Energy Efficiency and CHP Opportunities at WWTPs

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Presentation Outline

- Energy Efficiency and CHP
- CHP the Concept
- Biogas CHP Applications
- Market Potential & Michigan Status
- Summary

Energy Efficiency and CHP

- First things first... increase plant efficiency before pursuing a CHP project
- WWTPs are the largest energy users in a municipality
- Know where the energy is consumed in a WWTP
  - Aeration usually accounts for 50% of electric power
  - Influent Lift Pumps account for about 15-20% of electricity
  - Lighting and HVAC account for 5-15% of electricity consumed

Initial Steps towards Energy Efficiency

- Understand Rate Schedule(s) in use
  - Base Charge(s)
  - Consumption charge (kWh)
  - Time of use charges
  - Method of computing demand charges
  - Alternative Rate Schedule(s)
  - Power Factor Correction
- Many operators never see the monthly bill

Typical Energy Efficiency Measures in WWTPs

- Aeration upgrades
- Water Meters/AMR
- Digester Gas Utilization
- Leak Detection Systems
- Boilers
- SCADA
- Pumps
- Motors and Drives
- Building Envelope
- Lighting

Distributed Generation (DG)

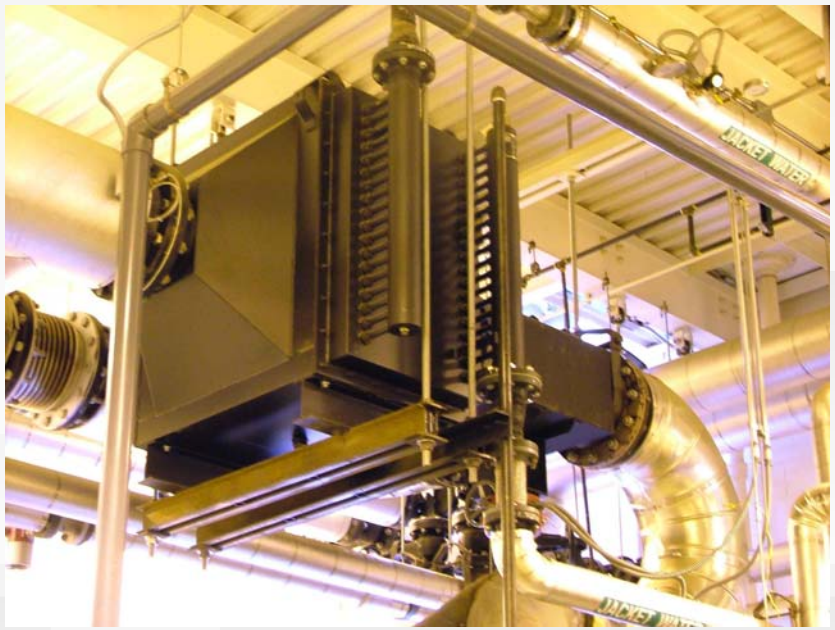
DG is …

- An Electric Generator
- Located At a Substation or Near a Building / Facility
- Generates at least a portion of the Electric Load

DG Technologies …..

- Solar Photovoltaic
- Wind Turbines
- Engine Generator Sets
- Turbine Generator Sets
  - Combustion Turbines
  - Micro-Turbines
  - Steam Turbines
- Fuel Cells

