Biomass Gasification 101

Edmonton Waste Management Centre of Excellence

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Organic Waste Treatment Technology for the Institutional, Commercial & Industrial Sectors

Edmonton, Alberta

June 4, 2012

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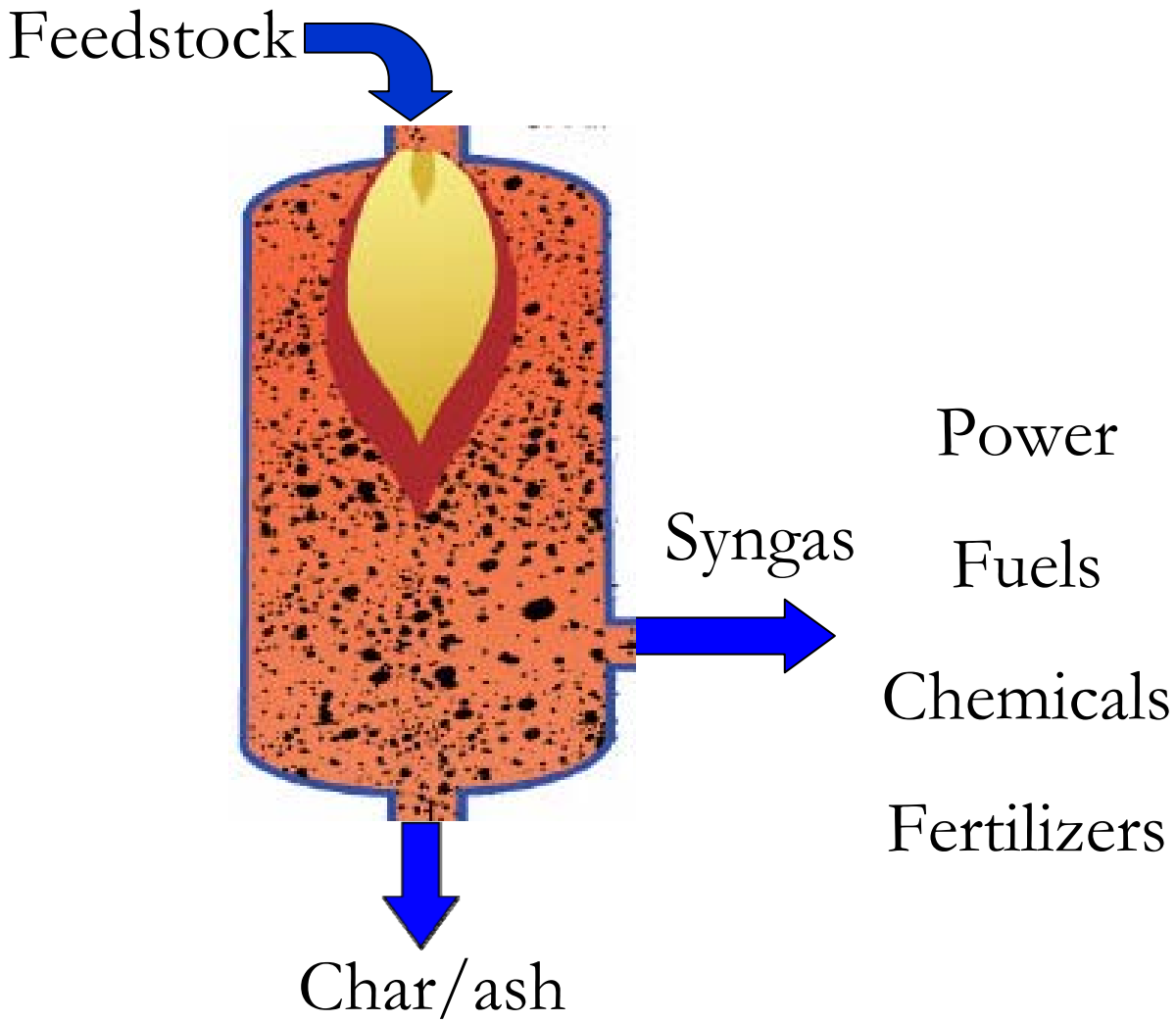
Topics

- What are pyrolysis and gasification?
- Historical uses for pyrolysis and gasification
- Biomass gasification technologies
- Municipal Solid Waste gasification
  - Gasification vs. Mass-burn Incineration
- Example projects

What are Pyrolysis and Gasification?



