: 99% Alkaline sorbent: down to 50 – 100 ppm Biological – 90-99%	Iron sponge: $25,000-35,000 Sulfa Treat: $30,000-50,000 Act. Carbon: [4] $60,000-75,000
Siloxane Removal	Regenerable Activated Carbon: Applied Filter Technology Regeneratable Resins: various Cyclic Refrigeration/Deep Dryer: Pioneer Liquid Absorption: Dow Chemical, Selexol	Activated Carbon: down to ppbv levels	Act. Carbon (for siloxane only): $6,000 – 12,000 Deep Dryer: [3] $85,000 – 100,000

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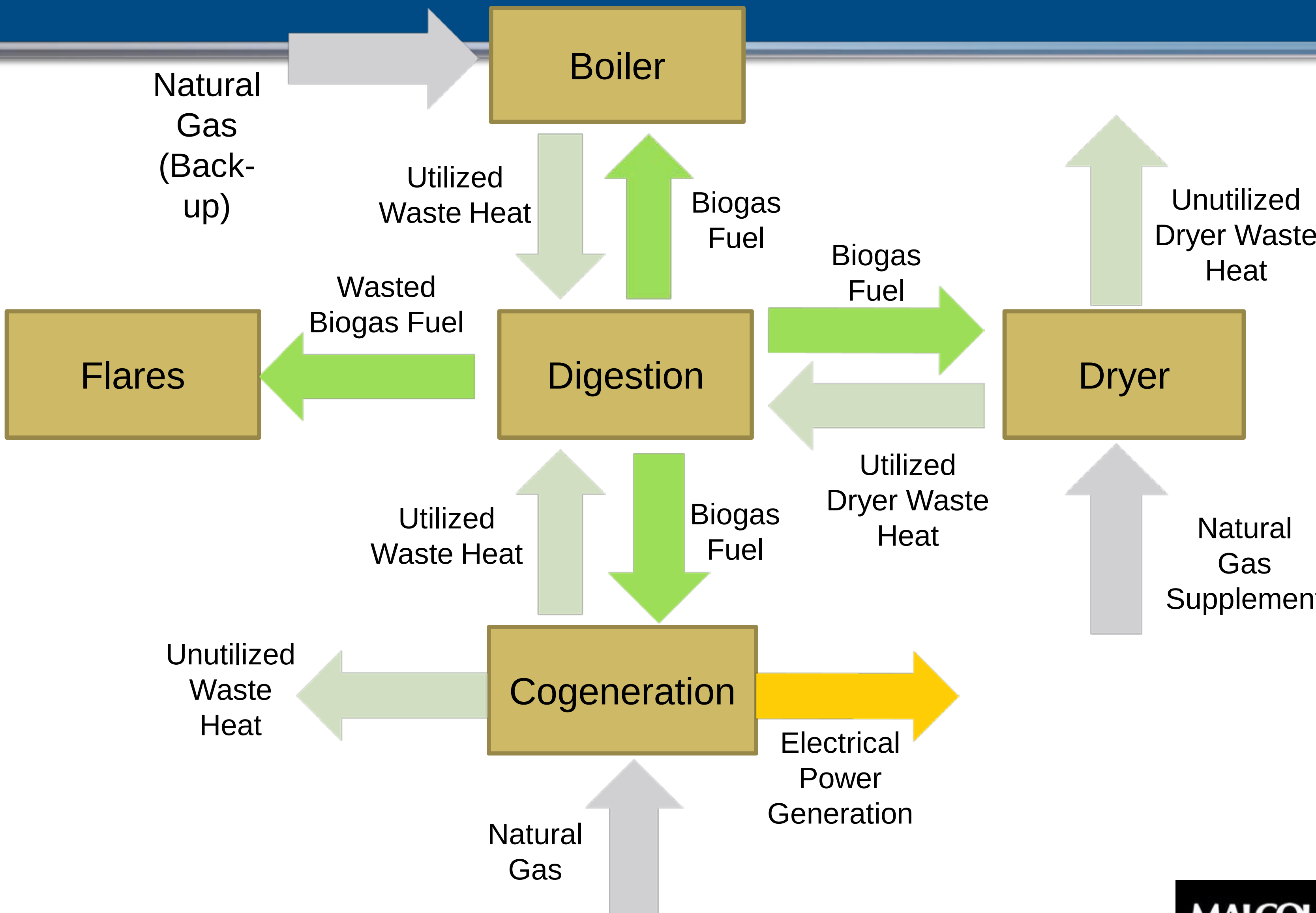
Energy Flow Schematic



Gas Utilization Equipment Efficiency

Technology	Net Electrical Efficiency		Net Thermal Efficiency		Size Range kW
	Range %	Typical %	Range %	Typical %	
Internal Combustion Engine	25 – 45	33	40 – 49	40	50 – 5K
Internal Combustion Engine – Lean Burn		37			
Gas Turbines	23 – 36	30	40 – 57	40	250 – 250K
Microturbines	24 – 30	27	30 – 40	35	30 – 250
Steam Turbine	20 – 30	25	20 – 45	45	500 – 1,300K
Stirling Engine	25 – 30	27	45 – 65	60	1 – 50

