Combined Heat and Power (CHP): A Concept for Wastewater Treatment Facilities

Presented At:
Energy Savings Opportunities for WWTFs:
Energy Efficiency & CHP

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Presentation Outline

- Overview of DG / CHP
- Biogas CHP Applications
- Market Potential & Indiana Position
- Summary

Distributed Generation (DG)

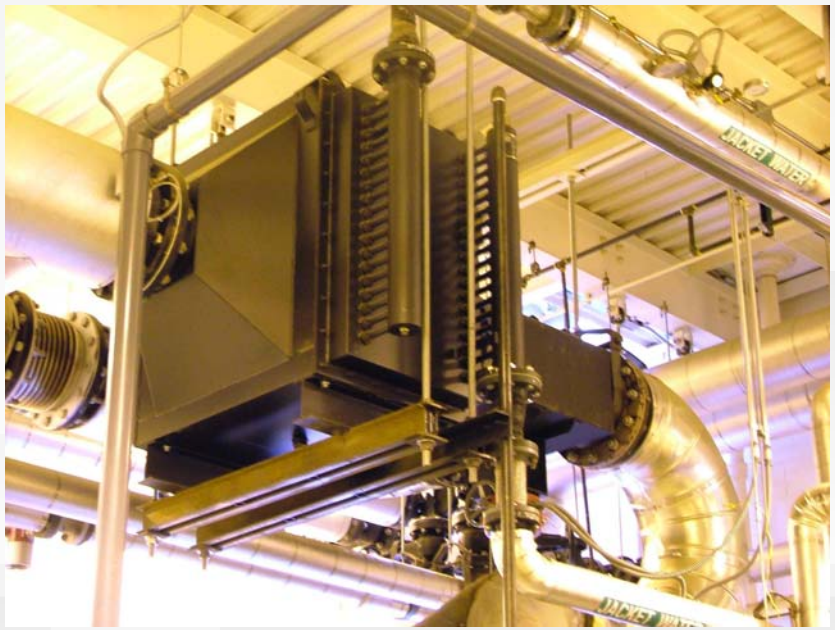
DG is …

- 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

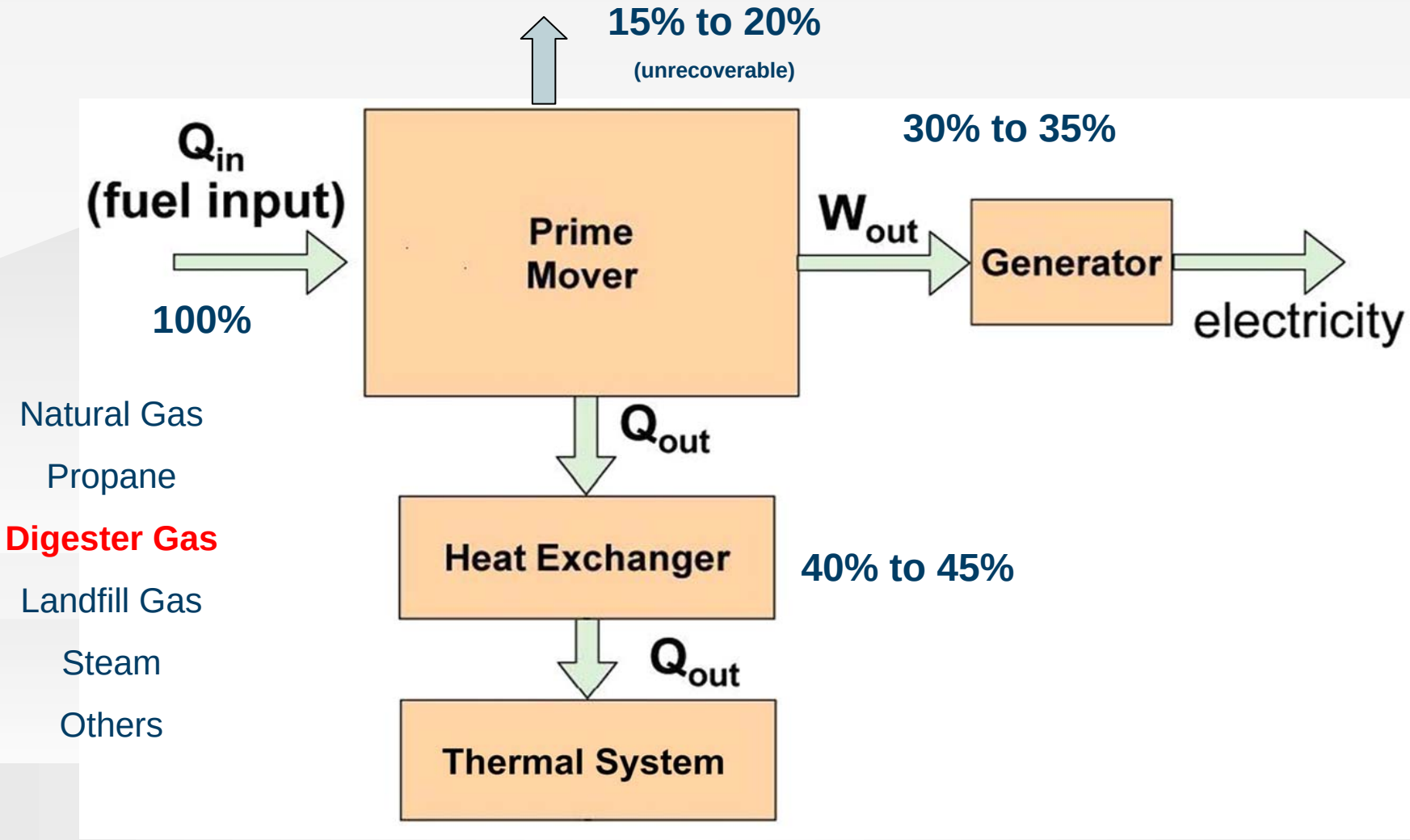


CHP is …

- An Integrated System
- 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 Gas