Combined Heat & Power (CHP)
A Form of Distributed Generation

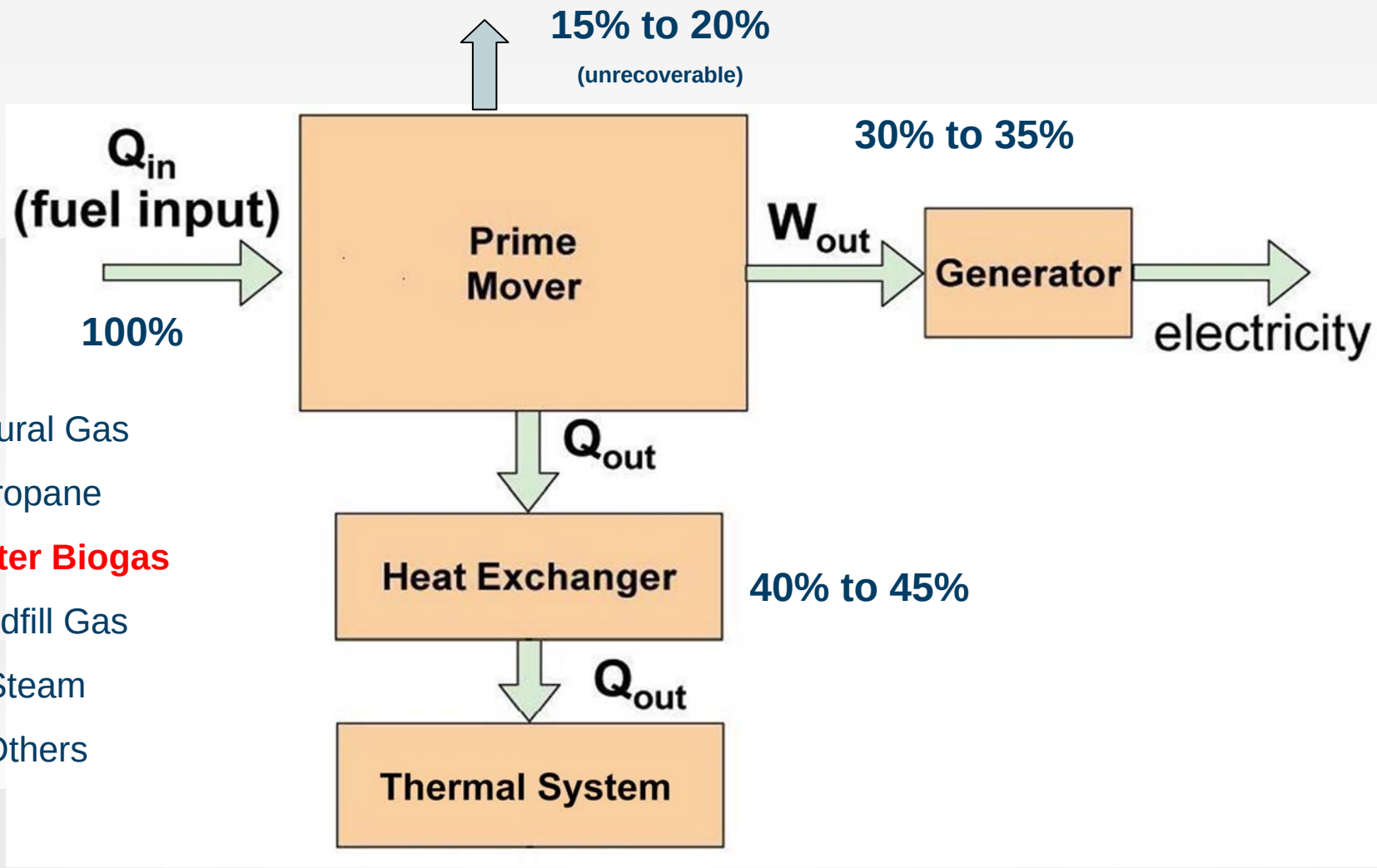


CHP is …

- An Integrated System
- A Suite of Technologies
- Located At or Near a Building/Facility
- Provides at Least a Portion of the Electrical Load and
- Recycles the Thermal Energy for
  - Space Heating / Cooling
  - Process Heating / Cooling
  - Dehumidification
  - Domestic Hot Water

Picture Courtesy of UIC

Combined Heat and Power



Natural Gas

Propane

Digester Biogas

Landfill Gas

Steam

Others

Normal CHP Configuration

- CHP Systems are Normally Installed in Parallel with the Electric Grid (CHP does not replace the grid)
- Both the CHP and Grid Supply Electricity to the Customer
- Recycled Heat From the Prime Mover Used for
  - Space Heating (Steam or Hot Water Loop)
  - Space Cooling (Absorption Chiller)
  - Process Heating and/or Cooling
  - Dehumidification (Desiccant Regeneration)

Generators and Inverters

Two Types of Generators

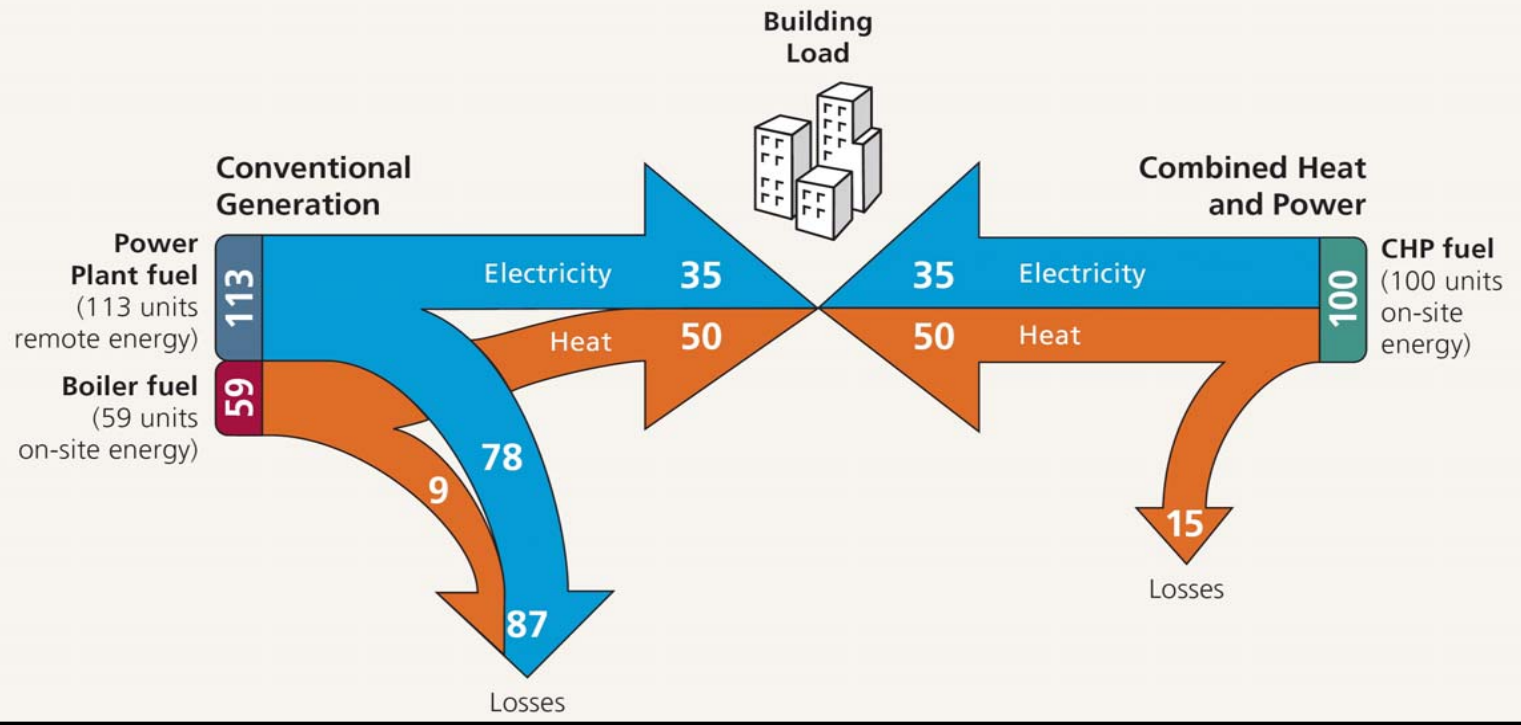
Induction

- Requires External Power Source to Operate (Grid)
- When Grid Goes Down, CHP System Goes Down
- Less Complicated & Less Costly to Interconnect
- Preferred by Utilities

