Waste to Energy Opportunities in Wastewater Treatment Facilities utilizing Anaerobic Digester and CHP Concepts and Technologies

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

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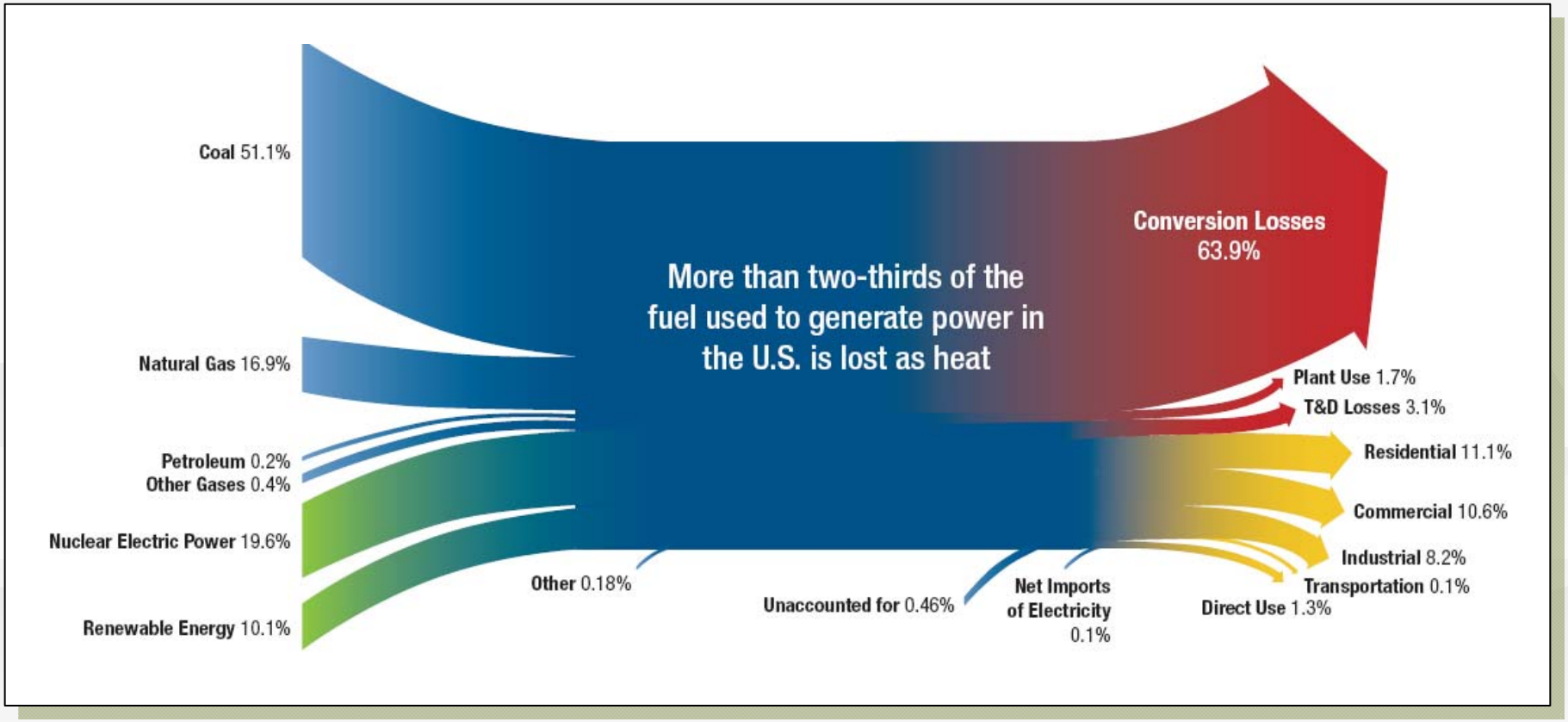
In Partnership with the US DOE

Topics Covered

- CHP Concept and Benefits
- WWTFs – An Attractive Target Market for CHP
- Basics of Anaerobic Digesters
- Digester Biogas Use Options and Treatment
- Market Challenges and Summary Messages