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

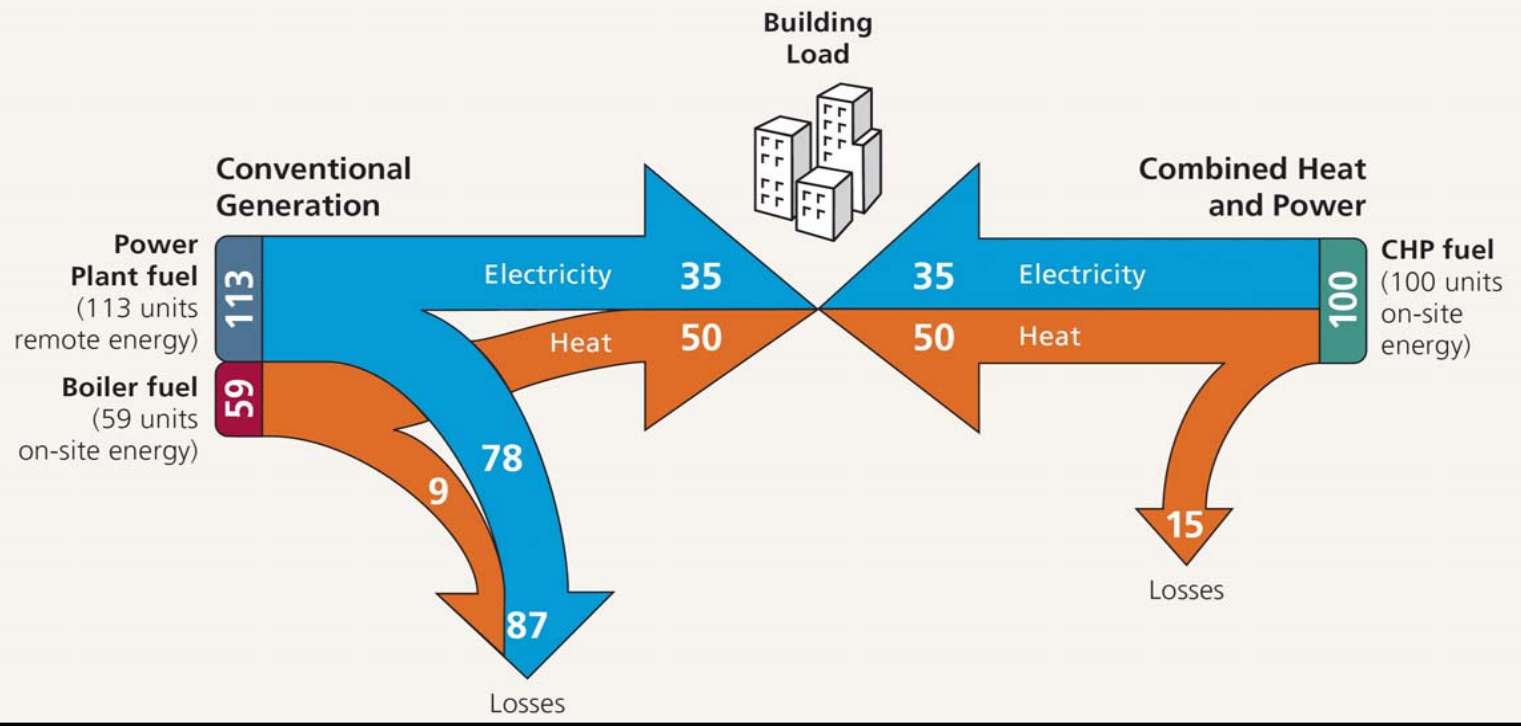
Induction

- 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%**

Candidate Applications for CHP

- Hospitals
- Colleges / Universities
- High Schools
- **Residential Confinement**
- High Rise Hotels
- Fitness Centers

- Food Processing Waste
- Farm Livestock Waste
- Waste Water Treatment

Anaerobic Digesters

- Landfill Sites
- Pulp & Paper Mills
- Chemicals Manufacturing
- Metal Fabrication
- Ethanol / Biodiesel Plants

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

Installed CHP

- 85,200 MW at approx. 3,378 sites (Nationally)
- Represents approx. 8% of total US generating capacity
- Saves an estimated 3 Quads* of fuel per year
- Eliminates over 400 million tons of CO_2 emissions annually

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- 2,308 MW at approx. 33 sites (Indiana)

* 1 Quad = 1 Quadrillion Btu's

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

Biogas CHP Applications (Digester Biogas)

- Wastewater Treatment Facilities
- Animal Waste / Manure Management
- Food Processing Waste

