CH2MHILL

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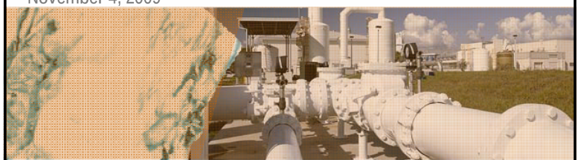
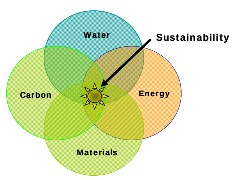
Joint Biosolids Conference, North Haven, CT
November 4, 2009



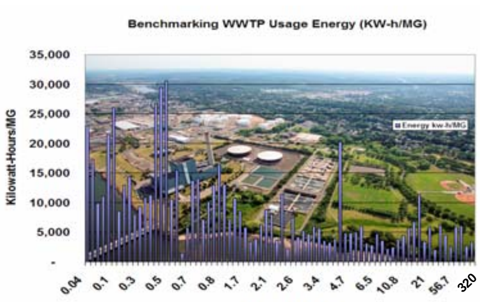
Bioenergy Technology Advances that Promote Wastewater Utility Energy Independence

Agenda

- Energy Usage & Sustainability
- Bioenergy Concepts
  - Renewable Energy
- Anaerobic Digestion Technology
  - Co-generation
  - Combined Heat & Power
- Examples
- WWTPs of the Future
- Summary



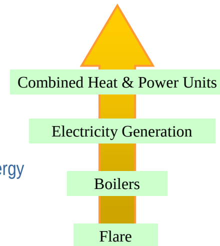
WWTP Energy Usage



Data Source: US EPA

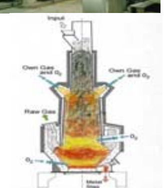
Bio-energy Concepts

- Best Use Of Biogas
  - Term Can Mean Different Things for Different Plants
- Typical Paradigm for Energy Efficiency:
  - 20-30% Reduction in Energy Consumption
  - CHP: Can Meet 50-108% of Plant Energy Demand
- Recognition of Wider Range of BioFuel Sources
  - Fats, Oils & Grease
  - Co-digestion with Food Waste



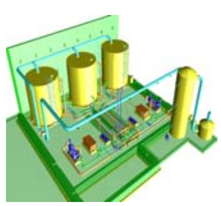
Renewable Energy at WWTP's

- Energy Supply
  - Integrated
    - Biogas
    - Heat Pumps
    - Hydro
    - Biosolids to Energy
  - Supplemental
    - Solar
    - Wind
  - Emerging
    - Algae
    - Microbial Fuel Cells
    - Biosolids to Energy



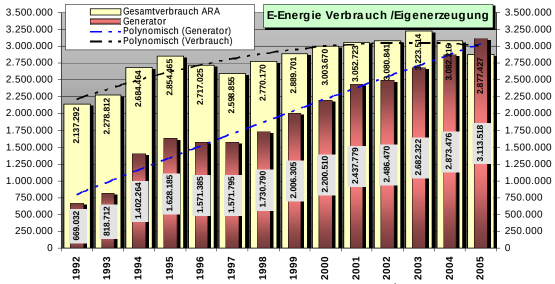
Biogas Production Techniques

- Advanced Anaerobic Digestion
- AD Pre-conditioning
  - Cell Lysis & Maceration
- Co-Digestion
  - Food wastes (Diverse characteristics)
  - FOG wastes (~100% volatile solids)



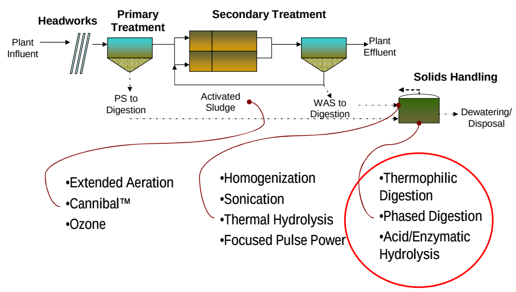
FOG Receiving Station, Johnson Co WWTP

Best In Class



Ability to Produce More Electricity Than The Plant Consumes

Biosolids Production

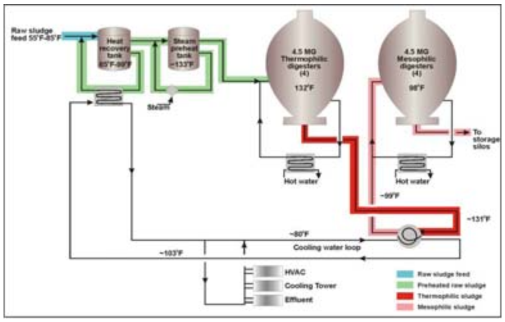


Anaerobic Digestion Technology

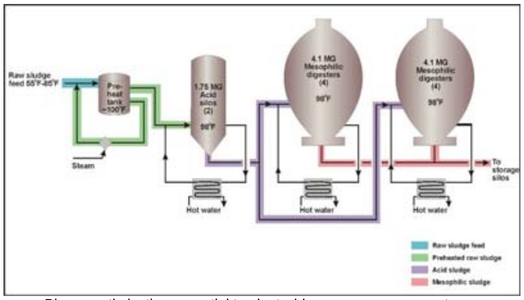
Getting more out of existing Anaerobic Digesters (AD)

