Biomass Combined Heat and Power (CHP) Systems
--- The Concept ---

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Forever Energy Biomass For Sustainable Energy Solutions

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Presented By:
Cliff Haefke
Midwest CHP Application Center
University of Illinois at Chicago

Presentation Outline

- Overview of DG / CHP
- Biomass CHP Applications
- Gas Clean Up
- Biomass Conversion Technologies
- 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 …..

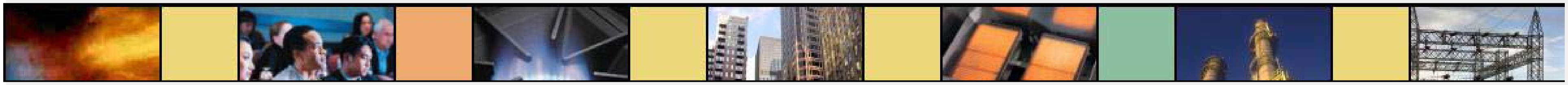
- Solar Photovoltaic
- Wind Turbines
- Engine Generator Sets
- Turbine Generator Sets
  - Combustion Turbines
  - Micro-Turbines
  - Steam Turbines
- Fuel Cells

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

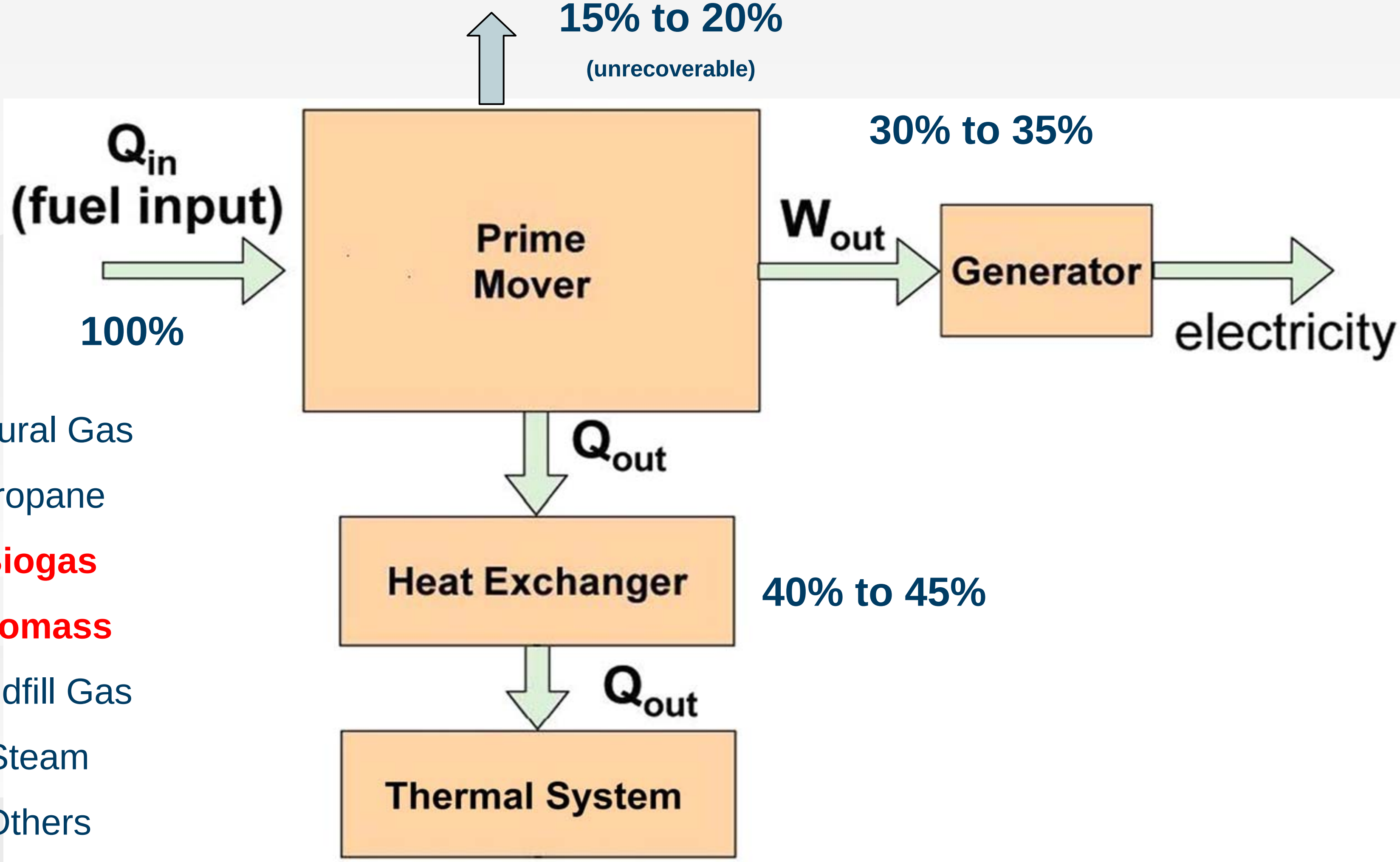
CHP is …

- 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

Biogas

Biomass

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

Candidate Applications for CHP

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

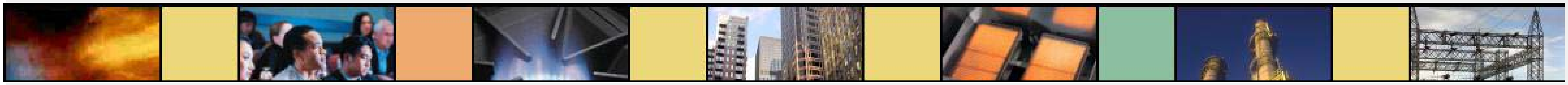
- Food Processing Waste
- Farm Livestock Waste
- Waste Water Treatment

Anaerobic Digesters

- Landfill Sites
- Pulp & Paper Mills
- Ethanol / Biodiesel Plants

Other Biomass

- Chemicals Manufacturing
- Metal Fabrication



Installed CHP Statistics

- 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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- 412 MW at approx. 30 sites (Iowa)

* 1 Quad = 1 Quadrillion Btu's