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

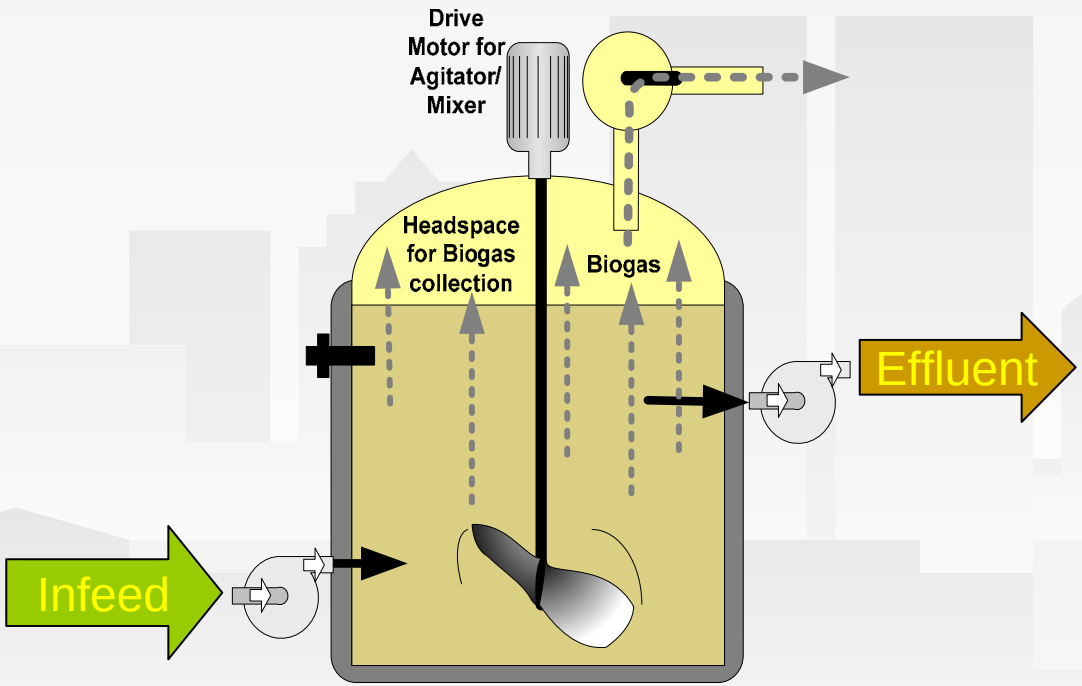
Anaerobic Digesters in Municipal WWTFs

- 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 WWTFs use two stages of treatment which are typically called
  - Stage 1 (primary digestion)
  - Stage 2 (secondary digestion)

Two Phases of Digestion

- Phase II (primary) Digestion
