Beyond Zero Net Energy:

Case Studies of Wastewater Treatment for Energy and Resource Production

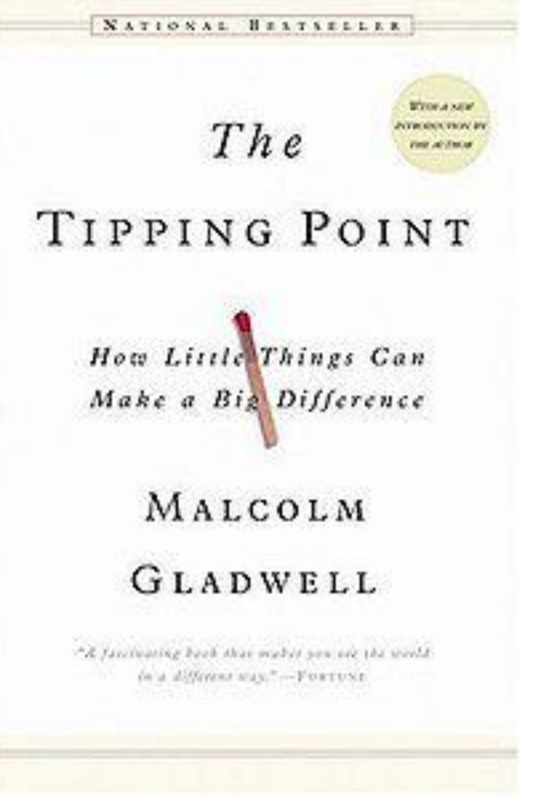
Bill Toffey

AWRA-PMAS Meeting

September 16, 2010

Are We at the "Tipping Point"?

- Malcolm Gladwell, author of Tipping Point, b. 1987; father a civil engineering professor
- "the moment of critical mass, the threshold, the boiling point."
- Discusses potentially massive implications of small-scale social events.
- Says real change is possible



Water Environment Federation

Jeanette A. Brown, testimony to Congress (2/4/2009), "Energy Efficiency and Energy Independence for Sustainable Wastewater Treatment"

"The landscape is changing as technologies and concepts are being developed to allow plants to be energy independent or even net energy producers. **This evolution in thinking moves wastewater treatment plants from being major energy *consumers* to net energy *producers* and represents a paradigm shift in the sector."**

Water Environment Research Federation

“Energy Opportunities in Wastewater and Biosolids” (March 2009)

- “Water and wastewater treatment operations have the potential to be net energy producers;”
- “Researchers have measured the energy content of raw wastewater samples and determined that it exceeds the electricity requirements for treatment by a factor of 9.3 to 1. That means that domestic wastewater, which has organic matter with embedded energy content, contains almost ten times the energy needed to treat it.”
- As of 2004, 1,006 facilities used anaerobic digesters; 19% generate power with the biogas
- Need more investment in research to unlock potential and development of optimization tool

Net Zero Energy – Why Bother? And Why Even Go Beyond to Positive?

Multiple Drivers: Facility and Location Specific

- Leadership Goals: The Exciting Vision
- Energy Pricing: High Costs and Subsidies
- New Regulations, Now or Anticipated
- State and Federal Grants for Projects
- Environmental Ideals of Community
  - Greenhouse Gases
  - Carbon Footprint
- Need for Capital Replacement

Water Services as Energy Consumers

- 30%-60% of a city’s energy bill is associated with the provision of water services
- U.S. water-related energy use is equivalent to 13% of the nation’s electricity consumption.
- The carbon footprint currently associated with moving, treating and heating water in the U.S. represents 5% of all U.S. carbon emissions

(From: Paul O’Callaghan, “Water & Energy”, Water Innovations Alliance,O2 Environmental, paul.ocallaghan@o2env.com, + 1 604 676 3581)

Much WWT is Fundamentally Screwy

- Toronto Calorimetry Study
  - Wastewater contains10 times the energy required for treatment
- Energy embedded in wastewater
  - Could meet between 2% and 12% of the national electricity demand
- Current WWT process is essentially an exercise in growing bacteria.
  - Food & nutrition, in the form of wastewater,
  - Give them air and oxygen, which consumes energy,
  - End up with a waste sludge which we have to dispose of

Electricity Usage Benchmarks

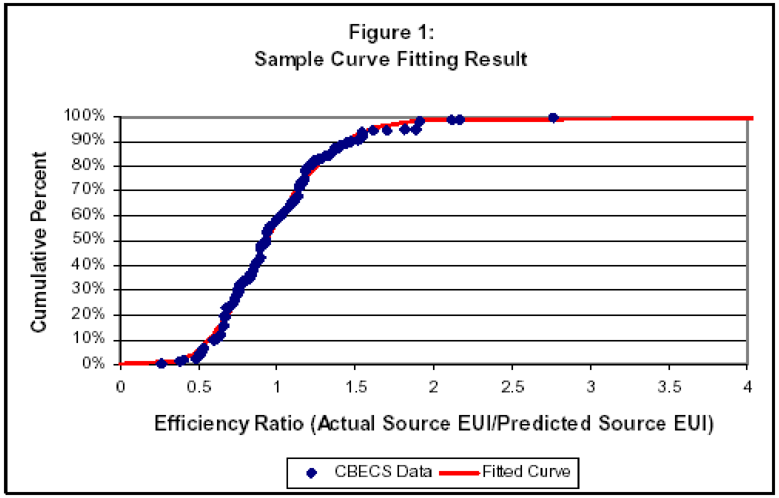


Figure 1:
Sample Curve Fitting Result

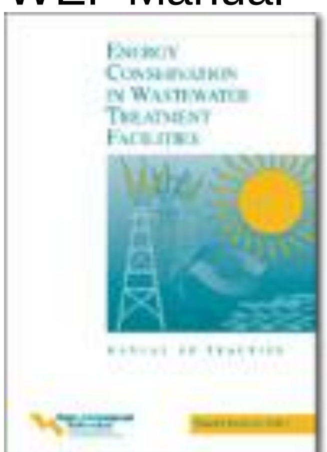
AwwaRF Index/EPA Energy Star

Wisconsin Focus on Energy

focus on energy

The power is within you.

WEF Manual



ACEEE WATER AND WASTEWATER ENERGY ROADMAP (WWER) 2004

Stakeholder Survey Results

One in a Series of ACEEE White Papers

Prepared by Elizabeth Brown and Neal Elliott

DRAFT: June 4, 2004

Typical Wastewater Electricity Use

Estimates of Electricity Used in Wastewater Treatment

kWh per MG treated (assumes belt filter press, no UV disinfection)

Source: "Energy Conservation in Water and Wastewater Facilities, WEF MOP No. 32, Appendix C)

Type of Treatment	1 MGD	10 MGD	100 MGD
Trickling Filter Plant	1,811	852	673
Activated Sludge Plant	2,236	1,203	1,028
Advanced Wastewater Treatment Plant (no nitrification)	2,596	1,408	1,188
Advanced Wastewater Treatment Plant (with nitrification)	2,951	1,791	1,558