Average Efficiency of U.S. Utility Generation



Source: DOE Energy Information Administration Annual Energy Review 2007

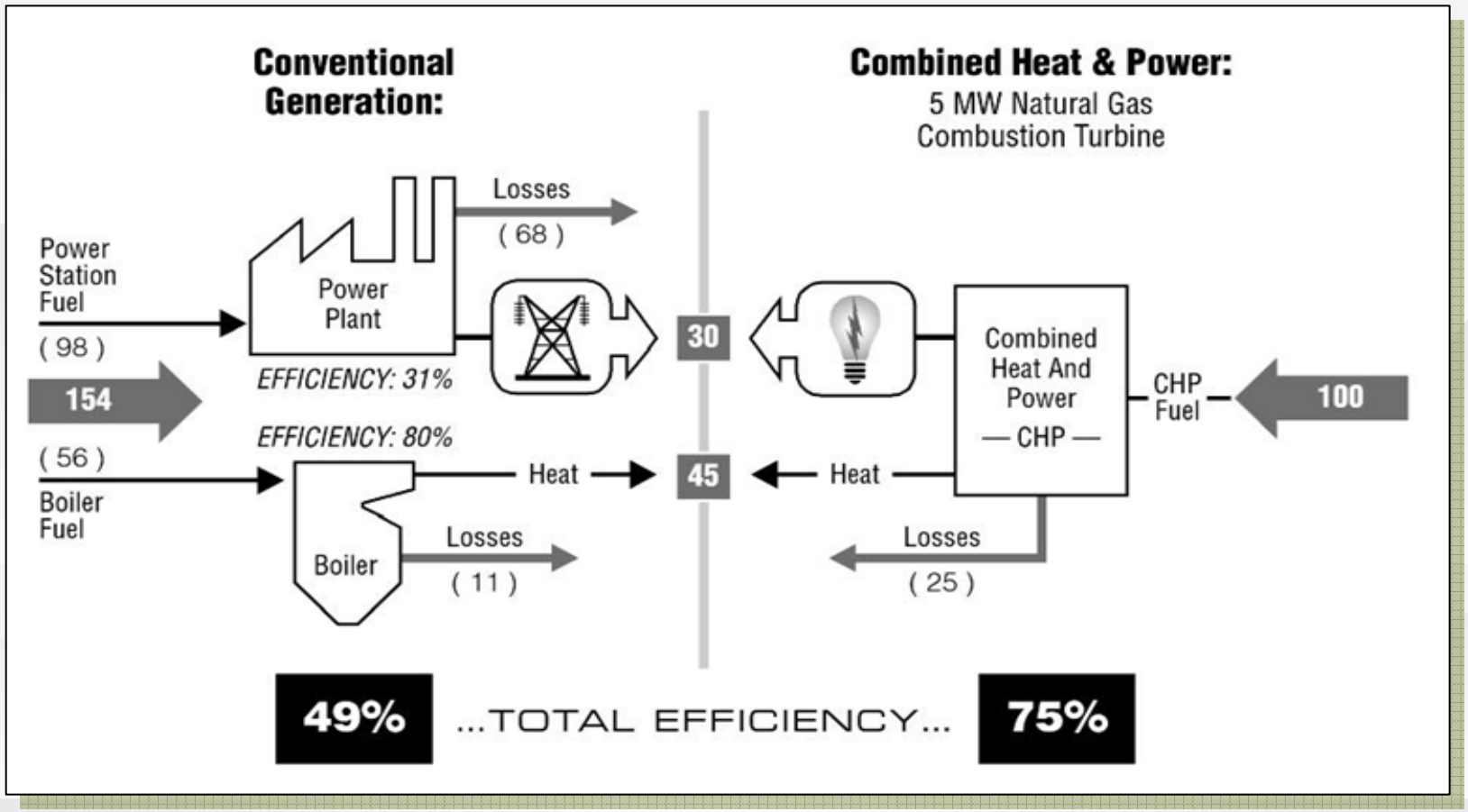
Combined Heat and Power (CHP)

A More Efficient Way of Delivering Energy

- A form of Distributed Generation (DG)
- 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