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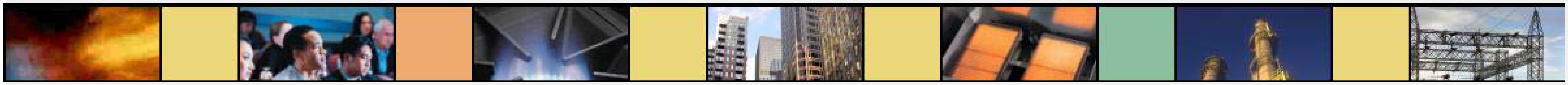
Source: Energy and Environmental Analysis, Inc. (May 2008), www.eea-inc.com

Installed Biomass CHP Statistics for Iowa

	Facility Name	Market Sector	City	Generating Capacity (kW)	Prime Mover Type	Fuel Type	Year of Installation
1	Jacobs Wood Corporation	Wood Products	Bettendorf	3,500	B / S Turbine	Wood	1992
2	Bertch Cabinet Manufacturing	Wood Products	Waterloo	279	B / S Turbine	Wood	1992
3	Davenport Water Pollution Control Plant	Wastewater Treatment	Davenport	1,600	Recip. Engine	Biomass	1995
4	Des Moines Metro Wastewater Reclamation	Wastewater Treatment	Des Moines	1,800	Recip. Engine	Biomass	1991
5	University of Iowa	Colleges / Universities	Iowa City	44,700	B / S Turbine	Biomass	1947
6	Bio-Energy Partners Metro Methane Recovery Facility	Solid Waste Facilities	Mitchellville	6,400	Recip. Engine	Biomass	1998
7	Top Deck Holsteins	Agriculture	Westgate	130	Recip. Engine	Biomass	2004

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



Biomass Fuels

- Made of organic material from a biological origin
- Consist of residues, waste, or byproducts derived from living (or once living) organisms = Renewable source of energy
- Over 9 GW of installed electricity from biomass fuels (nationally)
  - Annually over 37 billion kWh of electricity are produced from 60 million tons of biomass
  - Estimated 590 million wet tons of excess biomass available in U.S. each year