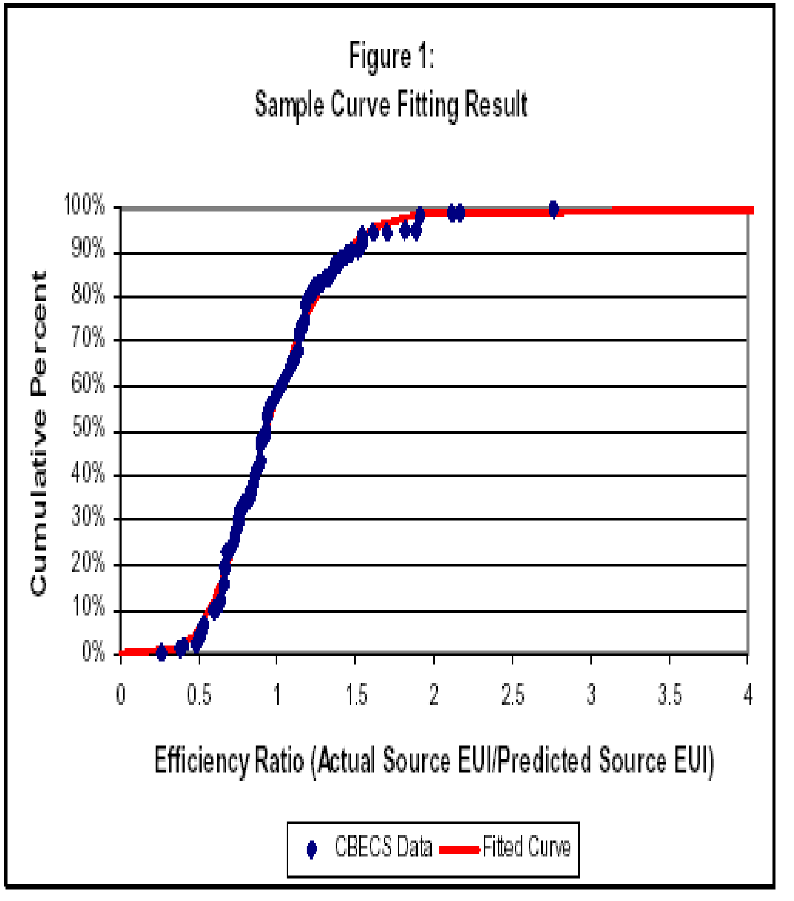
WEF Manual: Electricity Use by Process

(in kWh/MG)from WEF M.O.P No. 32, "Energy Conservation in Water and Wastewater Facilities, Ap C)

	1 MGD	10 MGD	100 MGD
Wastewater Pumping	171	140	118
Screens	2	1	1
Aerated Grit Removal	49	13	12
Primary Clarifiers	15	16	16
Aeration	532	532	532
Biological Nitrification	346	345	340
Return Sludge Pumping	54	51	38
Secondary Clarifiers	15	16	15
Chemical Addition	80	55	42
Filter Feed Pumping	143	82	67
Filtration	137	39	34
Thickening	6	203	131
Digestion	1200	170	155
Dewatering	0	46	25
Chlorination	1	3	3
Lighting and Buildings	200	80	30
Total Process	2951	1792	1559

AwwaRF: Energy Index Development for Benchmarking Water and Wastewater Utilities (Devine et al, 2007, 196pp)

Survey of Literature and utility operations to develop a statistical basis for the EPA Energy Star performance rating for wastewater.



Increase Electricity Requirements with Advanced Treatment

Carns, Global Energy Partners, LLC 2003

Energy Savings Don't Cover the Whole Story - New Regulations Will Require Better (i.e. More Energy Intensive) Treatment

Technology	kWh /MG	kWh / 1,000 m^3
UV Disinfection	+70 to +100	+18 to +26
Membrane Treatment		
Nanofiltration	+ 1,800	+ 475
Ultrafiltration	+ 1,000	+ 264
Low pressure microfiltration	+ 100	+ 26
Ozone	+ 170	+ 44

NYSERDA: Energy Efficiency in Municipal Wastewater Treatment Plants: Technology Assessment (Pakenas, 2004)

DSM (Demand-side Management):

- On-site electricity generation (outfall hydropower)
- Reducing electricity purchases through efficiencies (fine bubble diffusers, reduced MCRT, automatic DO monitoring)
- Shifting to off-peak electricity purchases (reduced aeration during mid-day, effluent storage)
- Using alternative fuels (gas storage for peak-price period generation)
- Using alternative treatment technologies (sludge drying with waste heat, heat extraction from sewage)

ACEEE: Roadmap to Energy in Water and Wastewater Industry (Elliot, 2007)

American Council for an Energy-Efficient Economy, roadmap workshop with EPA, AwwaRF, WERF, CEC, IEC, NYSERDA, ASE

- Training on energy practices
- Performance standards and metrics
- Metrics tied to permits and loans
- Reporting system web-based
- Proposed steering committee to:
  - Collect information
  - Coordinate demonstrations
  - Avoid duplication
- **Did not happen!**

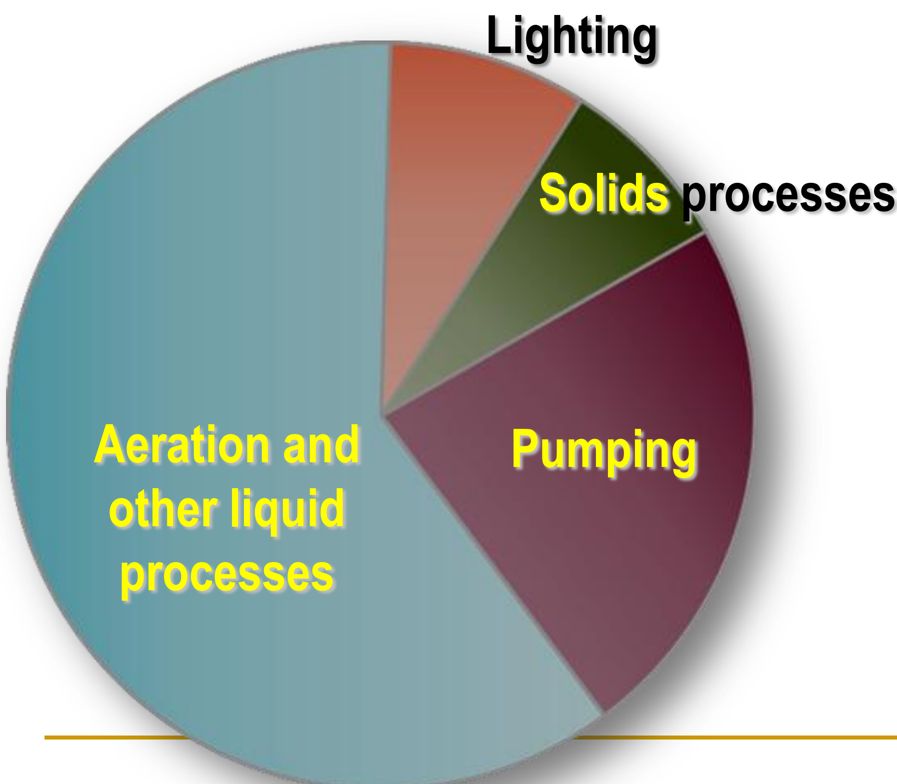
Different Approaches to NZE

- Can Target Net Zero Electricity
  - Distributed electricity production: solar, wind, biomass
- Can Embrace Peak Electricity Reduction
  - Demand Management
- Can Move to Net Zero Energy
  - Electricity balanced with Gas
- Each Approach Can Achieve NZE
  - High energy efficiency - Strass
  - Supplemental biogas production - EBMUD
  - Alternative energy development – ACUA