Synchronous

- Self Excited (Does Not Need Grid to Operate)
- CHP System can Continue to Operate thru Grid Outages
- More Complicated & Costly to Interconnect (Safety)
- Preferred by CHP Customers

Conventional Energy System vs. CHP



Energy System	Baseline (Conventional)	Alternative (CHP)
Electric Efficiency	35 units ÷ 113 units = 31%	35 units ÷ 100 units = 35%
Heating Efficiency	50 units ÷ 59 units = 85%	No Additional Fuel for Recycled Heat
Combined Efficiency	**85 units ÷ 172 units = 49%**	**85 units ÷ 100 units = 85%**

What are the Customer Benefits of CHP?

CHP does not make sense in all applications, but where it does make technical and economical sense, it will provide

- Lower energy costs
- Reduced energy consumption
- Increased electric reliability
- Standby power
- Improved environmental quality

CHP is a Proven Technology

National CHP Status (2009)

- ~85,000 MW installed at 3,500 sites (nationally)
  - Average capacity is 25.2 MW
  - Median capacity is 1.3 MW
- Represents almost 9% of total U.S. generating capacity, and over 12% of U.S. generation
- *Saves over 3 quads of fuel each year!*
- *Eliminates over 400 million tons of CO_2 emissions each year!*
- ***~2,860 MW installed at 87 Sites (Michigan)***

Candidate Applications for CHP

- Hospitals
- Colleges / Universities
- High Schools
- Residential Confinement
- High Rise Hotels
- Fitness Centers
- Landfill Sites
- Pulp & Paper Mills
- Chemicals Manufacturing
- Metal Fabrication
- Ethanol / Biodiesel Plants
- Food Processing Waste
- Farm Livestock Waste
- Waste Water Treatment

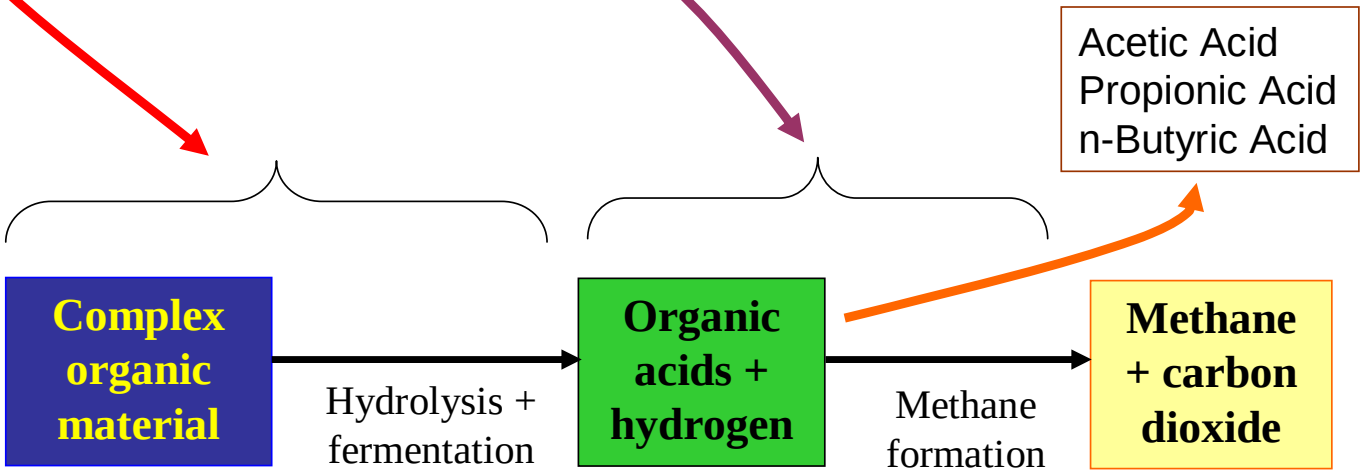
Anaerobic Digester Applications

Anaerobic Digesters

- Natural biological (bacterial) process that occurs when organic material decomposes biologically in the absence of oxygen
- When properly applied, digester technology can effectively assist in:
  - Sustainable
  - Economical
  - Environmentally balanced
  - Neighbor friendly practices

Anaerobic Digestion Process Overview

- Bacteria ferment and convert complex organic materials into acetate and hydrogen, and then-
- Methanogens convert the acetate and hydrogen into methane.