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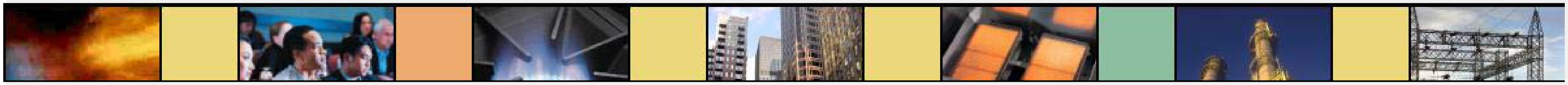
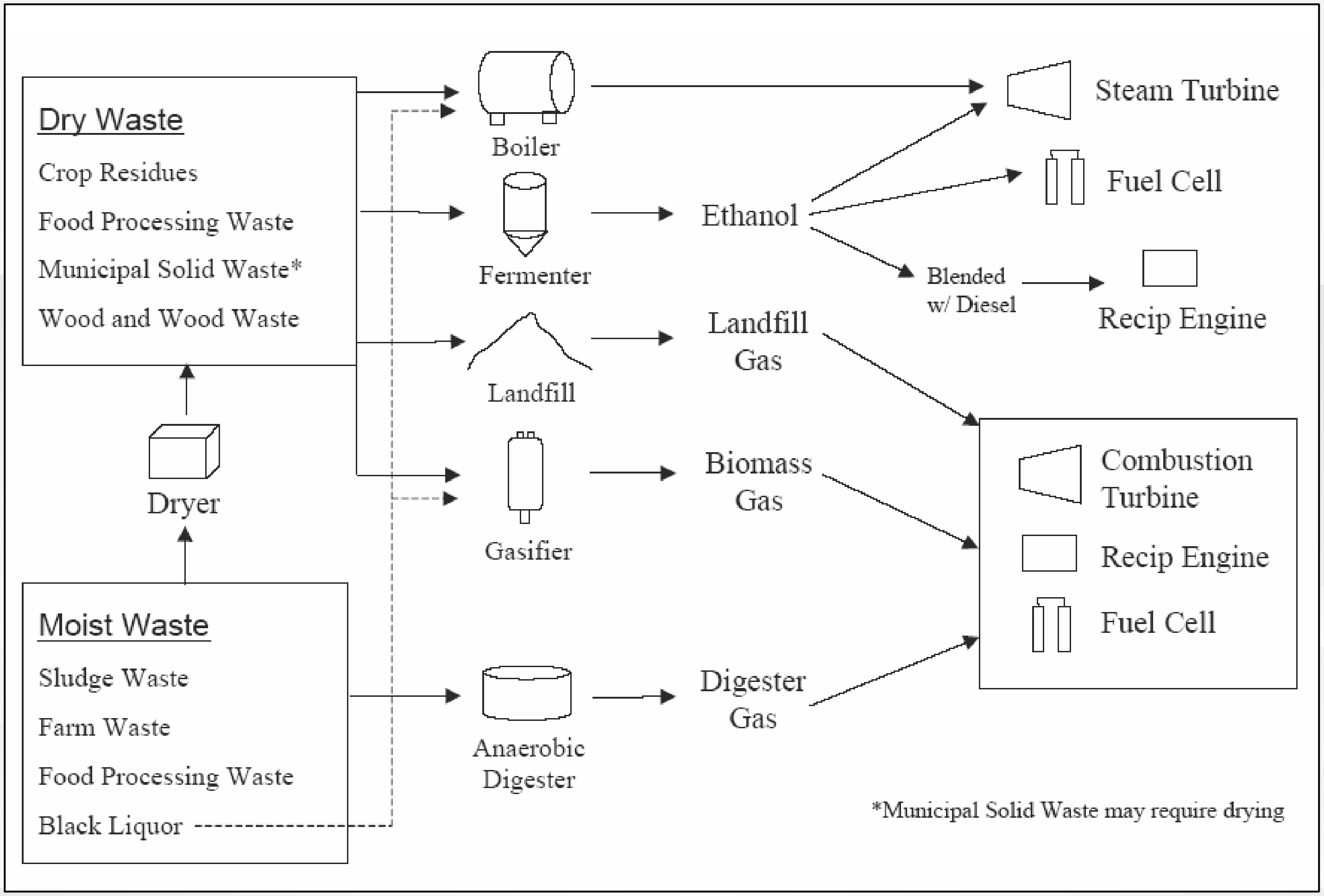
Source: http://www.eere.energy.gov/de/pdfs/chp_opportunityfuels.pdf



Flowchart of Biomass Fuels for CHP Applications



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

Gas Treatment and Equipment Modifications

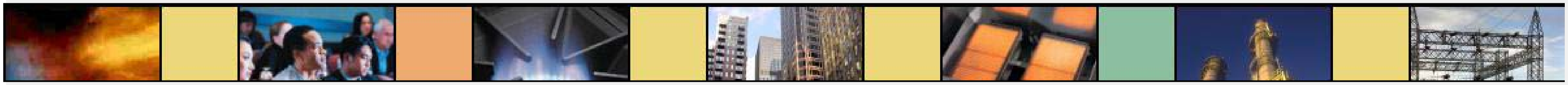
Biogas

- 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)

Biomass

- Most biomass power plants are direct-fired systems
- Can be costly to modify existing equipment for burning of 100% biomass
- Co-firing with coal is less costly to modify existing equipment and also reduces SO_2, NO_x, CO_2, and other air emissions (compared to coal-firing)
- Example biomass conversion technologies: stoker grate, underfire stoker boilers, fluidized bed boilers, co-firing boilers, gasifiers, etc.