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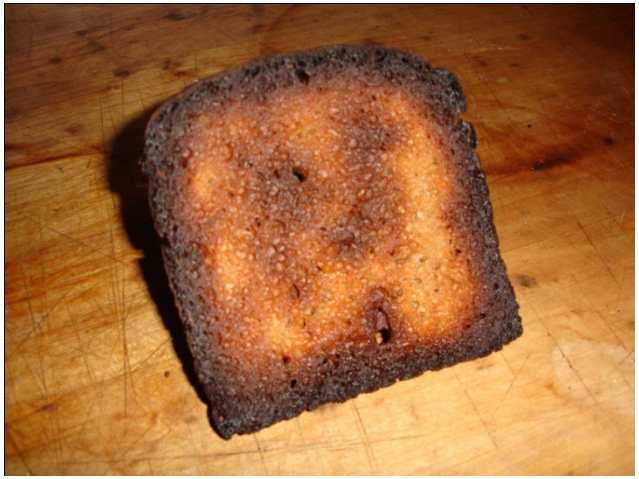
What is Pyrolysis?

- Thermal decomposition of organic materials at 200-800°C, in the absence of air or oxygen, into liquids, gases or a combination of liquids and gases
- It's not combustion; there's no burning!
- A mixture of un-reacted carbon char and ash remains as a residual

Pyrolysis at Home



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What is Gasification?

- Thermal conversion of carbon-based materials at 500-1,500°C, with a limited supply of air or oxygen, into a synthetic gas, or *syngas*
- It's not combustion; there's no burning!
- Gasification uses only a fraction of the oxygen that would be needed to burn the material
- An ash/slag remains as a residual
  - Little to no un-reacted carbon char remains

What's in the Syngas?

- Syngas contains mostly hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and water (H_2O)
  - it's <u>not</u> methane (CH_4), like natural gas
- Heating value is 5-16 MJ/kg (100-300 Btu/ft^3)
  - vs. natural gas at 52 MJ/kg (1,000 Btu/ft^3)
- Syngas can be used a fuel for generating power, or to make chemicals, fuels, or fertilizers

How has Pyrolysis been Used?

- Making charcoal from wood

- Making cooking additives

- Producing methanol ("spirit of wood")
  - Used by Kodak to make photo film

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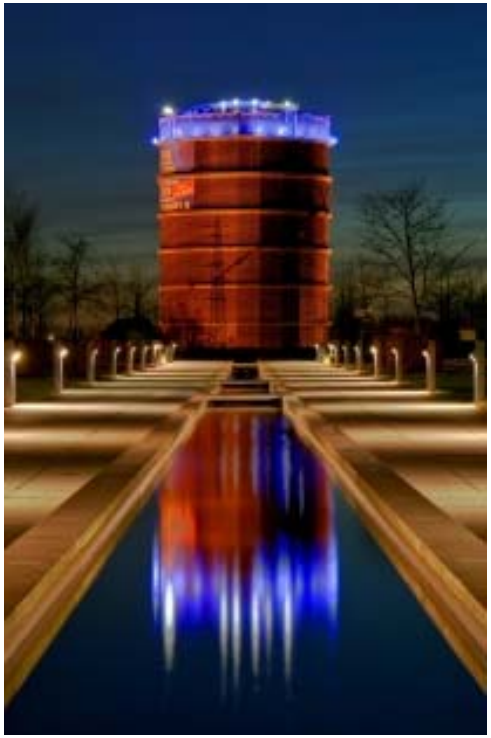
How has Gasification been Used?