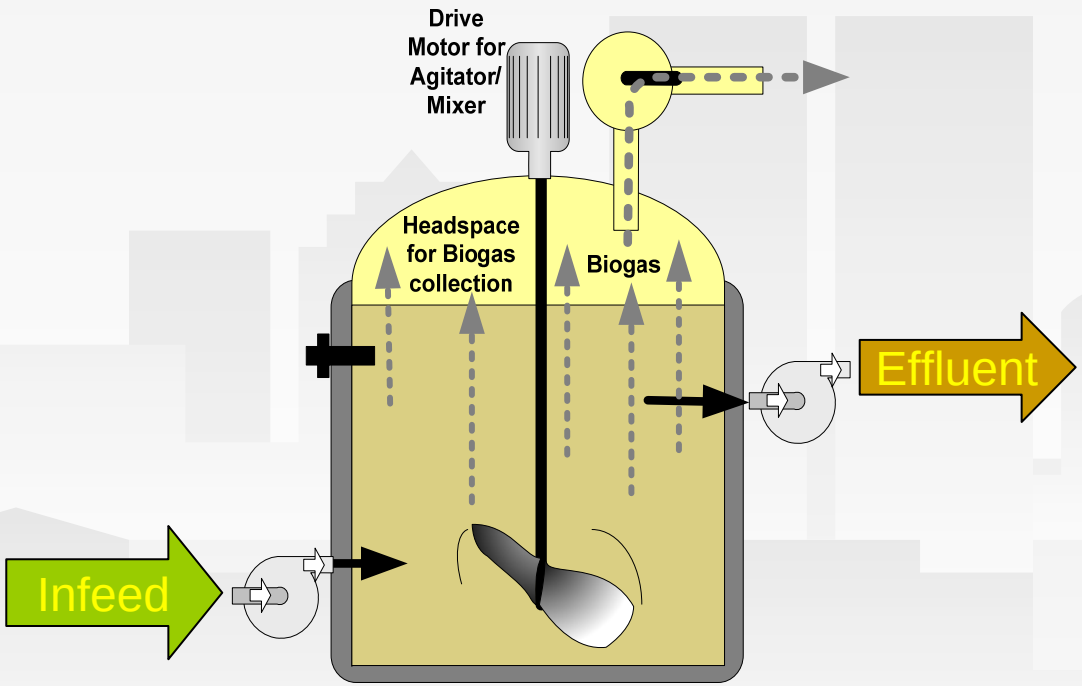
Anaerobic Digesters in Municipal WWTPs

- One of the primary steps used in a wastewater treatment plant is “stabilization”
  - Less odorous (make it quit stinking)
  - Pathogen organism reduction (kill the bugs that could cause a disease)
  - Reduce volume of sludge
- Many WWTPs use two stages of digestion treatment which are typically called
  - Stage 1 (primary digestion)
  - Stage 2 (secondary digestion)

Two Phases of Digestion

- Phase I (primary) Digestion
  - Majority of methane is generated during this phase
  - Bacteria in Phase I tank(s) thrive in a temperature range between 86°F and 100°F (Mesophilic)
  - Phase I digester tanks typically have a “fixed” stationary cover
  - Material is typically actively stirred by either a mechanical mixer or compressed biogas
- Phase II (secondary) Digestion
  - Not heated or mixed
  - Primary purpose is to allow digested solids/sludge to settle and to remove the “supernatant liquor”

Diagram of Complete Mix Digester



Typical Digester Gas Composition

Methane (CH_4)	60% to 70%
Carbon Dioxide (CO_2)	30% to 40%
Hydrogen Sulfide (H_2S)	2,000 to 3,000 ppm
Ammonia	3 to 4 ppm
Moisture	considered a saturated fuel
Other	trace amounts

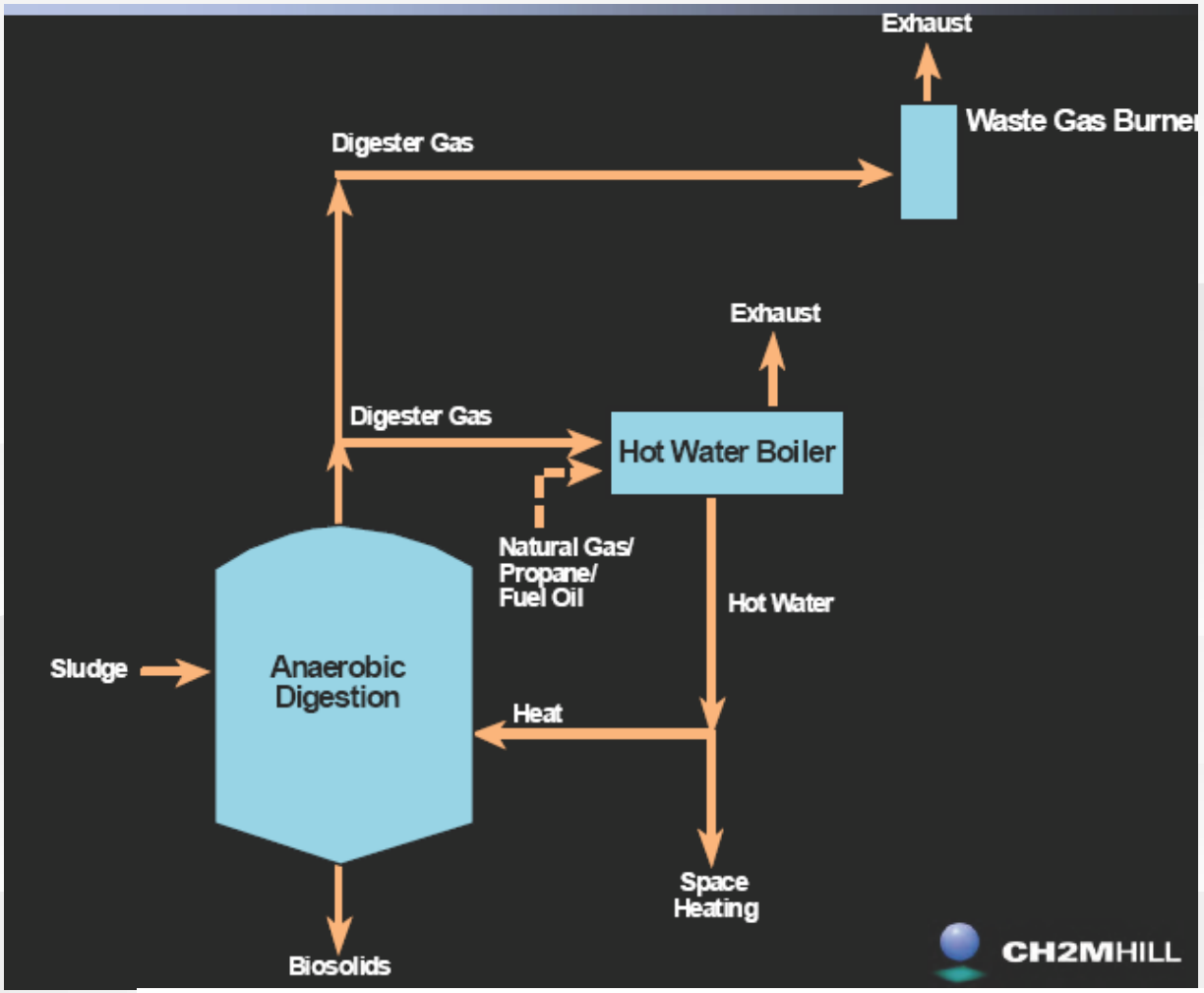
Contaminants of Most Concern:

- Water
- Hydrogen Sulfide
- Carbon Dioxide (for gas injection option)

Energy Recovery – Biogas
(60% to 70% Methane)

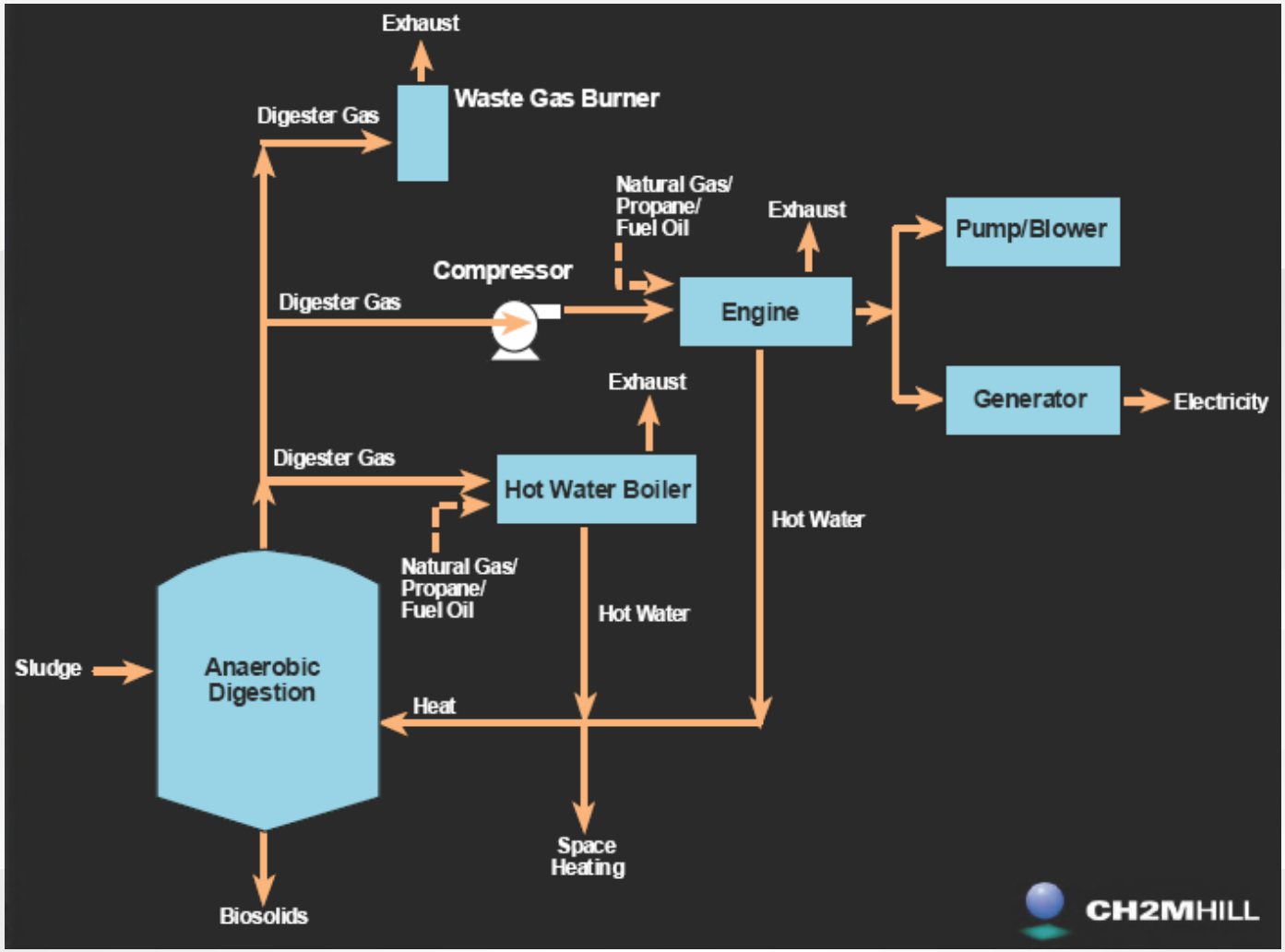
- Flare it
- Use it for heating
  - Displace natural gas / propane
- Use it for electric generation (CHP)
  - Displace purchased electricity
  - Displace natural gas (or other heating fuel)
- Clean it up for pipeline use