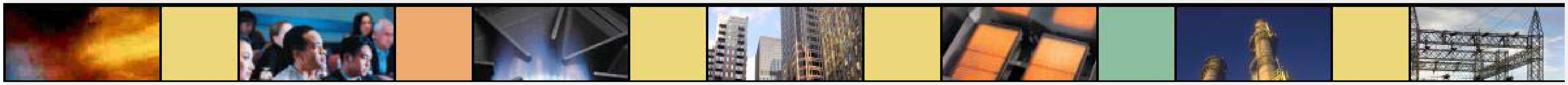
Source: http://www.epa.gov/chp/documents/biomass_chp_catalog.pdf



Operational Problems of Specific Fuel Components

Component of Waste and Byproduct Fuels	**Operational Problems**
Solids	Can cause erosion of critical surfaces or plugging of orifices
Water	Retards combustion and can cause erosion, corrosion, or catastrophic damage to critical surfaces or components
Non-methane fuel components (butane, propane, carbon monoxide [CO], hydrogen)	Can change combustion characteristics; if present in liquid form can cause physical damage
Sulfur and sulfur compounds	Can cause corrosion in engines, increase maintenance requirements (more frequent overhauls and oil changes), and poison catalyst materials
CO_2	Reduces heating value and combustibility
Siloxanes	Create a glassy deposition on high-temperature surfaces; particles can break off and damage working parts.

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



CHP Prime Movers (power generation technologies)

Prime Mover		Description
Steam Turbines		Convert steam energy from a boiler or waste heat into shaft power.
Gas (combustion) Turbines (including microturbines)		Use heat to move turbine blades that produce electricity.
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.
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.
Stirling Engines		Operate on any fuel and can produce either electricity through a generator or drive loads directly.

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

Comparison of Prime Mover Technologies Applicable to Biomass

Characteristic	Prime Mover					
	Steam Turbine	Gas/ Combustion Turbine	Micro-turbine	Reciprocating IC Engine	Fuel Cell	Stirling Engine
Size	50 kW to 250 MW	500 kW to 40 MW	30 kW to 250 kW	Smaller than 5 MW	Smaller than 1 MW	Smaller than 200 kW
Fuels	Biomass/ Biogas-fueled boiler for steam	Biogas	Biogas	Biogas	Biogas	Biomass or Biogas
Fuel preparation	None	PM filter needed	PM filter needed	PM filter needed	Sulfur, CO, methane can be issues	None
Sensitivity to fuel moisture	N/A	Yes	Yes	Yes	Yes	No
Electric efficiency (electric, HHV)*	5 to 30%	22 to 36%	22 to 30%	22 to 45%	30 to 63%	5 to 45%
Turn-down ratio	Fair, responds within minutes	Good, responds within a minute	Good, responds quickly	Wide range, responds within seconds	Wide range, slow to respond (minutes)	Wide range, responds within a minute
Operating issues	High reliability, slow start-up, long life, maintenance infrastructure readily available,	High reliability, high-grade heat available, no cooling required, requires gas compressor, maintenance infrastructure readily available	Fast start-up, requires fuel gas compressor	Fast start-up, good load-following, must be cooled when CHP heat is not used, maintenance infrastructure readily available, noisy	Low durability, low noise	Low noise
Field experience	Extensive	Extensive	Extensive	Extensive	Some	Limited
Commercializatio n status	Numerous models available	Numerous models available	Limited models available	Numerous models available	Commer-cial introduction and demonstr-ation	Commercial introduction and demonstr-ation
Installed cost (as CHP system)	$350 to $750/kW (without boiler)	~ $700 to $2,000/kW	$1,100 to $2,000/kW	$800 to $1,500/kW	$3,000 to $5,000 /kW	Variable $1,000 to $10,000 /kW
Operations and maintenance (O&M) costs	Less than 0.4 ¢/kWh	0.6 to 1.1 ¢/kWh	0.8 to 2.0 ¢/kWh	0.8 to 2.5 ¢/kWh	1 to 4 ¢/kWh	Around 1 ¢/kWh