- Making "town gas" from coal (1792)

- Manufactured gas plants – prior to discovery and widespread use of natural gas

Town Gas Holders



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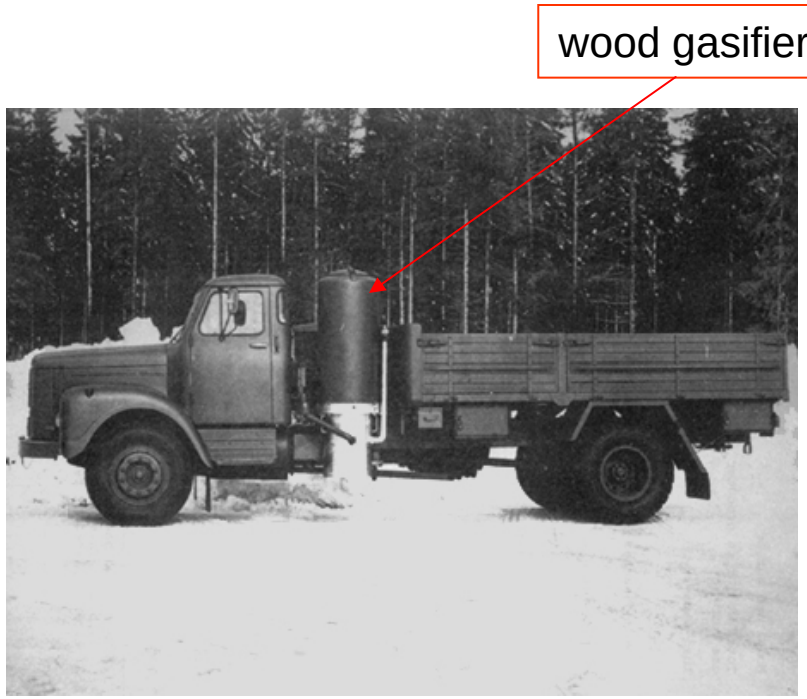
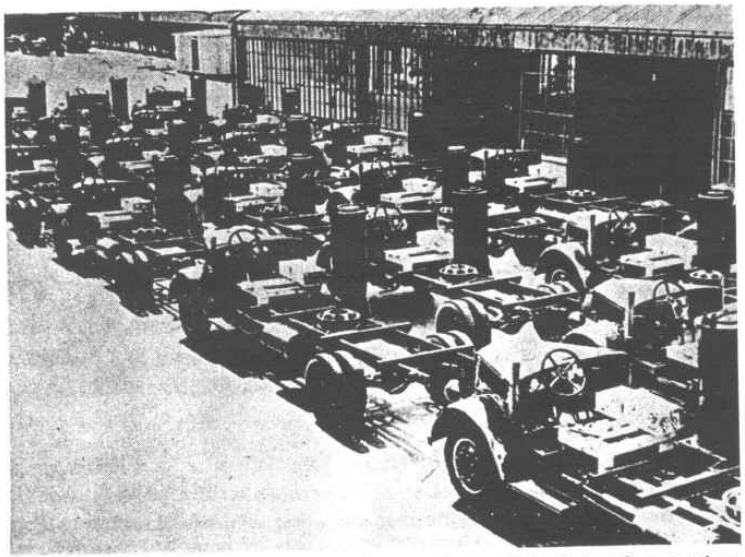
Town Gas Production
Schwarze Pumpe, Germany

How has Gasification been Used?

- Cars and trucks used small wood gasifiers for fuel





Germany, about 1943. Mass production of gas producer vehicles, Imbert factory, where some 500,000 gas producers were manufactured during World War II. (E. E. Donath)

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Biomass Gasification

Feedstocks

- Wood waste (sawdust, bark)
- Cultivated crops (switchgrass)
- Agricultural wastes
- Animal wastes (stall waste)
- Waste Water Treatment Plant biosolids
- Municipal solid waste (MSW)
- Blends





Feedstock Comparisons

	% Moisture	% Ash	% Volatile Matter	% Carbon	MJ/kg (Btu/lb)
Plastic	2	2	96	60	32.5 (14,100)
Pet Coke	8	0.5	10	81	32.6 (14,050)
Bituminous Coal	12	11	35	61	25.8 (11,100)
Poplar	5	1	82	47	19.5 (8,382)
Subbituminous Coal	30	5	31	48	18.9 (8,156)
Corn Stover	6	5	76	44	18.1 (7,782)
Corn Cob	6	2	72	46	17.1 (7,369)
Paper	10	5	76	44	15.8 (6,814)
Pine	17	0.5	71	42	15.8 (6,800)
Switchgrass	8	4	67	39	15.4 (6,636)
Chicken Litter	12	19	58	32	14.6 (6,310)
MSW	21	25	52	52	11.6 (5,000)
Dried Biosolids	10	20	60	10	8.0 (3,445)