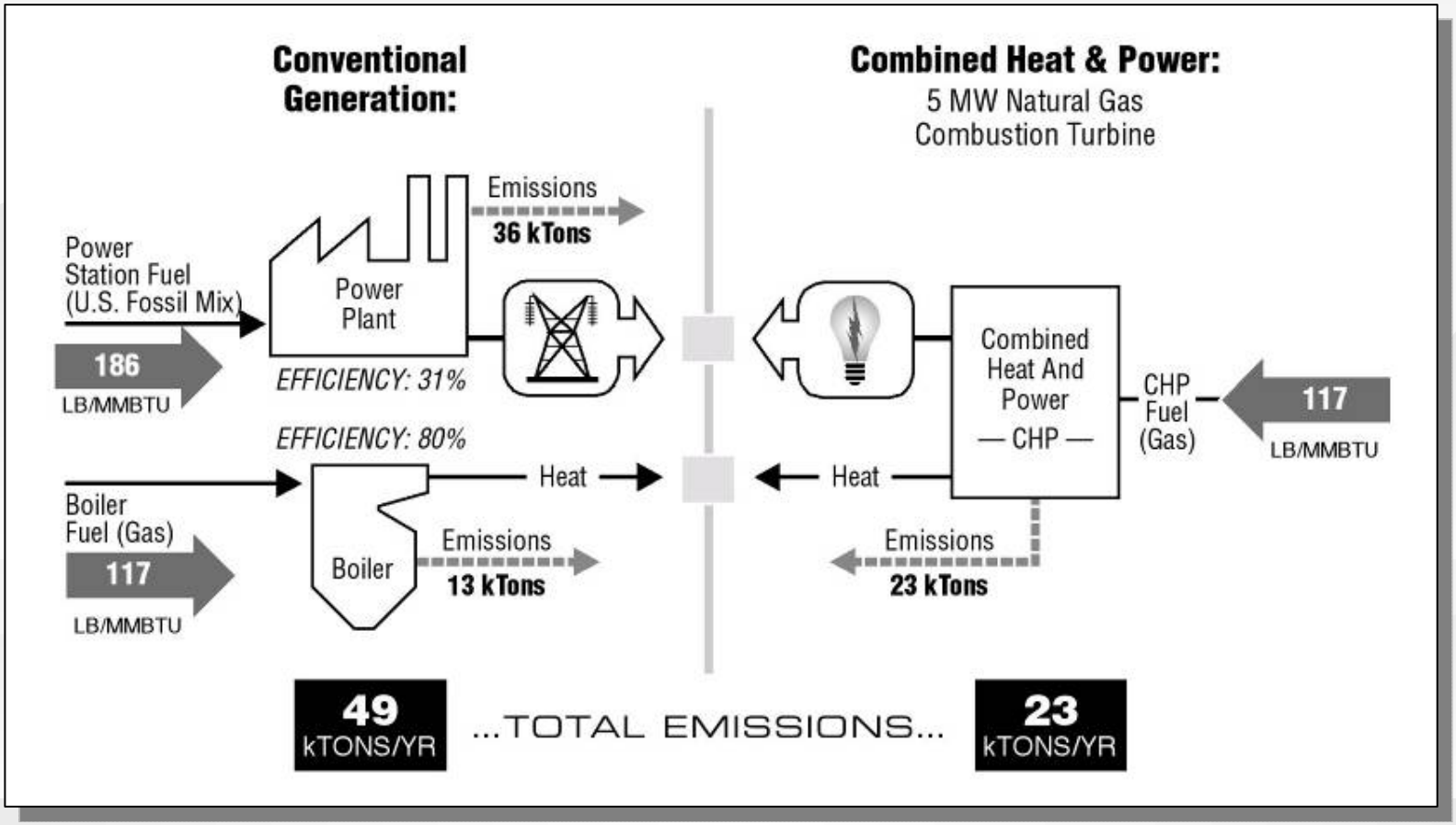
Picture Courtesy of UIC

Efficiency Benefits of CHP



Source: ICF International

Increased Efficiency Results in Reduced Carbon Emissions



Source: ICF International

Acronyms

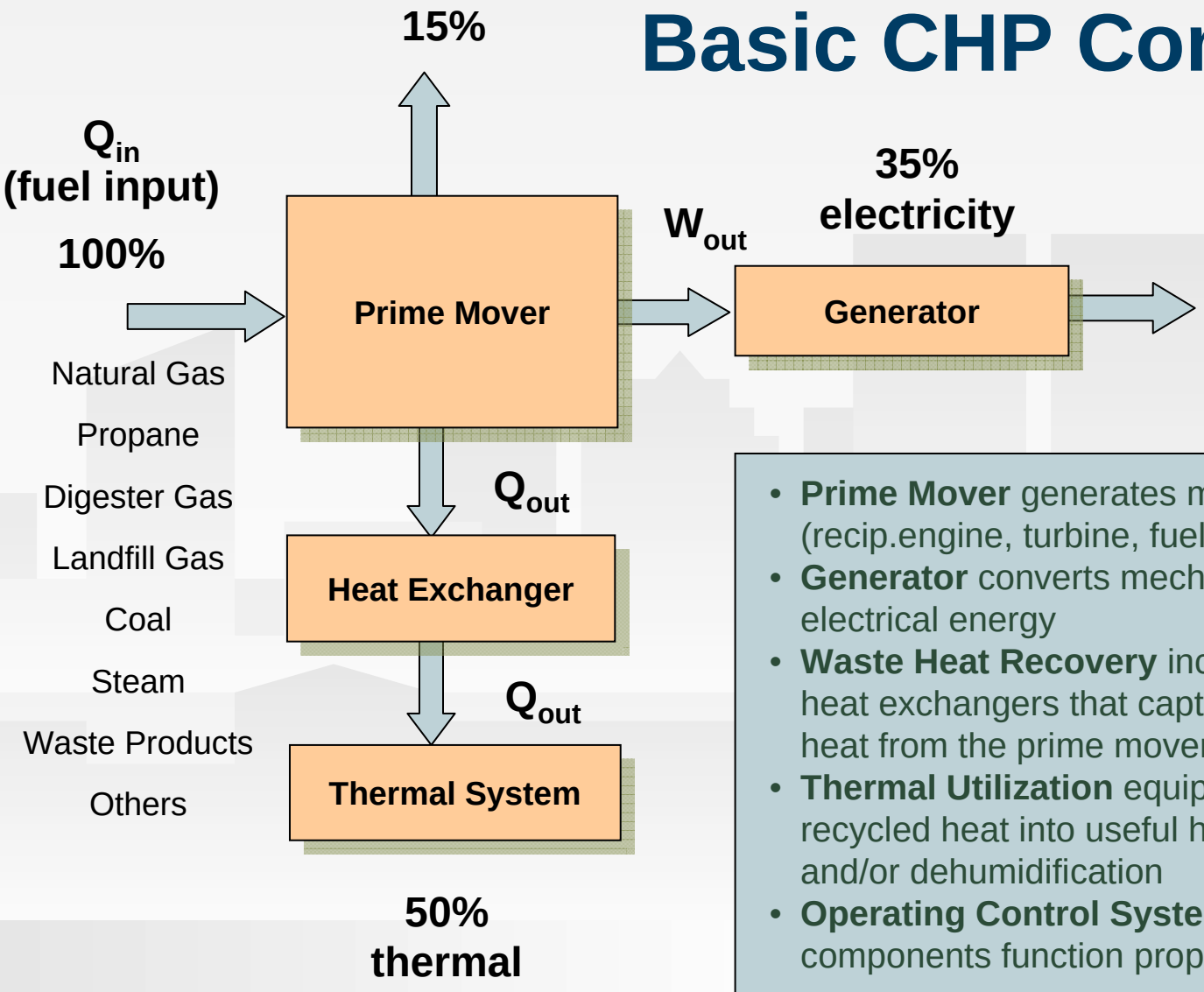
- Combined Heat & Power (CHP)
- Buildings Cooling, Heating & Power (BCHP)
- CHP for Buildings (CHPB)
- Integrated Energy Systems (IES)
- Total Energy Systems (TES)
- Tri-generation (Trigen)
- CHP for Industry
- Cogeneration

What are the Customer Benefits of CHP?