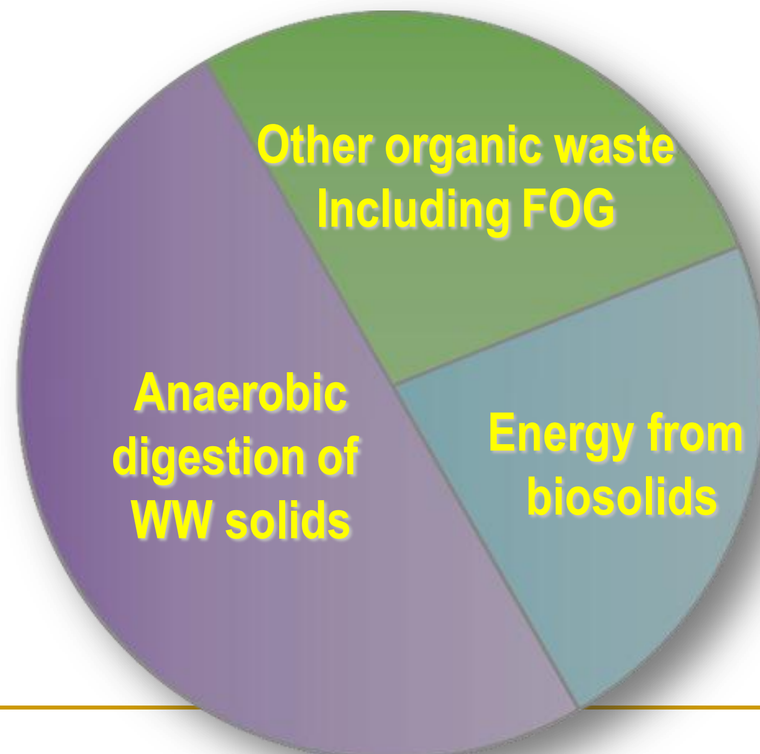
Wastewater Plants Can Produce Enough Electricity to Meet Demands,

(D. Parry, CDM)

Electric Demand



Potential Electric Supply



NZE Thru Efficiencies: Strass, Austria

Strass WWTP: Serves tourist population; 200,000 pe in summer)

Percentage of energy self-sufficiency was steadily improved starting from 49% in 1996 to 108% in 2005, without co-substrates

- Biogas converted to electrical energy by the 340 kW CHP unit at a high average efficiency of 38%.
- Maximum transfer of organics to digesters increased organic loading, decreased SRT and increased gas production
- Intermittent aeration controlled by on-line effluent ammonia
- Energy savings from side-stream treatment using DEMON®-process for deammonification

Energy Payback from Process Improvements: 30 to 50% Reduction

Carns, Global Energy Partners, LLC 2003

Energy Impacts of New Technologies - Energy Savers in Wastewater Treatment

Technology	kWh /MG	kWh / 1,000 m³
Fine pore diffusers	140	37
Ultra-fine pore diffusers	210	55
DO control systems	50 to 100	13 to 26
Blower control systems	50 to 150	26 to 40
Energy efficient blowers	100 to 150	26 to 40

Electricity Production at WWTP

- Original Purpose: emergency generation and peak shaving
- New Purposes:
  - Baseload electricity
  - Thermal heat production for digester
  - Thermal heat for residuals drying
  - Heat capture during incineration for steam for electricity, heating and cooling
- New Technologies: gas clean up, advanced engines, microturbines, fuel cells

Advances in Transforming Organic Solids to Energy

- Sludge to Biogas: *Anaerobic Digestion*
- Sludge to Syngas: *Gasification*
- Sludge to Oil: *Pyrolysis*
- Sludge to Fuel: *Carbonization*
- Supercritical Water Oxidation: *Aquacritox*

Anaerobic Digestion for Biogas

- Evolving Purpose of Digestion
  - Solids reduction for operational efficiency
  - Pathogen and Odor Control for regulations
  - Biogas production for energy efficiency
- Optimizing Digester Performance
  - From a standard of 38% to 50% to 65%+
  - Measuring performance as gas yield per feed mass (cubic feet of gas per pound of VS feed or milliliter of gas per gram of feed)

Optimized Biogas Utilization

(from Dru Whitlock, et al, CH2M Hill)

- **Digester Gas Treatment System (moisture, CO2, H2S, Siloxane removal)**
- **Energy Recovery Technologies - CapEx**
  - ***Boilers*** $200 per kW.
  - ***Reciprocating Gas Engine*** $2,200 per kW.
  - ***Gas-turbine Generator*** $2,200 per kW.
  - ***Microturbines*** $2,700 per kW
  - ***Fuel Cell Systems*** $7,100 – $9,800per kW

Gas Treatment Technology

Pretreatment of Wastewater Sludges

(from Dru Whitlock, et al, CH2M Hill)

- ***Processes and Mechanisms:*** *Sonication, Thermal Hydrolysis, Cambi Thermal Hydrolysis Process, BioThelys Process, Homogenization, Pressure Release*
- ***Mechanical Shearing Methods:*** *ABS-Kady Biolysis Process, Lysate Centrifuge, Pulsed Electric Field*

Advanced Anaerobic Digestion

(from Dru Whitlock, et al, CH2M Hill)

Multiple Goals: Pathogens, Odors, Energy, VSD

- ***Conventional High Rate with Recuperative Thickening AD System***
- ***Processes Employing Mesophilic Temperatures***
  - *Mesophilic Acid Hydrolysis—Single Tank AD System*
  - *Mesophilic Acid Hydrolysis—Plug Flow AD System*
- ***Processes Employing Thermophilic Temperatures***
- ***Temperature-Phased AD Systems***

Co-Digestion as Improving Asset Use

(D. Parry, CDM)

Vegetable Oil

Restaurant Grease

Chicken Waste

Excess Anaerobic Digestion and Cogeneration Capacity

Gas Clean-up and Electricity Generation

Lethbridge Wastewater Treatment Plant, Alberta, Canada

Co-Digestion Approaches
(from Dru Whitlock, et al, CH2M Hill)

- ***Co-Digestion of Combined Municipal PS + WAS and Expired Produce (EBMUD)***
- ***Codigestion of Combined Municipal PS + WAS and Manure (IEUA)***
- ***Biogas Production from High Solids Content Food and Green Wastes (UC Davis Trial of APS)***

Organic Waste-to-Energy Research

(Several projects with DOD, WERF, Edmonton Centre of Excellence, Recycling Companies and CDM (D. Parry, CDM))

Edmonton, Canada

- **Bench: Waste Characterization**
- **Lab: Acclimation**
- **Pilot: Scale up (Food to Fuel)**
- **Full scale: Demonstration**
  - Organic loading rate & digester performance
  - Waste characterization & biogas production