  - Majority of methane is generated during this phase
  - Bacteria in Phase 1 tanks thrive in a temperature range between 86°F and 100°F (Mesophilic)
  - Phase 1 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”

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

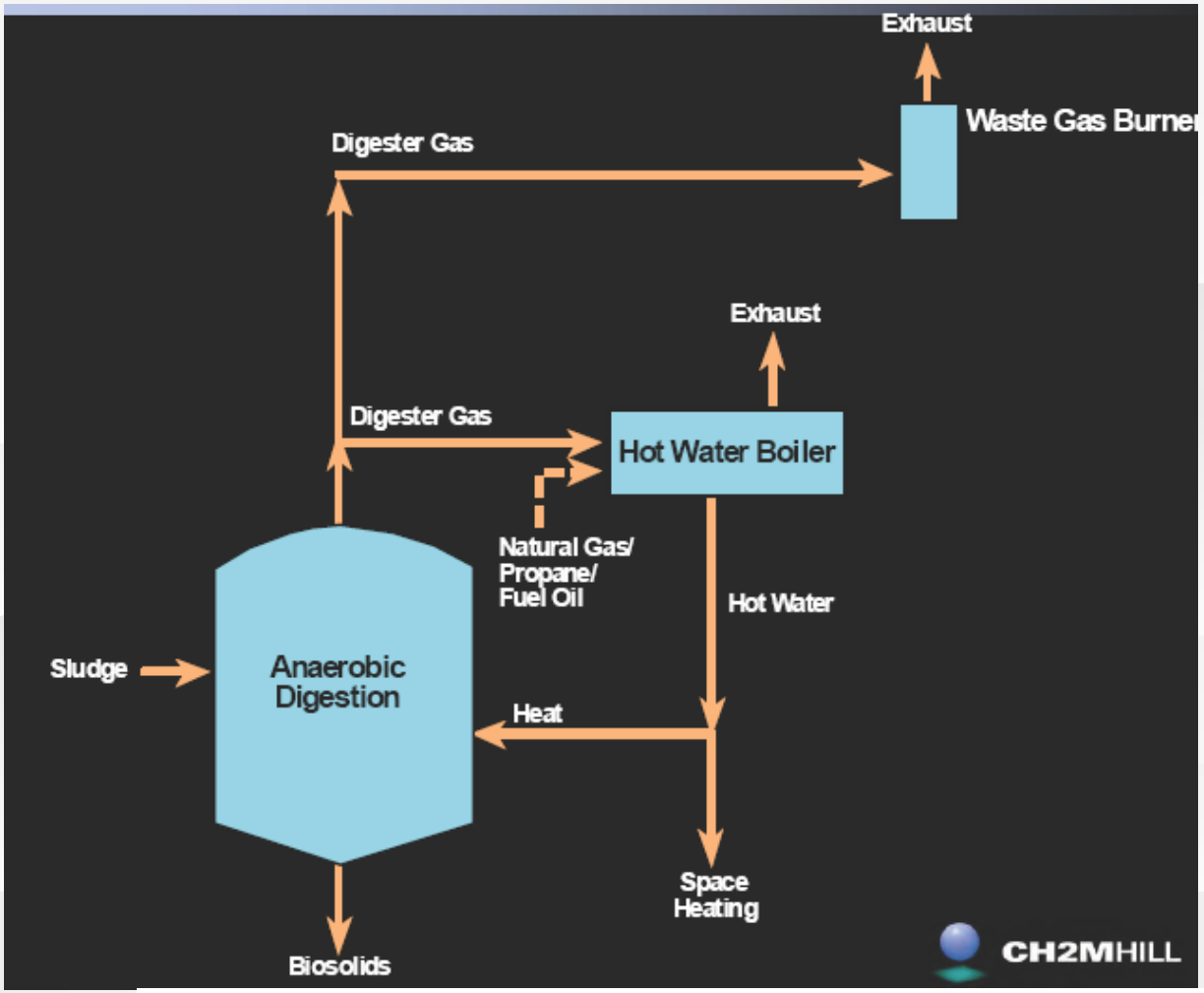
Contaminants of Most Concern:

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

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

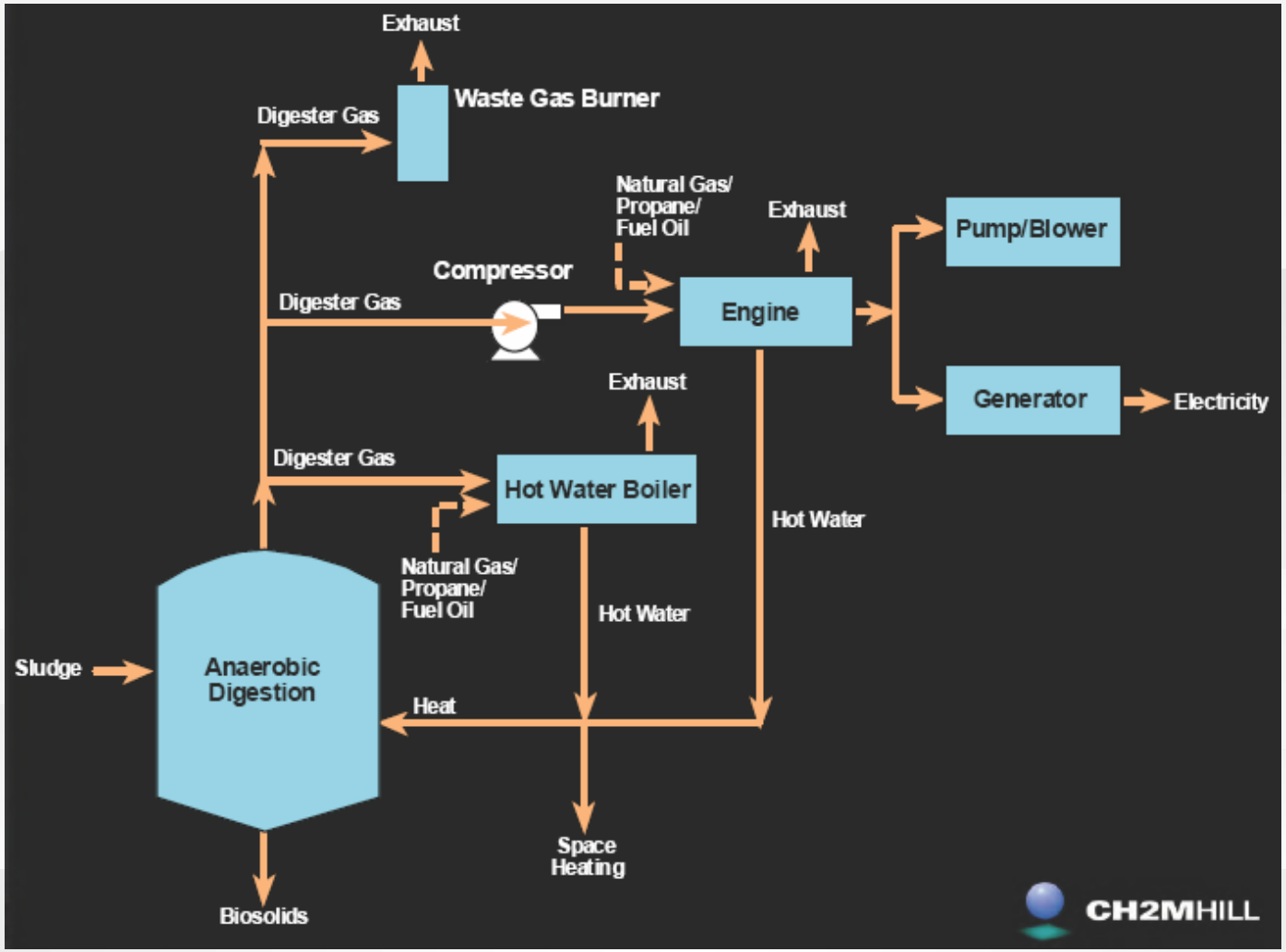
- Flare it
- Use it for heating
  - Displace natural gas / propane
- Use it for CHP
  - Displace purchased electricity
  - Displace natural gas (or other heating fuel)
- Clean it up for pipeline use