- TPAD : temperature-phased AD
- Two-phase AD: separate of acid hydrolysis from methane production:
  - Single AH vessel (completely –mixed)
  - Vessels in series (mixed except during transfers) (series minimizes *backmixing*)
  - Newest concept: Enzymatic Hydrolysis

Temperature Phased AD

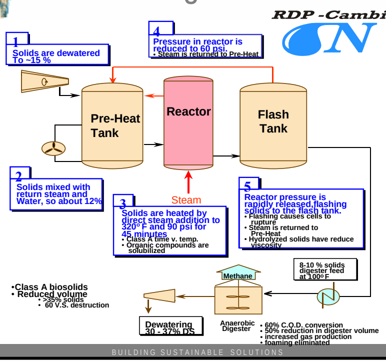


Two-Phase AD – 'Early American Style' One Acid Phase Digester



•Biogas optimization essential to plant wide energy management

Advanced Digestion Processes



Cambi- Reported Performance

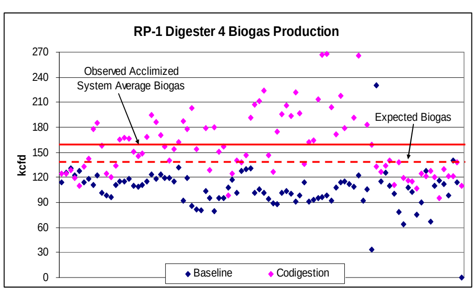
Parameter	Mesophilic AD	CAMBI + Meso AD
Digester Feed (%TS)	4-6	12-15
VSLR (kg VS/m^3/d)	1.5	3.5
VS Destruction (%)	40-55	55-65
Pathogen content	Class B	Class A
Dewatered Cake TS (%)	20-25	30-35

Co-digestion Biosolids & Food Waste

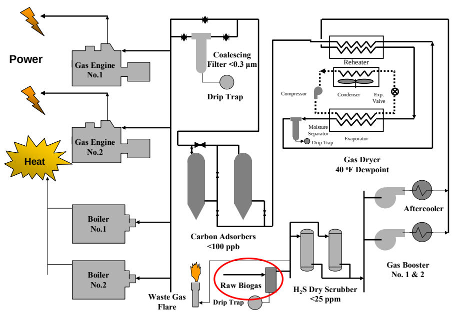
Scenario	Biogas (million cf/d)		Electricity (MW)	
	without Co-digestion	with Co-digestion	without Co-digestion	with Co-digestion
Scenario 1 (all 312 STPs)	98	155	223	352
Scenario 2 (114 STPs with ADs)	45	71	102	161

Biogas can be increased by 58% with co-digestion 60 MW increase

Co-digestion Full Scale Implementation



Co-generation System Components



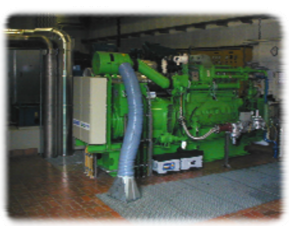
Co-generation Technology

1990's Era Technology Can Achieve:
- Average BTE: 36% (Brake Thermal Efficiency)
- Average NOx Emmisions: 2 gr NOx/bhp/hr
- Average Utilization: 89%
- Average Maintenance Cost: $0.022 /kW-Hr
- Avoided Cost: $2.96 M over 3 years in a 100 MGD Plant

Advanced Reciprocating Engine Systems (ARES) Program
- Three Phase Program; Started in 2000, Third Phase Slated for Completion by Middle of Next Decade
- DOD Funded, with Industry, Academia and State Government Support

Next Generation CHP

- Phase I Units
- Optimized Units Provide Efficiencies of About: 40-42% (Electricity)& 40-45% (Heat)
- Include Computerized Control & Remote Monitoring
- Integrated Gas Treatment System