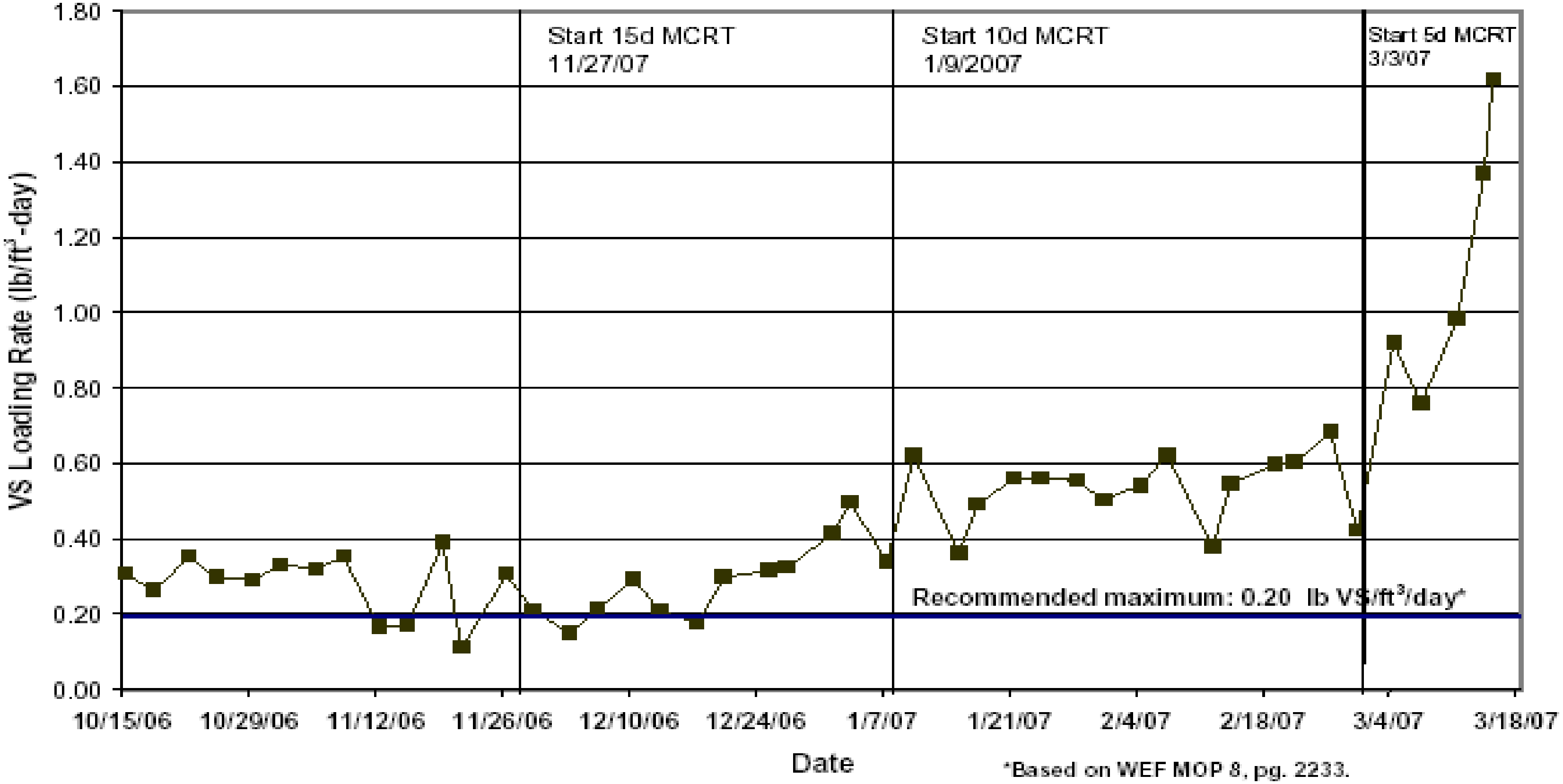
Leader in Organic Waste Processing: East Bay MUD (Oakland, CA)

- 1985 Cogeneration installed
- 2000 50% of electricity produced
- 2002 “Trucked Waste Acceptance”
- 2004 Post consumer food waste accepted
- 2007 100% of electricity produced
- 2010 2X biogas production; 2 new 4.5 MW
- Future: vehicle fuels, revenue from RECs

EBMUD: Food Waste Pulp for A.D.

EBMUD Digester Loading Rate

Figure 8 - Anaerobic Digestion of Food Waste Pulp Bench-Scale Study: Volatile Solid (VS) Loading Rate



Wastewater and Organic Waste Treatment Center, (D. Parry, CDM)

Des Moines Wastewater Treatment Plant, Des Moines, IA

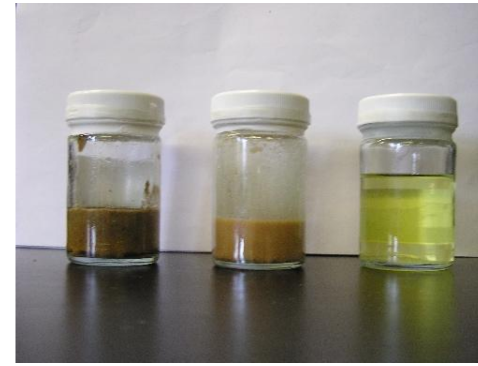
Comprehensive Biogas Treatment and Cogeneration System, (D. Parry, CDM)

Replaced 200 KW Phosphoric Acid Fuel Cell with two 800 kW Internal Combustion Engine-Driven Generators

Columbia Blvd Wastewater Treatment Plant, Portland, Oregon

FOG can be converted to biodiesel or biomethane

(D. Parry, CDM)

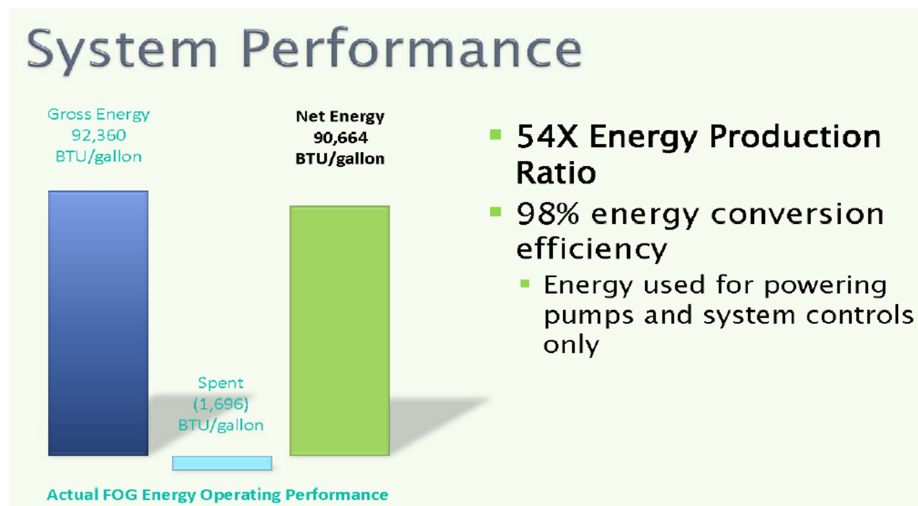


Biodiesel

Biomethane

FOG (fats, oils, grease)

Dick York, the champion of FOG for Anaerobic Digestion



Milbrae (CA) FOG Project

How did we boost bioavailability?

- **Automated Preconditioning**
  - Treatment begins immediately as FOG is off loaded.
  - FOG is combined with actively digesting sludge in a precise ratio.
- **'Bioreactor' Storage**
  - FOG-Sludge Mixture Blended into miscible, stable slurry. NO separation, NO clogs.
  - Chemical composition is changed, surface area maximized.
- **Continuous introduction**

Ontario Metro Area, Canada, Food Waste Supplementation

- Organic Resource Management Inc. prepares food scraps for anaerobic digestion *(Biocycle 2010)*

Feedstock guaranteed for WWTP digesters

(Biocycle 2010)

Clean, quality assured Feedstock

ORGANIC RESOURCE MANAGEMENT INC.

FROM LEFTOVERS TO LIGHTS®

Recipe in writing
Performance verified

Full Service Collection and Processing\

ORMI Harvests Feedstock – that is all we do

Technology Works Internationally: Grevesmuhlen, Germany

"Can a wastewater treatment plant be a powerplant? A case study," N. Schwarzenbeck, E. Bomball and W. Pfeiffer, WS&T, 57.10, 2008.

- Grevesmuhlen, northern Germany (72,000 pe)
- Degradation of sludge solids 20% higher with a dry residue load of 30% grease skimmings added to AD
- Gas increase with no adverse effect on AD, no solids increase from digester
- Power increased to 103 kW from 30 kW.