Biogas Boiler Heating Application Diagram



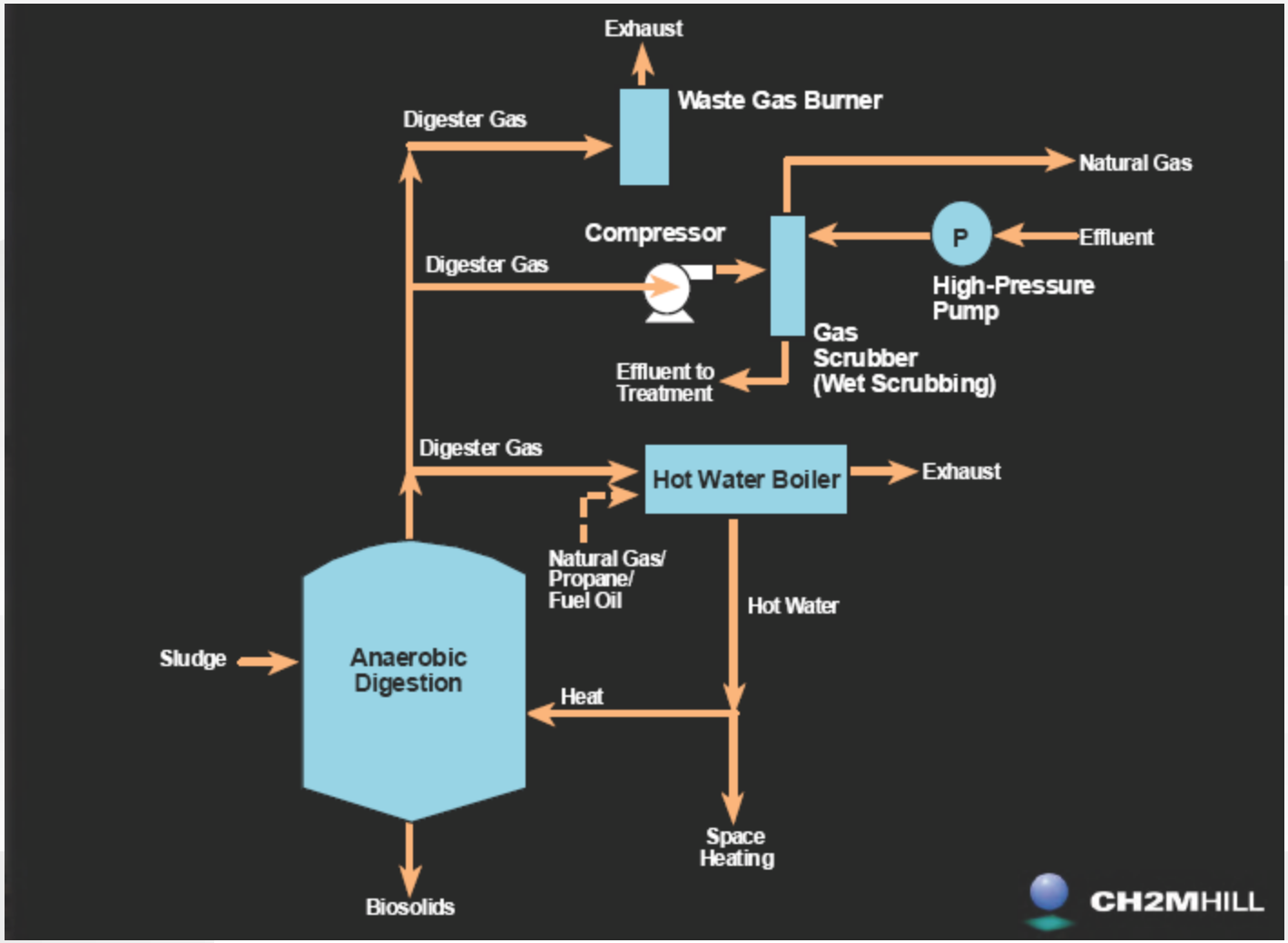
Source: Designing a Project - Rules of Thumb & Questions to Ask, Ron Sieger & Dru Whitlock, CH2MHill, August 11, 2005, http://www.intermountainchp.org/events/landfills/050811/presentations/sieger.pdf

Biogas CHP Application Diagram



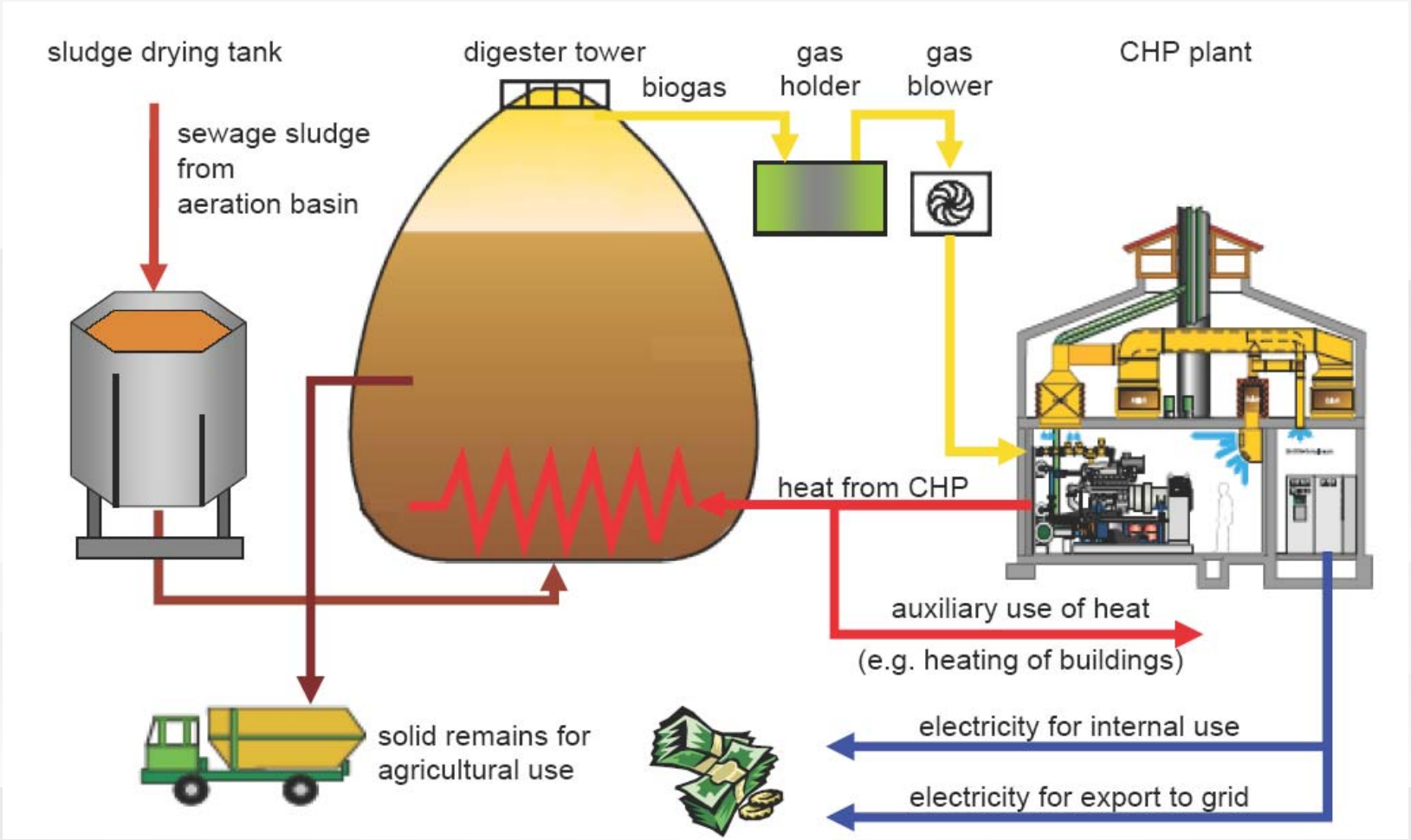
Source: Designing a Project - Rules of Thumb & Questions to Ask, Ron Sieger & Dru Whitlock, CH2MHill, August 11, 2005, http://www.intermountainchp.org/events/landfills/050811/presentations/sieger.pdf