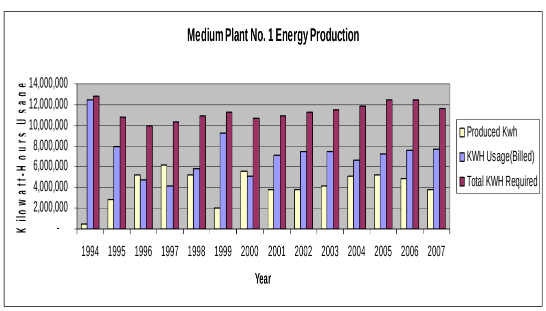
Co-generation Summary Table

	Engine Generator	Turbine Generator	Micro Turbine	Fuel Cell
Unit Size, kW	150 to 5,000	Over 1000	30-250	100-1000
Appropriate Plant Size	Small to Large	Large	Small	Small to Medium
Efficiency, %	30 - 42	24 - 30	25-30	30-50
Thermal Efficiency, %	40 – 50	45-50	45-50	40-50
Overall Efficiency, %	80 – 90	75 - 80	75-80	85-95
Typical Costs				
Maintenance, $/kWh	0.005 to 0.02	0.005 to 0.008	0.005 to 0.01	0.005 to 0.015
Installed, $/kWh	800 to 1500	1500 to 2000	1000 to 1500	3000 to 5000

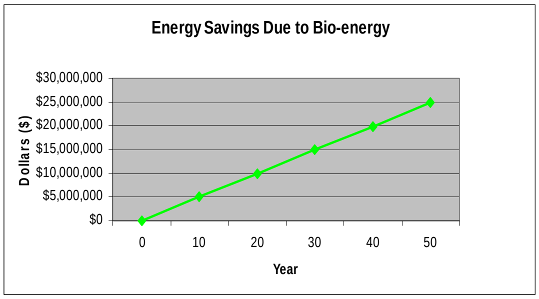
Example Comparison

Onsite Electrical Generation Efficiency					
FACILITY	Q(MGD)	TSS(mg/l)	Load(lbs TSS)	KWhrs/month Produced	KWH/month/LB TSS
LARGE PLANT No. 1	320	360	960,768	14,215,117	**14.8**
					100% Biogas
LARGE PLANT No. 2	320	200	533,760	2,211,000	4.1
					100% Biogas
LARGE PLANT No. 3	110	220	201,828	5,647,786	**28.0**
					100% NG CT
MEDIUM PLANT No. 1	21	280	49,039	374,471	7.6
					100% Biogas
LARGE PLANT No. 4	102	210	178,643	290,500	1.6
					100% Biogas

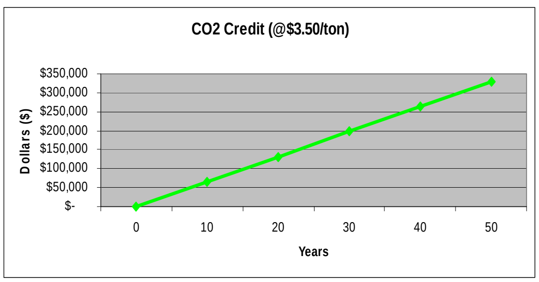
Plant Energy Production Comparisons



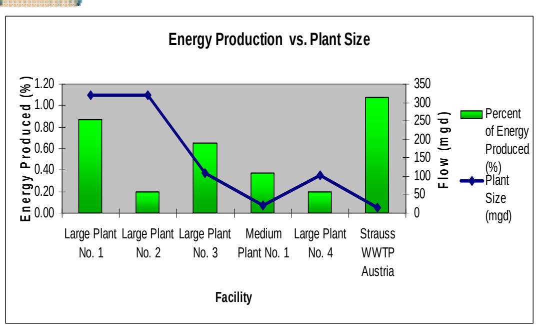
Medium Plant No. 1 Life Cycle



Medium Plant No. 1 Carbon Credit

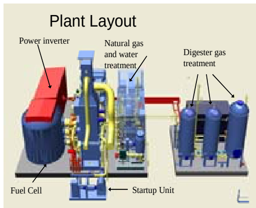


Energy Production



Bioenergy Fuel Cells

- Fuel Cells Have Grown Up!
- Raw and scrubbed digester gas, and natural gas sources
- Very low emissions
  - CO < 13 ppm
  - NOx < 0.2 ppm
- Economics Typ < 15 yrs with grant funding



Renton WWTP, WA

WWTP's of the Future

- Transforming Leadership in Energy Efficiency
  - "Carbon Conversion Factories"
  - From Energy Sink to Energy Source
- Renewable Energy Portfolio
  - 7% Currently to Dominate
- Biofuel Augmentation
- Bioenergy Fuel Cells
- Microbial Fuel Cells
- Export Energy to Grid

Organo-trophs (Living Fossils)

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Organo-Machines (Dead Fossils)

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

Summary

- WWTP's Can Achieve Energy Independence
- 80-90% Energy Can Be Produced from Bio-energy
- Significant Energy Savings and Carbon Credits
- Advanced Anaerobic Digestion Processes Increase Bio-energy Utilization
- Co-digestion Increases Energy Production
- Fuel Cells Hold Promise for Future
- Leadership in Efficiency Requires WWTP's to Become Energy Sources NOT Sinks