Grevesmuhlen, Germany, Approaches NZE

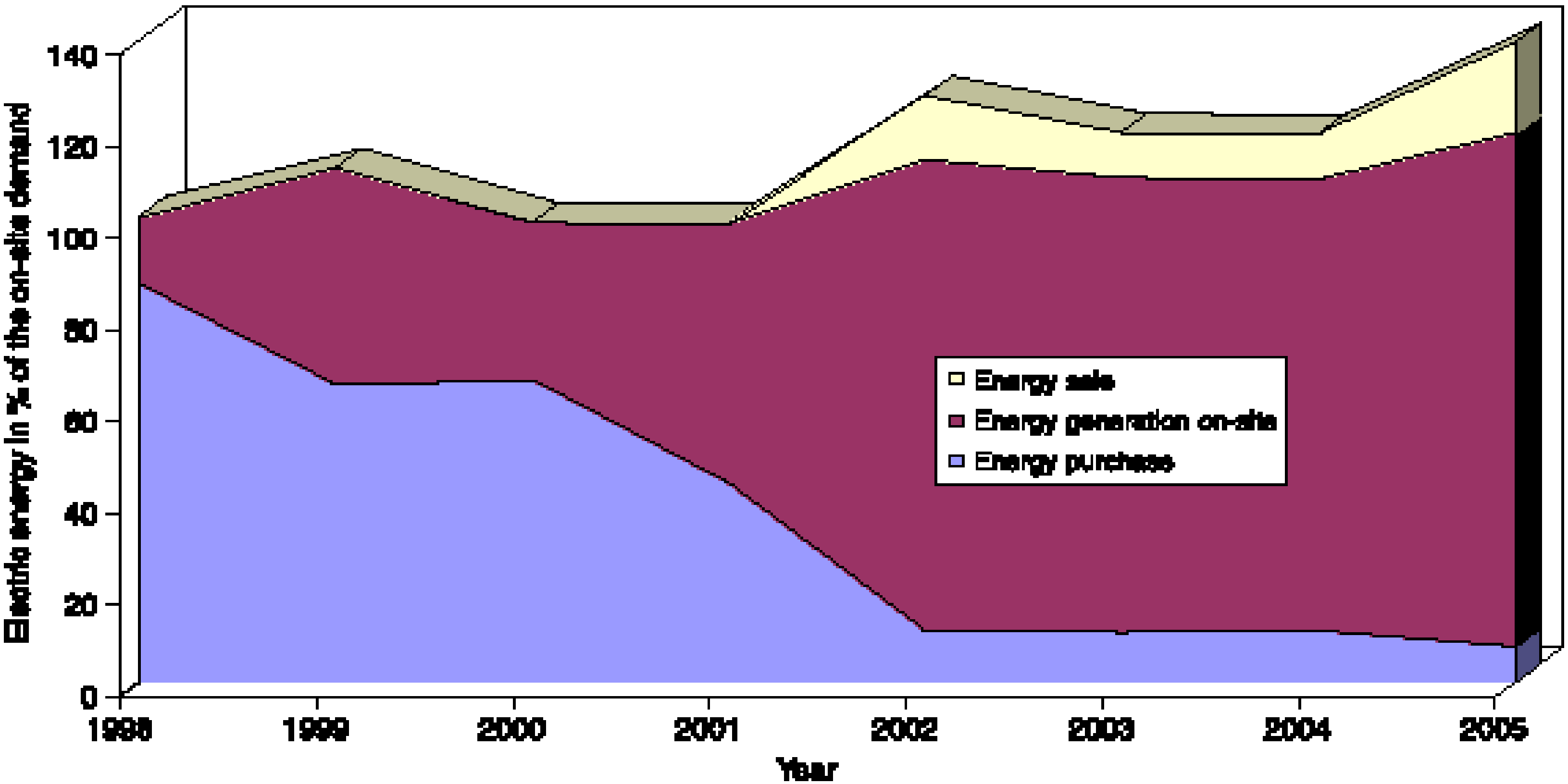


Figure 8 | Development of acquisition, generation and sale of electric energy.

Budapest Sewage Works: South-Pest Wastewater Treatment Plant

- Excess Anaerobic Digester capacity developed for handling organic solid waste
- Waste receiving and treatment station and thermophilic digester unit operate with French technology
- Gas engines are Austrian products
- Plant is self-sufficient in terms of heat energy

(Source: http://www.fcsm.hu/en/content/index.php/93)

Velenje, Slovenia

Municipality of Velenje operates a WWTP of 50,000 population equivalents (PE) with two mesophilic anaerobic digesters of a combined volume of 2000 m3

- Virtually complete degradation of Organic Waste
- no increase in effluent VSS during the experiment
- degradation efficiency increased from 71% to 81%.
- 80% increased biogas quantity.
  - Biogas Production Rate increased from 0.32 to 0.67m3m-3digester d-1.
  - Specific Biogas Production increased from 0.39 to a peak of 0.89m3 kg-1 VSS inserted.
- Electrical energy production increased by 130% and heat energy production increased by 55%.

"Potential of Co-digestion" (IEA Bioenergy)

Large scale co-digestion plant, Holsworthy, UK
(Picture courtesy of Rudolf Braun, Austria)

Legislation on organic waste reduction in landfills in selected European countries

COUNTRY	BANNING YEAR	CRITERIA / REMARKS
EU		Reduction of untreated organic waste to 35% by 2014
Austria	2004	Waste >5% TOC or Upper heating value >6 MJ/kg TS
Denmark	1997	Ban for all wastes that can be incinerated
Finland	2002	All wastes shall be treated prior to landfill
Sweden	2005	All untreated organic wastes
Switzerland	2000	All organic waste
U.K.		Reduction targets for biodegradable wastes based on 1995 levels: Down to 75% by 2010; down to 50% by 2013 and down to 35% by 2020. Since 2001 new landfills must only take pretreated waste

Large Scale Centralised Co-digestion Plant Grindsted, Denmark
(Picture courtesy of Rudolf Braun, Austria)

Large Scale Centralised Co-digestion Plant Lemvik, Denmark (Picture courtesy of Teodorita Al Seadi, Denmark)

- 121 CO-DIGESTION PLANTS IN EUROPE

“The optimisation of food waste addition as a co-substrate in anaerobic digestion of sewage sludge,”

Hyun-Woo Kim, Sun-Kee Han and Hang-Sik Shin, *Waste Manag Res,* 2003; 21; 515

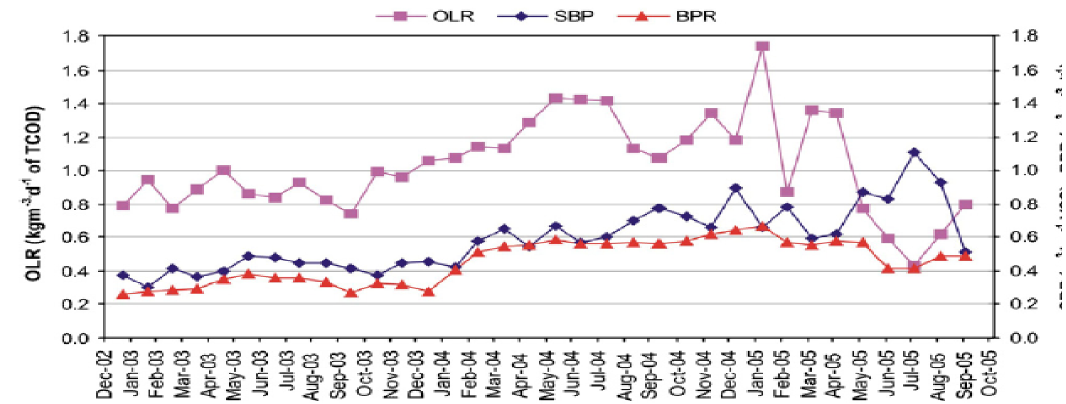
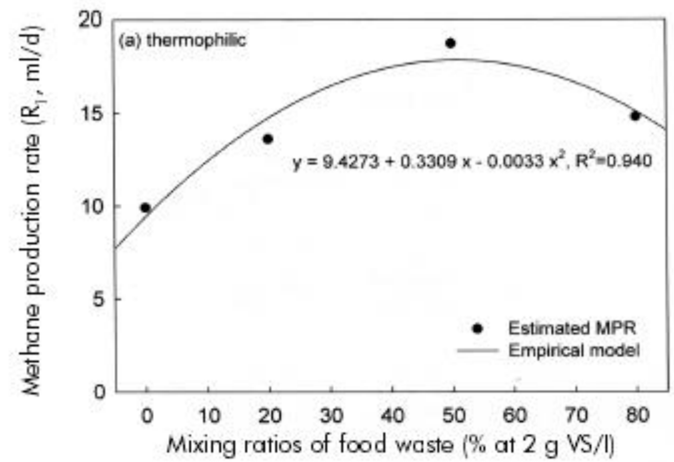


Fig. 3 – OLR and monthly average biogas production.