Biogas Boiler Heating Application



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



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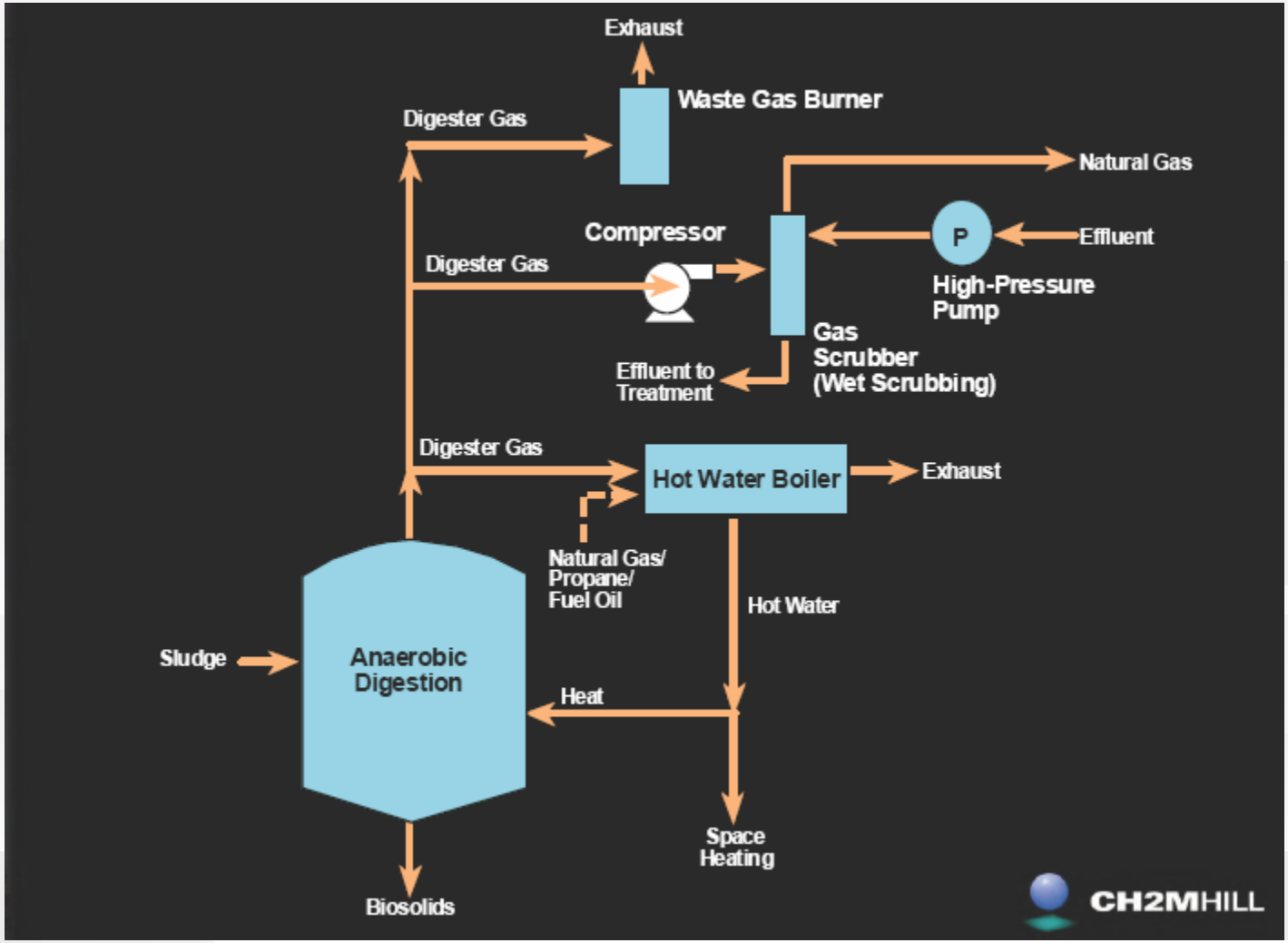
Biogas to Natural Gas Pipeline Application