Biomass Gasification vs. Combustion

- Wide range of feedstocks
  - Easier to gasify some feedstocks than to try to burn them
- Environmental advantages over biomass combustion:

–Concentrates ash contaminants in the gasifier, so that the boiler, reciprocating engine or gas turbine burns syngas, not the actual biomass

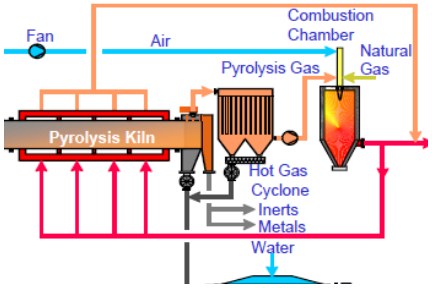
–Syngas can be piped to multiple users

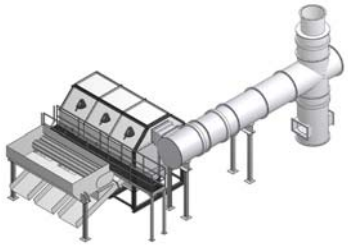
–Ash/slag can be a usable by-product

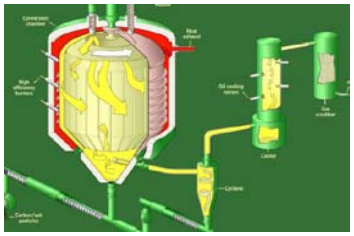
Biomass Gasifiers

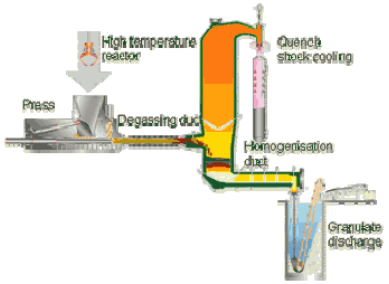
- "Typical" biomass gasifiers:
  - 20 kg/hr to 300 tonnes/day
  - Air-blown
  - Atmospheric pressure
  - 500-1,000ºC
  - Fixed bed or fluid bed
  - Syngas is combusted directly in a boiler to make steam for a steam turbine generator

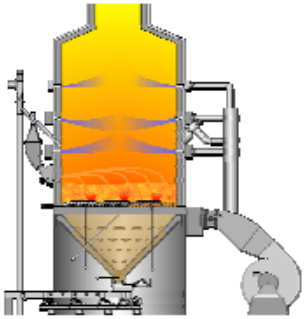
Biomass Gasifiers – Many Types for Different Feedstocks and Applications