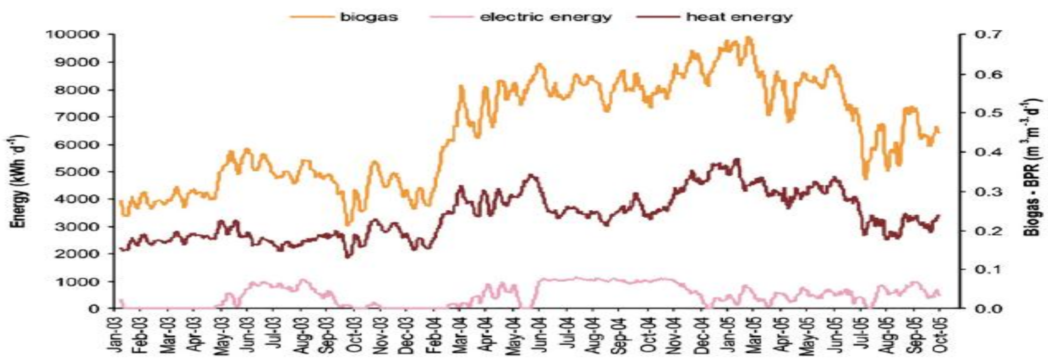


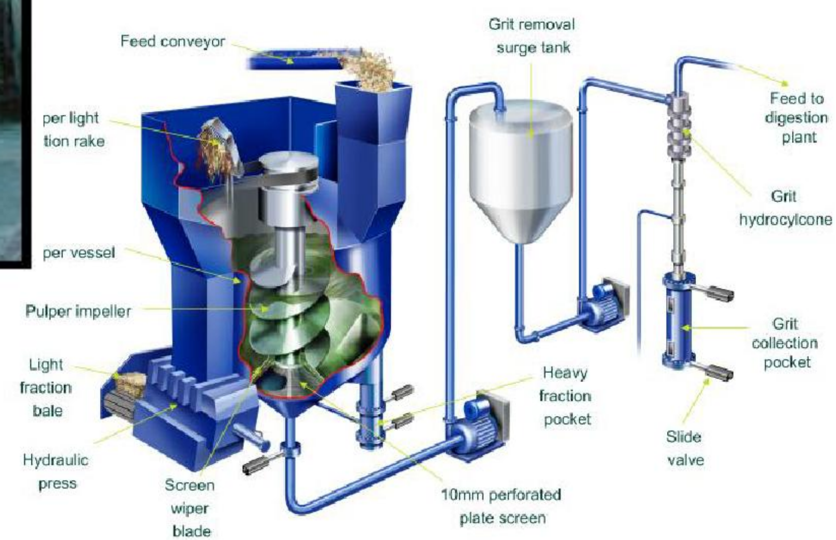
Fig. 4 – Daily biogas production and power output.

"Integrated Sustainable Solutions – Co-digestion of Solid Waste at WWTPs and the BTA Process as a Pretreatment Step" Joerg Blischke, Alan Wong, Kevin Matthews, WEFTEC 2009

- More than a dozen WWTPs and centralized AD plants use BTA to accept organic feedstock for co-digestion with biosolids
- Typical co-substrate addition rates range between 5 and 20 percent by weight of sludge feed
- Biogas yield raised by 40 to 230 percent

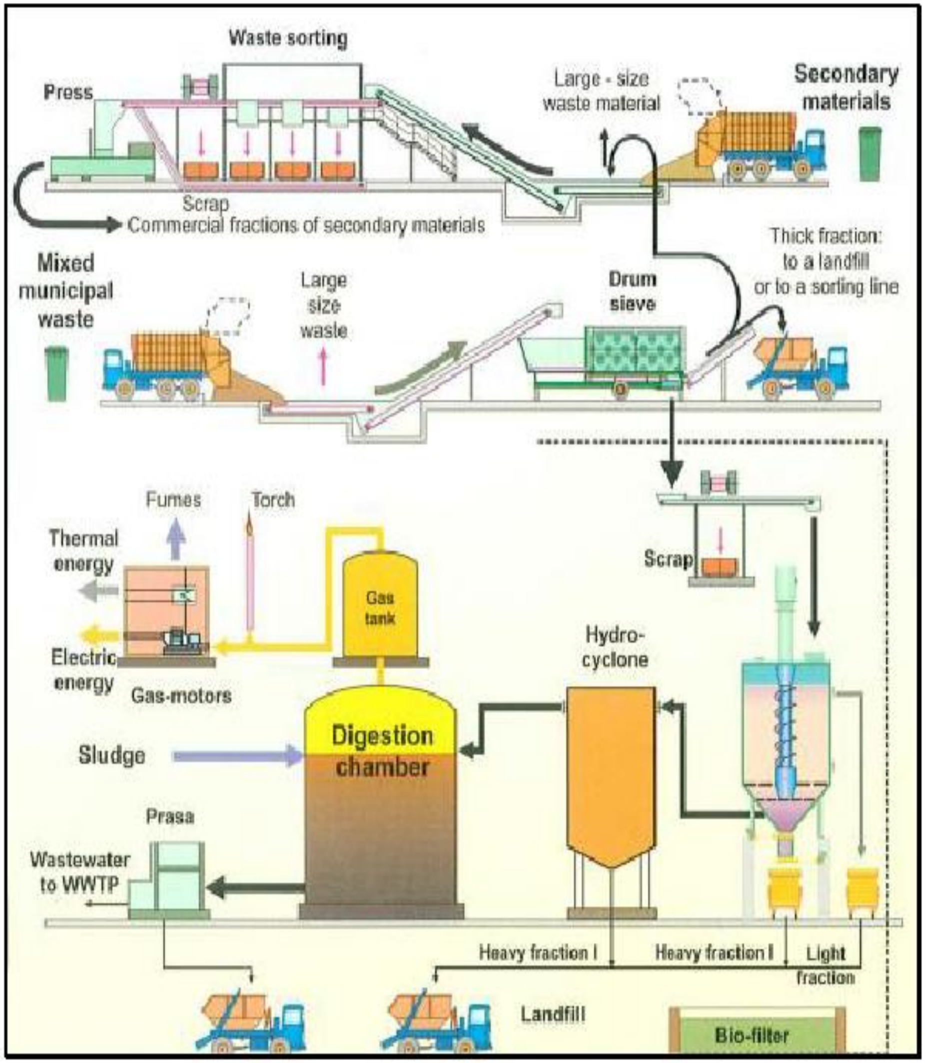
“Integrated Sustainable Solutions - The BTA Process”

Hydropulper & Grit Removal System



BTA Example: *Pulawy, Poland*

- Start-up: 2001
- Capacity: 22,000 MT/yr
- Waste input: OFMSW (mechanically pre-treated municipal solid waste)
- Process: BTA Pre-treatment prior to co-digestion at WWTP
- The waste treatment facility in Pulawy, Poland is located at the city's landfill site and processes
- 22,000 tons per year of mixed MSW.