Biogas to Natural Gas Pipeline Application Diagram



Source: Designing a Project - Rules of Thumb & Questions to Ask, Ron Sieger & Dru Whitlock, CH2MHill, August 11, 2005, http://www.intermountainchp.org/events/landfills/050811/presentations/sieger.pdf

Full Anaerobic Digester / CHP System WWTP Diagram



Source: Energy from Biogas CHP Systems with Gas Engines, Stefan Kohler (MDE), October 24, 2007, www.cogeneration.org

Electric & Thermal Coincidence Needed for CHP

- Steady Use of Recovered Thermal Energy
  - Heat the digester
  - Heat the sludge entering digester (pre-heating)
  - Heat facility (building heat)
  - Cool facility through an absorption chiller
  - Heat potable water
- Steady Use for the Electricity
  - Displace electricity utilized by the WWTF
  - Possibly sell excess electricity to utility

CHP Technologies
(Biogas Applications)

- Prime Movers:
  - Combustion turbines
  - Reciprocating engines
  - Microturbines
  - Fuel Cells
- Gas clean up (H_2S)
- Gas compression (turbines and microturbines)
- Generator / heat recovery
- Grid interconnect hardware

Advantages & Disadvantages CHP and Anaerobic Digesters

Advantages

- Odor mitigation
- Pathogen reduction
- Energy savings
- Heating fuel savings
- Reduced electric bills
- Qualified for net metering
- Qualified for renewable energy

Disadvantages

- Adding complexity to WWTF facility
- Commitment to digester system management (labor & maintenance)
- Commitment to CHP system maintenance
- Capital costs
- Electric utility interconnect can be tedious

Installed CHP Status in WWTFs

- 16,000+ municipal wastewater treatment facilities (WWTFs) in U.S.
- ~ 1,000 WWTFs with a total effluent flow rate greater than 5 MGD
- ~ 544 WWTFs with anaerobic digesters
- ~ 106 WWTFs utilize biogas to generate electricity and/or thermal energy

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- Don't forget about industrial wastewater treatment facilities
- 50,000+ industrial WWTFs

Source: Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities, EPA CHP Partnership, December 2006, http://www.epa.gov/chp/documents/wwtf_opportunities.pdf

Source: Combined Heat and Power Market Potential for Opportunity Fuels, Resource Dynamics Corporation, December 2004, http://files.harc.edu/Sites/GulfCoastCHP/MarketAssessments/CHPPotentialOpportunityFuels.pdf

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Rules of Thumb for Considering CHP at a WWTF

# of gallons a typical WWTF processes per day for every person served	100 gallons
Heating value of WWTF biogas	600 btu/ft^3
Cubic feet (ft^3) of digester gas generated per person per day	1.0 ft^3
Power generation rate (watts) at that gas flow rate	2.2 watts
Power generation rate (kW) for a 4.5 million gallon per day (MGD) WWTF	100 kW
Minimum size of WWTF for an economically feasible biogas-to-energy facility	4.5 MGD
More industry (fats, grease, carbohydrates, organics), more gas	

Source: Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities, EPA CHP Partnership, December 2006, http://www.epa.gov/chp/documents/wwtf_opportunities.pdf

Exercise
(using Rules-of-Thumb)

- City population = 200,000 people
- How much power can be generated?