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

- Lower Energy Costs
- Reduced Energy Consumption
- Increased Electric Reliability
- Standby Power
- Improved Environmental Quality
- Public Relations Benefits

Basic CHP Components



- **Prime Mover** generates mechanical energy (recip.engine, turbine, fuel cell)
- **Generator** converts mechanical energy into electrical energy
- **Waste Heat Recovery** includes one or more heat exchangers that capture and recycle the heat from the prime mover
- **Thermal Utilization** equipment converts the recycled heat into useful heating, cooling, and/or dehumidification
- **Operating Control Systems** insure the CHP components function properly together

CHP Integrated System

- Prime Movers:
  - Reciprocating Engines
  - Industrial Gas Turbines
  - Micro-turbines
  - Steam Turbines
  - Fuel Cells
- Heat Recovery (Exchangers)
  - Hot Water
  - Steam
  - Direct Exhaust Gases
- Thermal Systems:
  - Absorption Chillers
  - Steam or Hot Water Heating Loops
  - Steam Turbines (Bottoming Cycle)
  - Desiccants
- Generators
  - Synchronous
  - Induction
  - Inverter

CHP Prime Movers (power generation technologies)

Prime Mover	Pic	Description	Size Range	Heat Recovery
Reciprocating Internal Combustion (IC) Engines		Operate on a wide range of liquid and gaseous fuels but no solid fuels. The reciprocating shaft power can produce either electricity through a generator or drive loads directly.	< 5 MW	Hot water, Low Pressure Steam, Exhaust
Gas (combustion) Turbines		Use heat to move turbine blades that produce electricity (larger applications).	> 2 MW	Large steam loads and high pressure steam
Microturbines		Use heat to move turbine blades that produce electricity (smaller scale).	30 – 250 KW	Hot water and exhaust gases
Fuel Cells		Produces an electric current and heat from a chemical reaction between hydrogen and oxygen rather than combustion. They require a clean gas fuel or methanol with various restrictions on contaminants.	< 2 MW	Hot water and low pressure steam
Steam Turbines		Convert steam energy from a boiler or waste heat into shaft power.	> 50 kW	High pressure to low pressure steam drops

Source: http://www.eere.energy.gov/de/pdfs/chp_opportunityfuels.pdf

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

What Makes A Good CHP Application?

- Good Coincidence Between Electric and Thermal Loads
- Central Heating/Cooling System
- Large Cost Differential Between Electricity (Grid) and CHP Fuel --- “Spark Spread”
- Long Operating Hours
- Economic Value of Power Reliability is High
- Installed Cost Differential Between a Conventional and a CHP System (*smaller is better*)
- Renovation and/or expansion of existing facilities

Candidate Applications for CHP

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

Wastewater Treatment Facilities

A Key Target Market for CHP

The key factor for CHP is those WWTFs that utilize Anaerobic Digesters.

Energy Efficiency in WWTFs

- 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 WWTF
  - 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

Anaerobic Digesters

- **Anaerobic Digestion** is the natural biological (bacterial) process that occurs when organic material decomposes biologically in the absence of oxygen
- **Anaerobic Digesters** are reactors for accomplishing and controlling anaerobic digestion process
- When properly applied, digester technology can effectively assist in:
  - Sustainable
  - Economical
  - Environmentally balanced
  - Neighbor friendly practices