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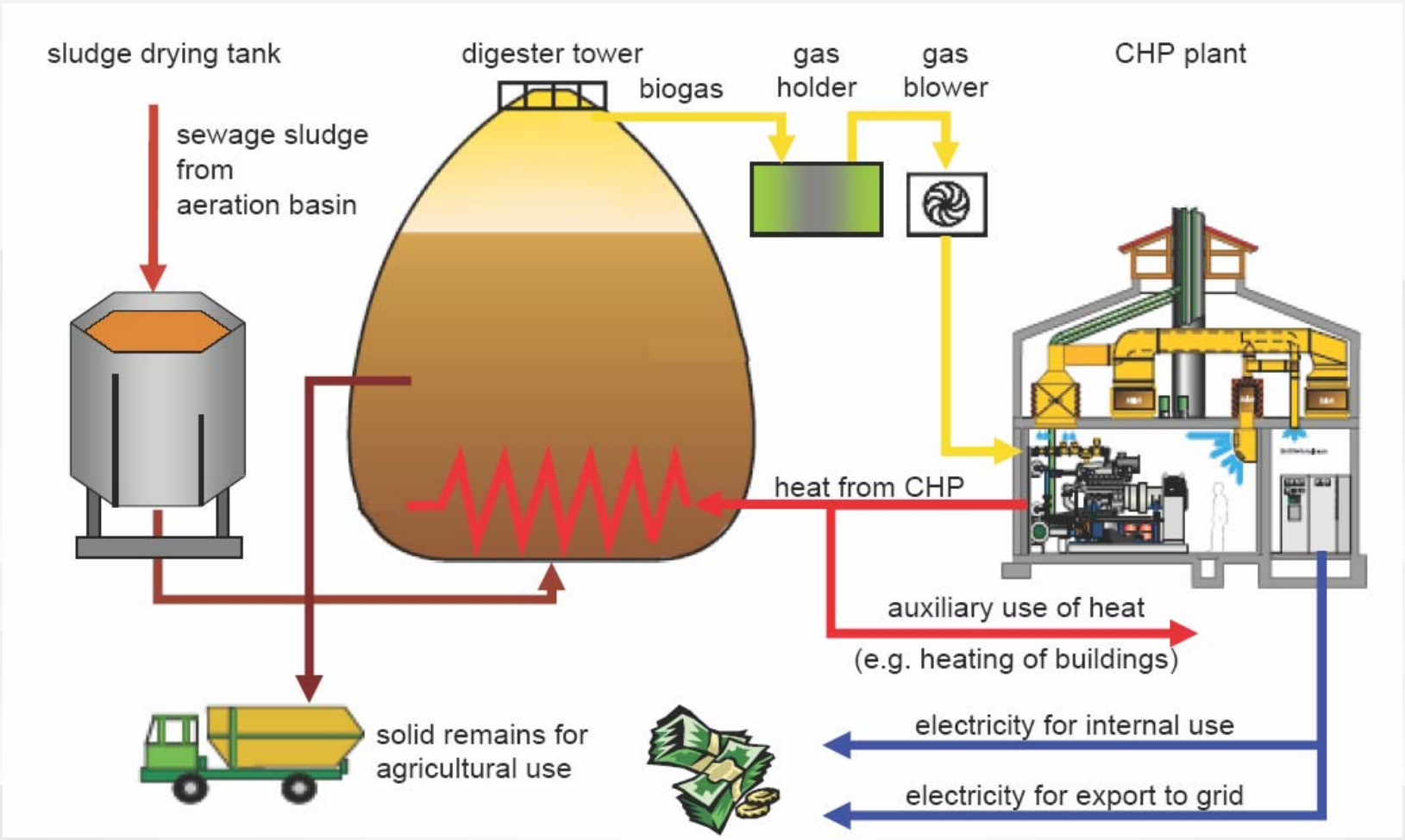
Anaerobic Digester / CHP System