200,000 people x 2.2 watts/person =

440,000 watts or 440 kW

Existing AD / CHP Systems in Midwest WWTPs

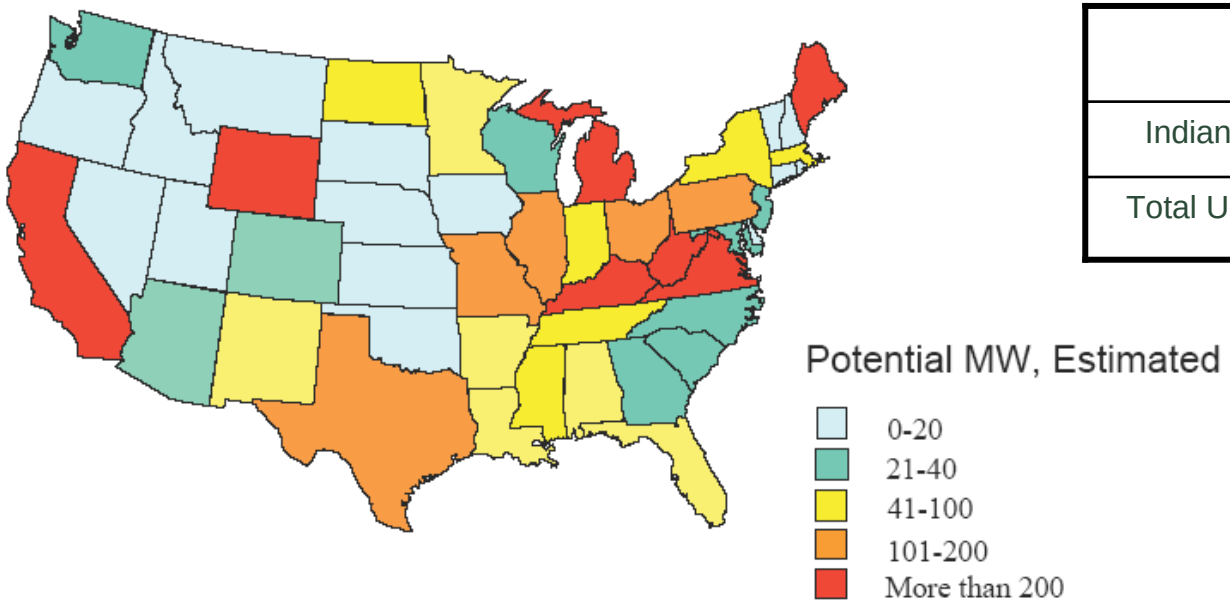
State	Org	Year	Prime Mover	Size
IL	Rock River Water Reclamation District	2003	ERENG	2,475 kW
IL	Aurora Sanitary District	1987	ERENG	2,100 kW
IN	City of West Lafayette	2009	MT	TBD
IA	City of Davenport	1995	ERENG	1,600 kW
IA	Des Moines Metro Wastewater Recl. Facility	1991	ERENG	1,800 kW
MN	City of Albert Lea	2003	MT	120 kW
MN	Rochester Water Reclamation District	2007	ERENG	1,050 kW
NE	City of Omaha - Papillion Creek Wastewater Treatment Plant	1987	ERENG	1,500 kW
NE	City of Omaha - Missouri River Wastewater Treatment Plant	1985	ERENG	3,000 kW
NE	Lincoln Wastewater Div Of Public Works	1992	ERENG	900 kW
OH	KB Compost Services, Inc. (Akron)	2007	ERENG	330 kW
OH	Bayview Wastewater Treatment Plant	2008	ERENG	5,200 kW
OH	Lima Wastewater Treatment Plant	2003	MT	90 kW

Source: Energy and Environmental Analysis, Inc. (May 2008), www.eea-inc.com

Total CHP Market Potential in Municipal WWTFs

If 1 MGD is the cut-off size limit for feasible AD/CHP applications…
(note: technically feasible, not economically feasible)

Figure 4-1. Potential MW for WWTP ADG Projects by State



	Potential Projects	Potential MW
Indiana	633	439
Total U.S.	6,850	4,275

Source: Combined Heat and Power Market Potential for Opportunity Fuels, Resource Dynamics Corporation, December 2004, http://files.harc.edu/Sites/GulfCoastCHP/MarketAssessments/CHPPotentialOpportunityFuels.pdf

WWTPs in Michigan (> 5 MGD) with at Least One Anaerobic Digester

Facility Name	County	Authority Name	Total Influent (MGD)	Potential Electric Capacity (kW)
Grand Rapids WWTP	Kent	Grand Rapids, City Of	54.6	1,213
Wyoming WWTP	Kent	Wyoming WWTP	14	311
Flint WPCF	Genesee	Flint, City Of	43.3	962
Marysville STP	St. Clair	Marysville, City Of	6.14	136
Warren WWTP	Macomb	Warren, City Of	30	667
Pontiac STP	Oakland	Pontiac Dept Of Pub Wks	8	178
Warren WWTP	Macomb	Warren, City Of	30	667
Pontiac STP	Oakland	Pontiac Dept Of Pub Wks	8	178
Detroit STP	Wayne	Detroit Board Of Water Co	660.5	14,678
Ann Arbor WWTP	Washtenaw	Ann Arbor Dept Of Pub Wks	15.14	336
Ycua WWTP	Washtenaw	Washtenaw County DPW	8.27	184
Monroe Metro WWTP	Monroe	Monroe Metropolitan Waste	15.8	351
Saginaw STP	Saginaw	Saginaw DPW Pu	8.3	184
Jackson WWTP	Jackson	Jackson, City Of	13.4	298
Benton Harbor-St Joseph	Berrien	Benton Harbor St Joseph J	7.21	160
Midland WWTP	Midland	Midland , City Of	8.5	189
Huron Valley WWTP-South	Wayne	Huron Valley	14	311

Summary for CHP / Anaerobic Digester Applications

- Appropriate when digester being installed for odor mitigation and pathogen reduction
- Difference between technical and economic feasibility (size of facility)
- Good match for thermal energy (digester)
- Significant market (manure, food processing, waste water treatment, community digesters)
- Turn an operational cost (waste product) into a revenue resource
- Investigate federal and state incentives for biogas CHP projects

Questions / Discussions

Contact Information

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Midwest CHP Application Center

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Contact us… we are here to support the Midwest in exploring and implementing CHP projects!!!