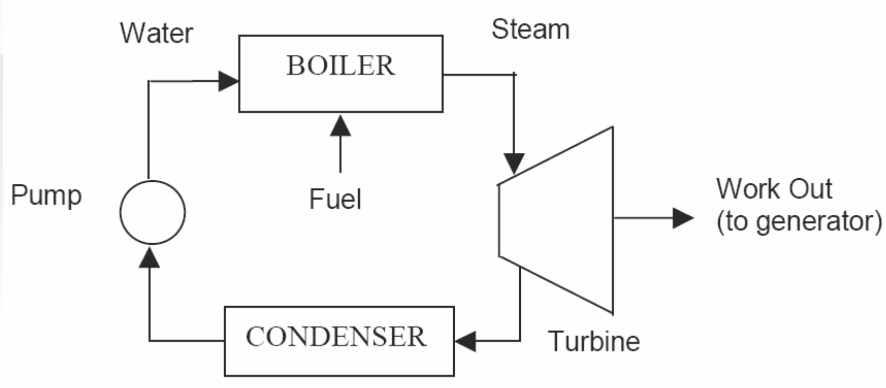
Source: http://www.epa.gov/chp/documents/biomass_chp_catalog.pdf

Biomass Conversion Technologies

- Boiler (combustion)
- Fermentation (production of ethanol)
- Landfill Gas
- Gasification
- Anaerobic Digestion

Boiler (combustion)

- Solid-fueled boilers: fuel is dried, pulverized (if necessary), and incinerated to generate heat and produce steam to be used in a steam turbine
  - Fuel is often broken down into chips to avoid pulverization
- Incineration
  - Stokers are most often selected for incineration (work with almost any fuel and require no modifications)
  - Fluidized bed boilers are sometimes required due to emissions
- Solid biomass fuels have relatively low Btu content
- Boiler built for biomass fuels would typically cost between 50-100% more than a normal boiler (also steam turbine costs may increase by 25%)
- If coal-fired boiler and steam turbine already exist, biomass can be co-fired with some modifications to boiler and no/minimal changes to the steam turbine
- Natural gas boilers can more easily be modified to operate on low-Btu fuels than solid-fueled boilers



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

Fermentation (production of ethanol)

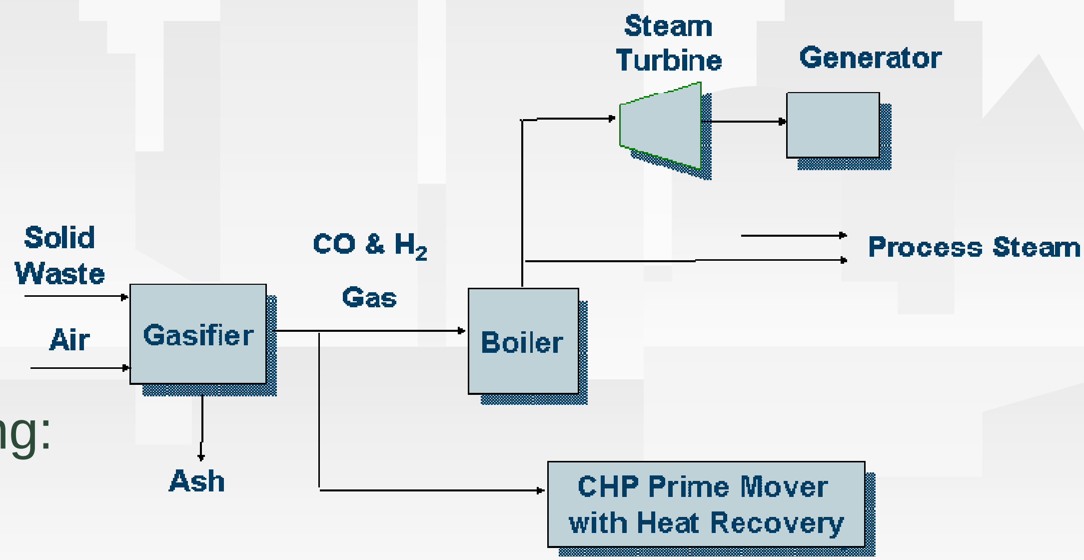
- Ethanol is a liquid fuel produced from the fermentation of wood waste, crop residues, farm wastes, and other biomass fuels
- Ethanol is not widely used for stationary power production
- Ethanol's largest use as a fuel comes from being blended with gasoline and diesel fuels for vehicle engines
- Ethanol is believed by many to be the best present choice to provide energy to fuel cells (besides pure hydrogen), as it has demonstrated
  - Fewer emissions
  - Higher efficiencies
  - Better performance
- Unlike hydrogen, ethanol is readily available and much of the required infrastructure is already set in place (gasoline pumps and pipelines can easily be converted to ethanol)