Anaerobic Digesters in Municipal WWTPs

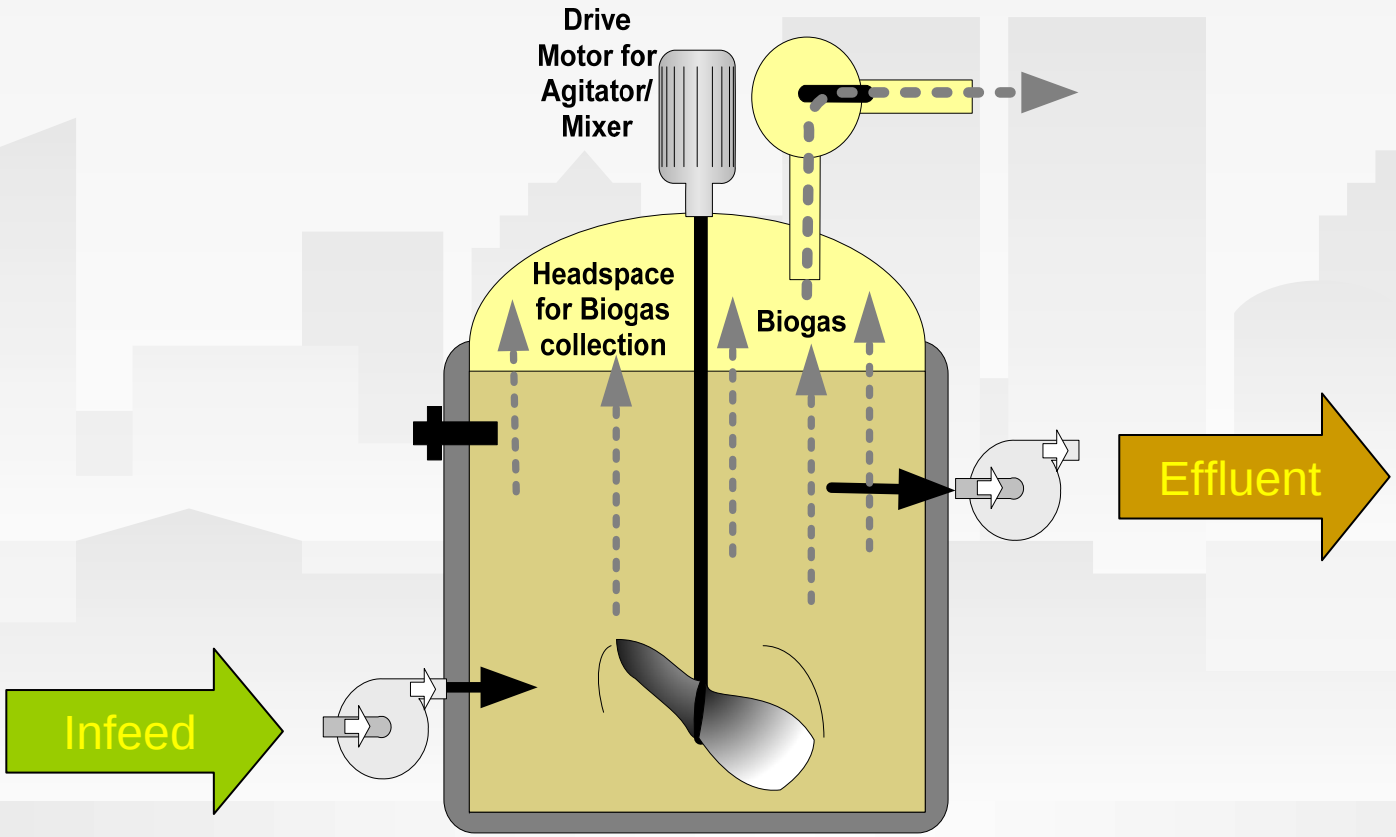
- One of the primary steps used in a wastewater treatment plant is “stabilization”
  - Less odorous (make it quit stinking)
  - Pathogen organism reduction (kill the bugs that could cause a disease)
  - Reduce volume of sludge
- Many WWTPs use two stages of digestion treatment which are typically called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

Type of Digester Utilized in Municipal WWTFs



Typical Digester Biogas 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**
- **Siloxanes**
- **Hydrogen Sulfide**
- **Carbon Dioxide (for gas injection option)**

Digester Biogas Applications

- Flare
- Boiler Fuel
- On-Site Power Generation (DG)
- On-Site Combined Heat & Power (CHP)
- Blend with Natural Gas in Pipelines
- NGV Fuel