Kingston (NY) WWTP Dryer Uses Digester Biogas

DBOO by Aslan Environmental Services

- 6 MGD conventional WWTP
- Until 4 years ago unsuccessful cogen,
- Installed Seeghers Dryers, modified for small scale applications, utilizing digester biogas
- Automatic operations 24-7
- Operational cost $250/dry ton
- Facility DBOO by Aslan; no public financing
- Pellets recycled at no cost to agency

Greater Lawrence (MA) Sanitary District: Closed-loop Energy System with Dryer

- Uses biogas for biosolids dryers
- Two direct drive rotary dryers and two RTOs
- Water heated by dryer exhaust used to heat digesters
- Privately owned and operated by NEFCO
- Closed-loop energy trading saves $600,000 in natural gas annually

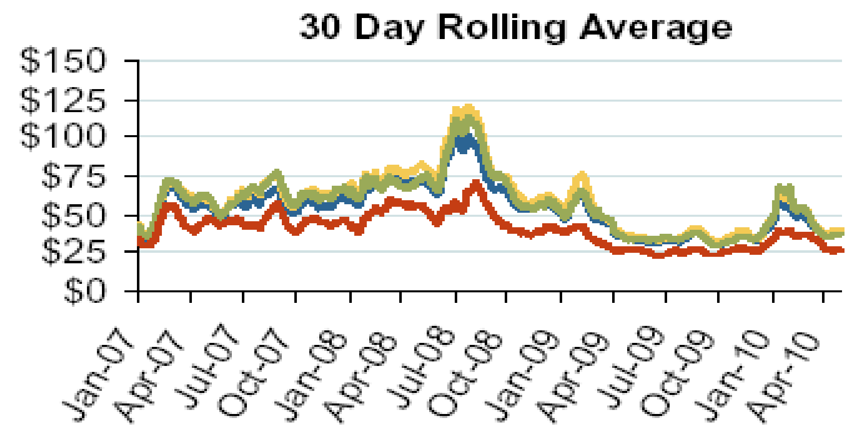
(Source: Donovan, 2004)

Storing Biogas to Meet Peak Needs

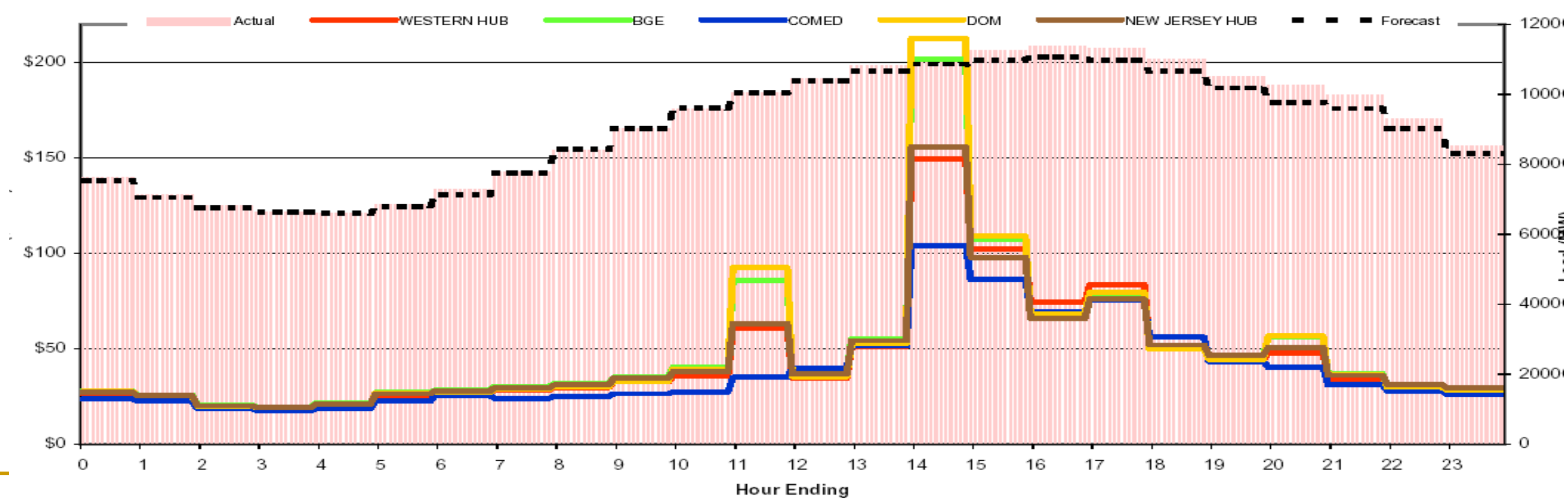
***JDV* DOUBLE MEMBRANE GAS HOLDER**

The ***JDV* Double Membrane Gas Holder** is a proven design to store digester gas with low total cost of ownership. The storage system is easier to install, has lower upfront capital costs and requires lower operating capital when compared to other methods of gas storage.

Generating Electricity When Grid Prices Are High



Friday August 14, 2009



Lille, Sweden: Digester Biogas to Vehicle Fuel

- 1.1 million people
- Biowaste and biosolids for anaerobic digestion
- 4 million cubic meters of purified biogas
- 150 municipal bus fleet fueled with compressed biogas

END USE SOLUTIONS

FOCUS

Small-Scale Natural Gas Liquefier

Gas Technology Institute (GTI) has developed small-scale natural gas liquefaction systems for use in vehicles, remote gas recovery, bio-gas recovery, and other specialty natural gas markets. This work is presently targeted at 5,000 to 30,000 gallon per day production capability. Linde BOC has licensed this technology and is actively pursuing commercialization on a world-wide basis.

Milton Regional Sewer Authority – Plan for Net Energy Production

Charles Wunz, Herbert, Rowland & Grupic

HRG
Herbert, Rowland & Grubic, Inc.
Engineering & Related Services

- 4 MGD conventional WWTP with ConAgra load, equivalent to 45 MGD loading
- Requires organic load capacity upgrade
- Planning for anaerobic treatment of ConAgra load, reducing energy usage 30 percent
- Installation of CHP, with waste heat for biosolids dryer
- Will net meter twice the electrical production as use in
- $34 million in state-assisted loans

Gloversville-Johnstown (NY) Wastewater Treatment Plant

- Johnstown IDA attracts yoghurt plant next to WTP
- Build force main for whey to digester
- 2 – 150kW generators replaced with 2 – 350 kW generators (95% of demand)

Sacramento Municipal Utility District: Partnership with WWTP for Energy

- Joint project with SRCSD at Sacramento Regional Wastewater Treatment Plant – Biogas already used at SMUD Co-Gen
- Utilizes excess capacity at largest inland water discharger in CA (181 mgd permitted capacity)
- Study Objectives:
  - Pump food processing waste and brown grease directly into the digester instead of primary and secondary treatment systems.
  - Increase gas production and methane content of the gas produced in the digesters.
  - Monitor biosolids characteristics in the digester, and potential operational issues for a full scale system
  - Obtain data on the economic factors to better assess economic feasibility of a full scale project
- Pilot Test conducted in four phases: Dec. 2008 – September 2009

Other Major City Plans for Energy Production

- City of Tacoma, Washington: Solid Waste Division will prepare organic waste for delivery to Wastewater Division for dual phase digestion.
- Metro Vancouver, BC: Full Scale pilot plant for high strength organic waste testing at Annacis Island multiple stage thermophilic digesters
- Pinellas County, FL: Codigestion supplements biogas sufficient to support both dryers and CHP

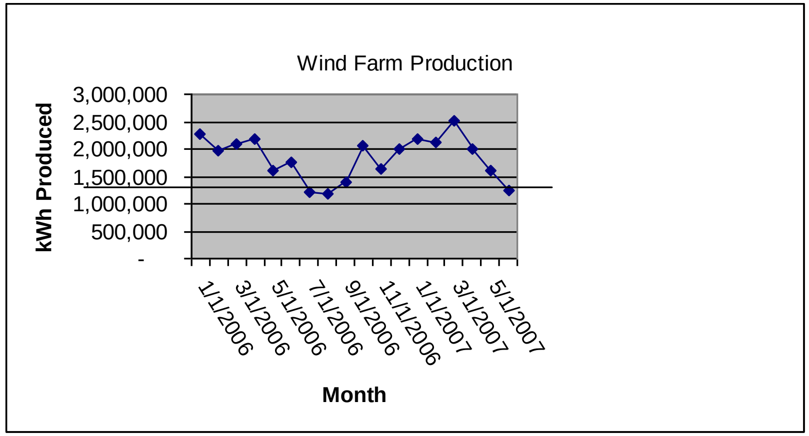
Leader in Alternative Energy: Atlantic County Utility Authority (ACUA)

ACUA: Wind Farm

- Five 14 foot diameter wind turbine towers. 262 feet high, each 1.5 MW at 14 mph wind.
- Blades are 120 feet long; total height from the ground to the tip of the blade over 380 feet (height of a 35 story building); turn 10 – 20 rpm, tip speed 120 mph.
- Privately owned by Jersey Atlantic Wind, LLC; cost over $12 million, with ACUA contract to purchase at fixed rate for 20 years.