Courtesy WEF MOP 32, 2009

Power Generation Cost Summary Comparison for Different Approaches

	Installed Cost ($/kW)	Operating Cost ($/kWh)	Power Production Cost* ($/kWh)
Gas Turbines	$2,000	$0.010	$0.04
IC Engines	$1,700	$0.015	$0.04
Microturbines	$3,000	$0.016	$0.06
Fuel Cell	$8,500	$0.035	$0.16

*10 year write down @5%

Presentation Review

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Questions

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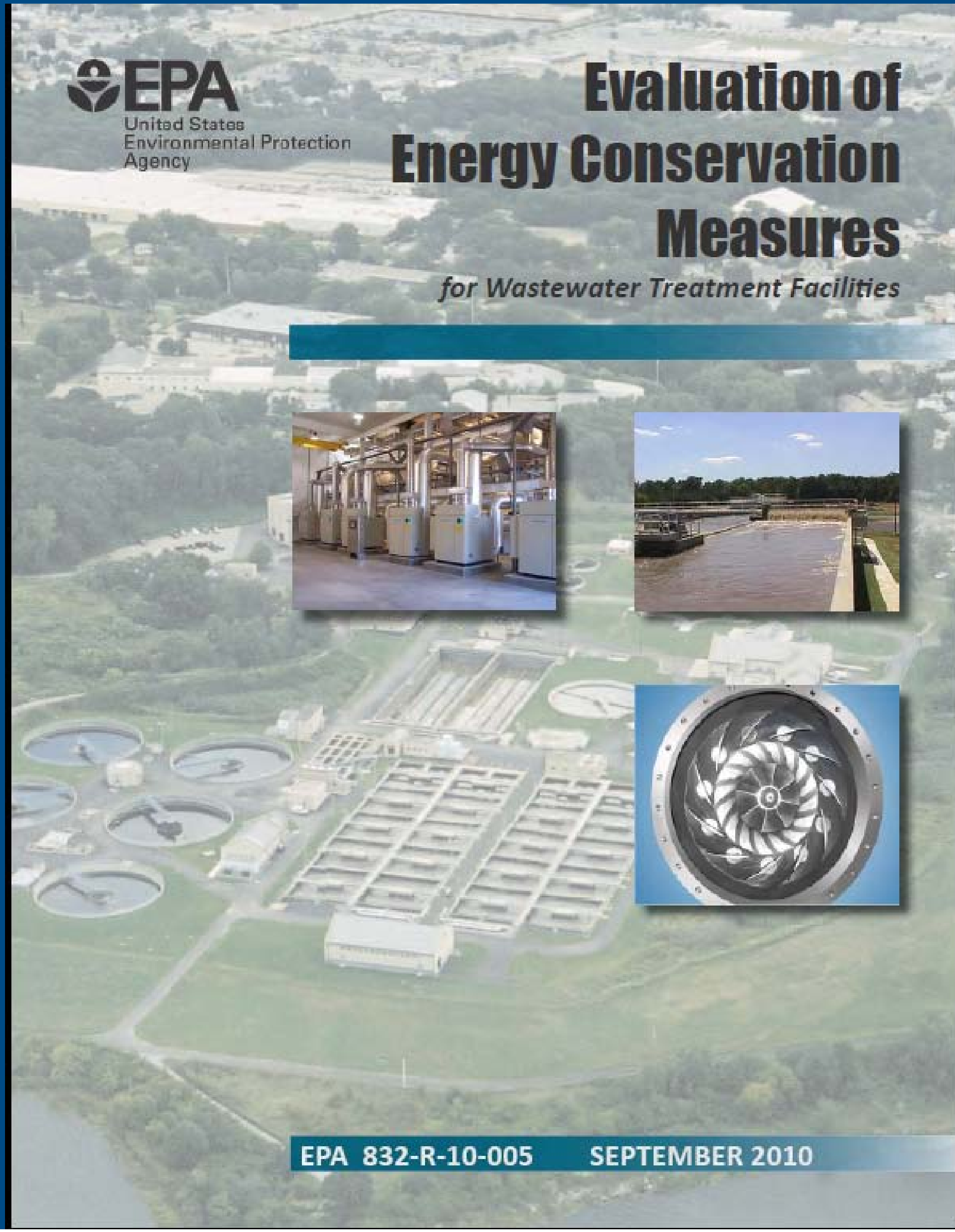

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Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities

Prepared by:

Eastern Research Group, Inc.

www.erg.com

and

Energy and Environmental Analysis, Inc.

www.eea-inc.com

Prepared for:

U.S. Environmental Protection Agency

Combined Heat and Power Partnership

www.epa.gov/chp

April 2007

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