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

Electric & Thermal Coincidence

- 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 (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 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

WWTF AD / CHP Systems – Midwest

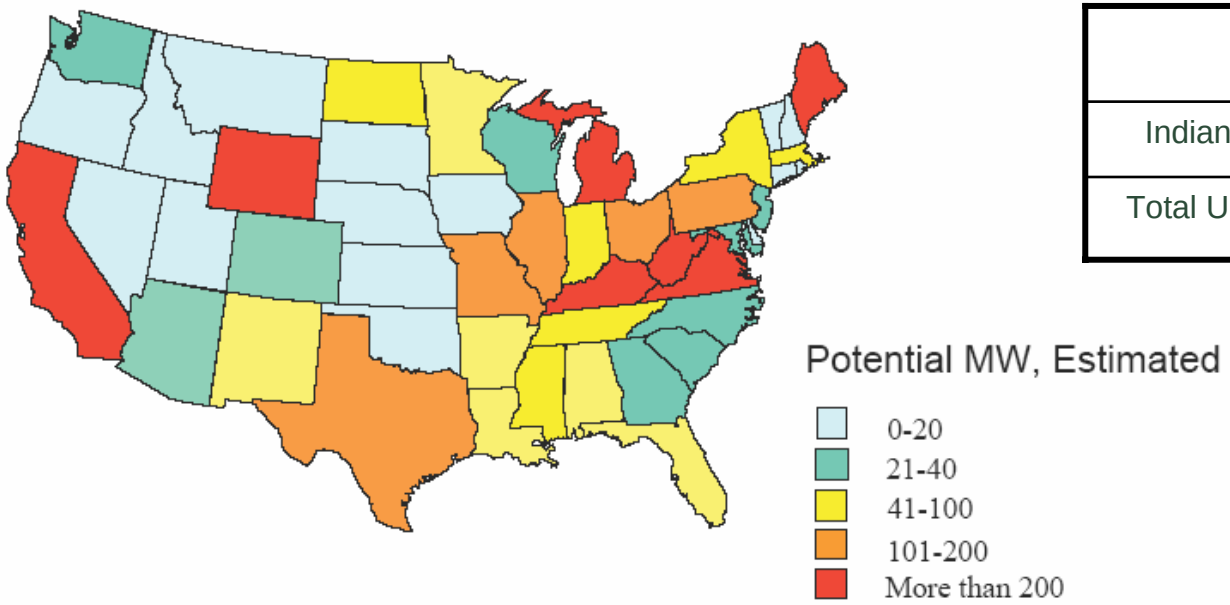
State	Org	Year	Prime Mover	Size
IN	City of West Lafayette	2009	MT	TBD
IA	City of Davenport	1995	ERENG	1,600 kW
IA	Des Moines Metro Wastewater Recl. Facility	1991	ERENG	1,800 kW
IL	Rock River Water Reclamation District	2003	ERENG	2,475 kW
IL	Aurora Sanitary District	1987	ERENG	2,100 kW
MN	City of Albert Lea	2003	MT	120 kW
MN	Rochester Water Relcamation 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	???
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	283	66
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

Summary CHP / Digester Applications

- Appropriate when digester being installed for odor mitigation and pathogen reduction
- 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

Questions / Discussions

Contact Information

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