ACUA: Wind Power As Electricity Source

2007 Data for Wind Generation at ACUA



	Actual Total kWh Usage	Acutal Per Cent Windpower	Acutal kWh from Wind	Savings from Grid price	Actual Kwh from Grid	Total Electric Cost Windmill plus Grid
January	1,544,001	68.46%	1,057,060	$ 41,408	486,941	$136,523.44
February	1,491,237	70.44%	1,050,392	$ 42,300	440,845	$132,252.57
March	1,617,955	73.08%	1,182,360	$ 46,899	435,595	$142,205.19
April	1,582,673	65.16%	1,031,340	$ 41,300	551,333	$141,779.46
May	1,555,838	61.41%	955,512	$ 35,031	600,326	$139,836.47
June	1,626,301	53.93%	877,013	$ 40,369	749,288	$154,455.26
	9,418,005		6,153,677	$ 206,938.41	3,264,328	$847,052.39
			65%	$ 15,000.00	35%	
				$ 221,938.41		

ACUA: Solar Power as Electricity Source

- Five Solar Panel Installations
  - 2 roof Top Installations- 204 panels – 36 Kw
  - 2 Ground Mount Fixed Installations-1716 panels –300 Kw
  - 1 Canopy Parking Lot Installation – 936 panels – 164 Kw
- 500 Kw total Solar Power Capacity
- 3.25% of electric usage produced in 2006

Leader in Total Resource Management: Landis Sewage Authority

New Jersey's "Greenest" Wastewater Plant

- Zero discharge of effluent to surface waters
- Recycling of biosolids to farms and forests
- Anaerobic digester biogas fuels170 kW generator with thermal recovery for digester heating at $1.3 million
- Wind generator installed by LSA
- 4 MW solar panels on 14 acres developed in a "Public/Public/Private partnership"

Outside-The-Box for Managing Organics, Materials and Energy

- Heat extraction from wastewater
- Nutrient removal using processed WAS
- Algae production from effluent
- Industrial symbiosis involving steam and biogas
- Micro-hydroelectricity
- Resource extraction: biopolymers, inerts for biobricks, phosphorus removal

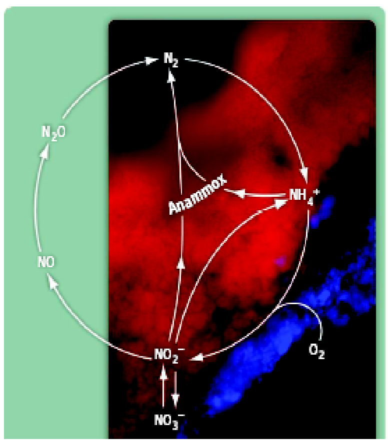
Advances in N Removal with Novel Microbes Affect Energy Use and Production

ENGINEERING

Sewage Treatment with Anammox

B. Kartal,[1] J. G. Kuenen,[2] M. C. M. van Loosdrecht[2]

Wastewater treatment including high rat[e] anammox processes have the potential to become energy-neutral or even energy-producing.



The nitrogen cycle including anammox. Molecular nitrogen (N_2) is fixed biologically or industrially to ammonium (NH_4^+), the main fertilizer for plants. When ammonium is released to the environment, it may be oxidized by aerobic, nitrifying bacteria and archaea to nitrite (NO_2^-) and nitrate (NO_3^-), respectively, which plants can use as an additional nitrogen source. Under anaerobic conditions, nitrate and nitrite may be reduced back to ammonium, or to nitrogen gas through denitrification. Nitrite can also be combined with ammonium to give nitrogen gas in the anammox reaction. (**Background**) Outer layer of a compact nitrogen-producing granule for possible use in energy-generating wastewater treatment. The anammox bacteria (red) are on the inside of the granule; the nitrite-producing bacteria (blue) reside in a 40-µm-thick layer on the outside, ensuring that oxygen does not reach the anoxic anammox bacteria. The bacteria have been stained with fluorescent 16*S* rDNA probes.

Proceedings of the 11th World Congress on Anaerobic Digestion (AD11) 23-27 September 2007

Anammox brings WWTP closer to energy autarky due to increased biogas production and reduced aeration energy for N-removal

Hansruedi Siegrist, David Salzgeber, Jack Eugster and Adriano Joss
Eawag, Swiss Federal Institute for Aquatic Science and technology, Überlandstrasse 133, PO Box 611, CH-8600 Dübendorf, Switzerland. (E-mail: siegrist@eawag.ch)

Wastewater Innovations for Energy Efficiency

- **Anaerobic Membrane Bioreactors**

  Proposed demonstration plant at the Masdar Ecocity in Abu Dhabi.

- **Microbial Fuel Cells**

  The Israeli company EMEFCY is marketing the MEGAWATTER process which does just this.

- **Advanced Primary Treatment**

  Micromedia Filtration has a demonstration plant operating in Woodsville, New Hampshire

Passamaquoddy Tribe Algae-to-Oil Using Effluent

- *KEY POINT-SELF SUFFICIENT!*
- Carbon Neutral
- Waste products, when using Chlorella (42% oil dry-weight)
  - Waste gas = oxygen
  - "oil cake" is dried chlorella, sold in health food stores for $700/lb
  - Fertilizer can be sewage effluent

Sipayik 100 gal. bio-reactor, sewage treatment plant (250 ml/4 day)

Lille, Sweden: Digester Biogas to Vehicle Fuel

- 1.1 million people
- Biowaste and biosolids for anaerobic digestion
- 4 million cubic meters of purified biogas
- 150 municipal bus fleet fueled with compressed biogas

END USE SOLUTIONS

FOCUS

Small-Scale Natural Gas Liquefier

Gas Technology Institute (GTI) has developed small-scale natural gas liquefaction systems for use in vehicles, remote gas recovery, bio-gas recovery, and other specialty natural gas markets. This work is presently targeted at 5,000 to 30,000 gallon per day production capability. Linde BOC has licensed this technology and is actively pursuing commercialization on a world-wide basis.

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Wastewater Treatment Using Algae - A Comprehensive Guide from Oilgae

Wastewater Remediation - A Critical Problem

For Enquiry >

Sustainable remediation of wastewater ï¿½ both from municipal from industrial sources ï¿½ is a critical need world over. Many of the current practices used in remediation either rely on expensive and sometimes environment-unfriendly chemicals or in using considerable amounts of energy. Neither of these aspects is sustainable in the long run.

Comprehensive Alternative Energy Production: Biosolids for Biomass

Reading Anthracite's Repplier Mine in Minersville, Pennsylvania

TIPPING POINT: Resource Center for Converting Wastes into Products and Energy