Landfill Gas (LFG)

- If uncontrolled, LFG contributes to smog and global warming
- LFG is a by-product of the decomposition of MSW in an anaerobic environment
- LFG makeup is approximately 50% methane, 50% carbon dioxide, and <1% non-methane organic compounds (NMOCs)
- Every 1 million tons of MSW equals ~ 0.8 MW of electricity or ~ 432,000 cfd of LFG
- The **amount of methane generated** by a landfill over its lifetime is dependent on
  - Composition and age of the waste
  - Quantity and moisture content of the waste
  - Design and management practices of the facility
- **Heat Recovery Applications**
  - On-site heat uses are generally minor and largely limited to space heating
  - Can send hot water or steam off-site by pipe
  - Pipe LFG off-site and locate electric generation at end user's location and recover heat for building's loads
- Resource: EPA's Landfill Methane Outreach Program (LMOP) www.epa.gov/lmop

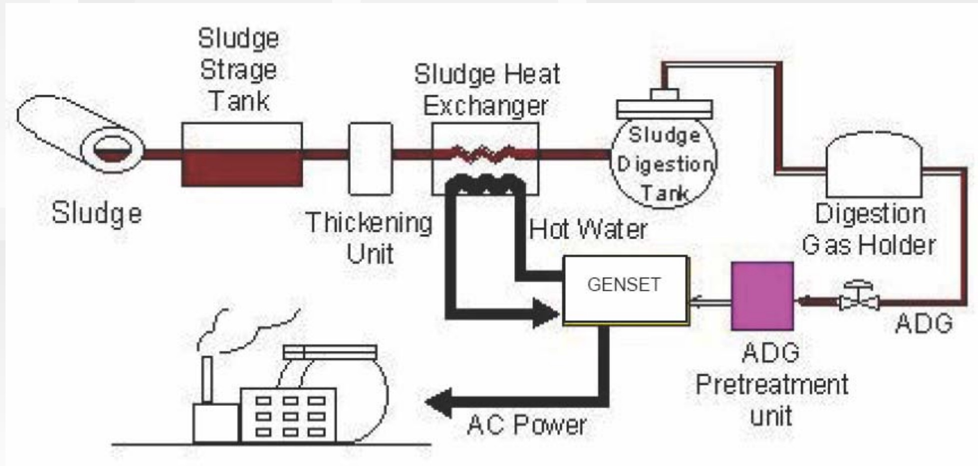
Gasification

- Pyrolysis: vaporize the volatile compounds & produce char (fixed carbon)
- Combust char with O_2 to form CO & CO_2 (generate the heat for gasification)
- Gasification: Char reacts with CO_2 & steam to produce CO & H_2
  - Producer Gas
  - Syn Gas
  - Wood Gas
- Heating value of syngas can range from 100 – 500 Btu/cubic foot
- Advantage over Direct Firing: Gas can be cleaned and filtered to remove problem chemical compounds before being burned



Anaerobic Digestion (AD)

- ADG is a gas recovered from the **decomposition of organic material by bacteria in the absence of O_2**
- An AD is a sealed, heated enclosure that provides a suitable environment for naturally occurring anaerobic bacteria to convert waste into methane gas and remover harmful constituents
- **Source materials** can be 1) wastewater (public sewage or industrial), 2) animal manure, or other 3) organic waste sludge
- **Heat Recovery Applications**: Pre-Heating Sludge, Heating Digester, Heating/Cooling Facility, Heating Hot Water
- 50-60% methane and 30% CO_2
- Potential to be a steady and reliable source of fuel (i.e. free fuel)
- Most ideal CHP technologies are reciprocating engines, microturbines and fuel cells



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Summary

- CHP is one of the most efficient technologies that exist today and can provide multiple benefits (CHP is not a new technology)
- Biomass fuels provide many CHP opportunities (lower cost or even free fuel source)
- Heating application is required for CHP
- Each site needs to be evaluated on an individual basis
- Gas clean up is critical (don’t ignore)

Questions / Discussions

Contact Information

Cliff Haefke

312/355-3465

chaefk1@uic.edu

Energy Resources Center

University of Illinois @ Chicago

Midwest CHP Application Center

www.chpcentermw.org