Electric & Thermal Coincidence in WWTFs

Technically Good Match for CHP Technologies

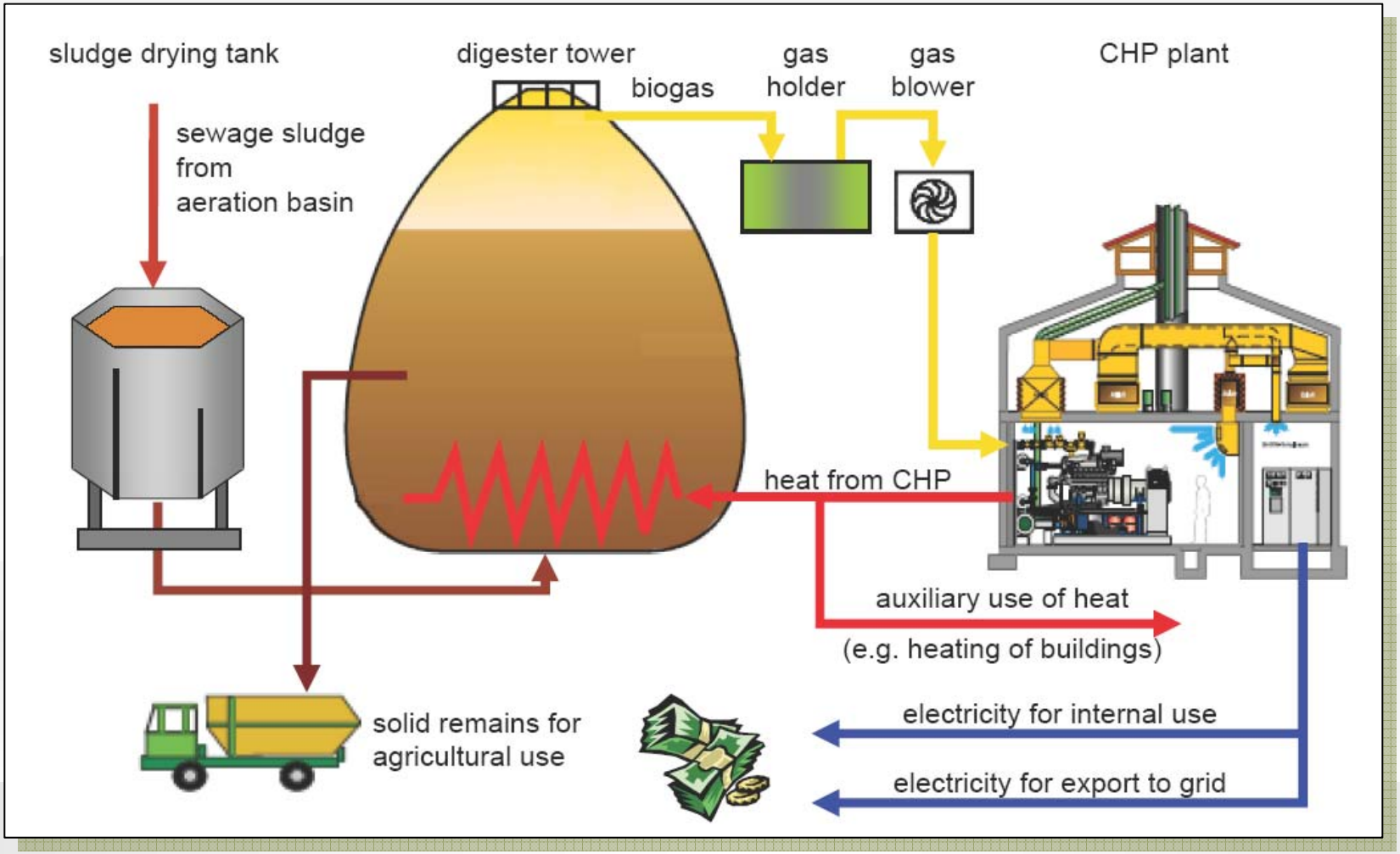
- Steady Use of Recovered Thermal Energy
  - Heat the digester
  - Heat the sludge entering digester (pre-heating)
  - Heat facility (building heat)
  - Cool facility through an absorption chiller
  - Heat potable water
- Steady Use for the Electricity
  - Displace electricity utilized by the WWTF
 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

Gas Treatment and Equipment Modifications

- Some amount of gas cleaning is required for almost any application using biogas
- **Verify minimum gas specifications of gas equipment and application**
- Take multiple measurements of untreated gas
- If not treated, gas contaminants can
  - Damage equipment and thereby reduce life of equipment
  - Reduce performance of equipment (reduced efficiencies)

Source: http://www.epa.gov/chp/documents/biomass_chp_catalog.pdf

Anaerobic Digester / CHP System Diagram



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

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

Market Challenges

- Unstable / Uncertain Energy Prices
- Lack of Awareness of the Technology Concept, Status, Benefits, and Issues
- Electric Utility Resistance
- Need for Internal Champions: Technical & Financial
- Competing for Capital Development $
- Not Enough “Sizzle”
- Quantifying Non Utility Cost Benefits

Summary Messages

- CHP is a highly efficient and integrated suite of technologies
- CHP is not right for every application in every location
- Where CHP makes sense, it can and will provide a number of benefits
- WWTFs are an attractive market sector for CHP
- Turn an operational cost (waste product) into a revenue resource

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