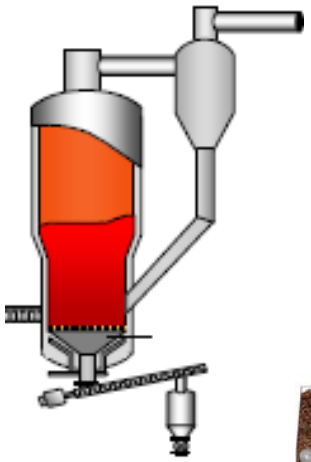


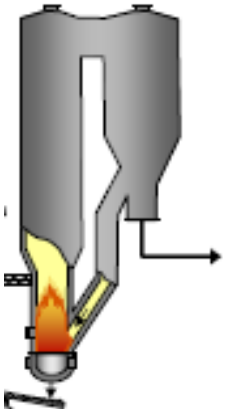


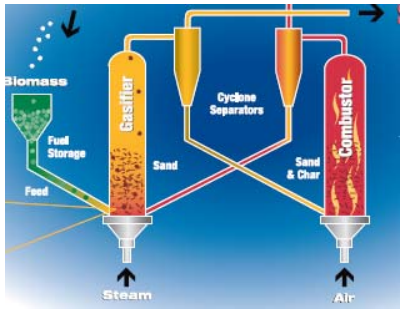












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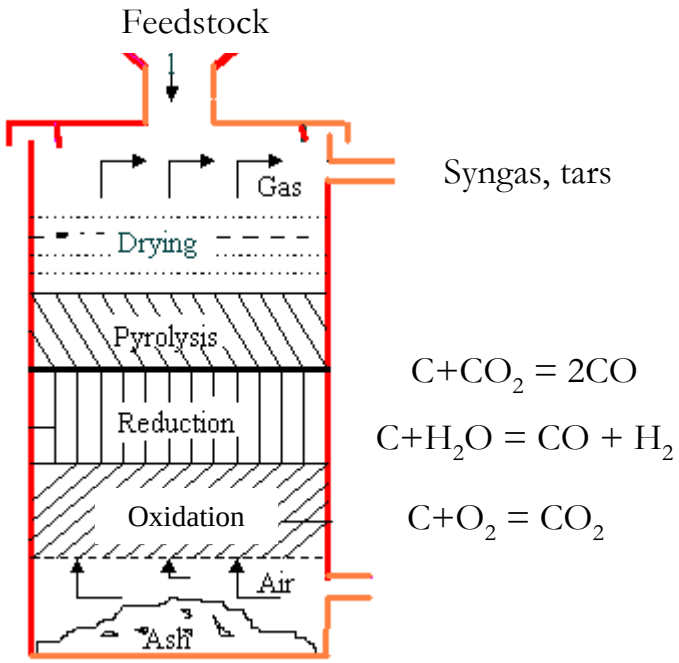
Fixed Bed Gasifier – Updraft

- Feedstock is pre-dried before it gets to gasification zone
- Can handle high moisture biomass
- Heat source is oxidation of char
- Operates at low temperatures
- High amount of tar in syngas
  - Must be cleaned prior to downstream use



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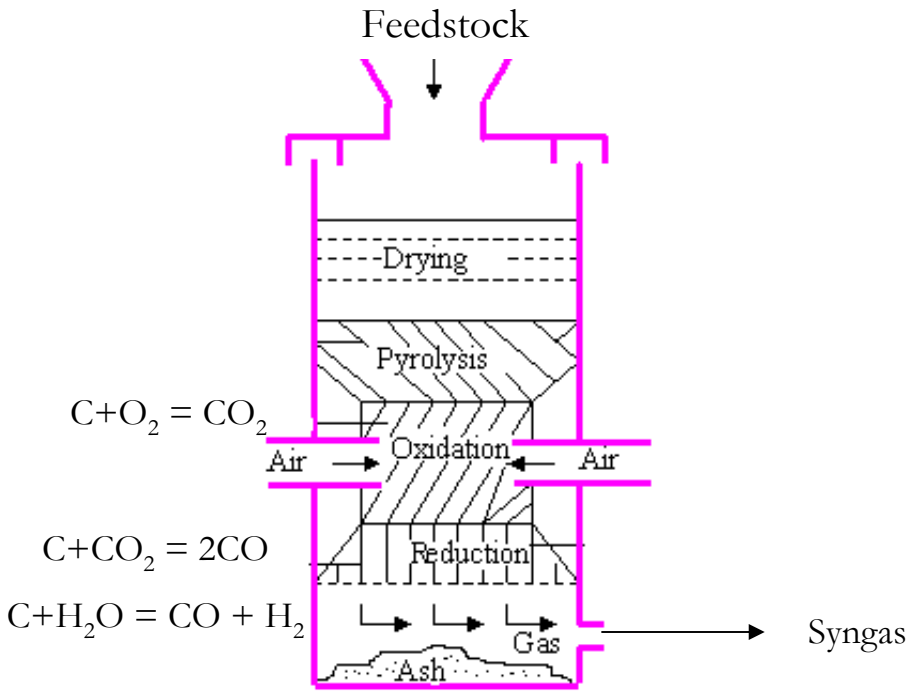
Fixed Bed Gasifier – Downdraft

- Needs low moisture (<20%) and low ash
- Fines are a problem
- Heat source is oxidation of volatile gases
- Operates at high temperatures
- Low tars in syngas



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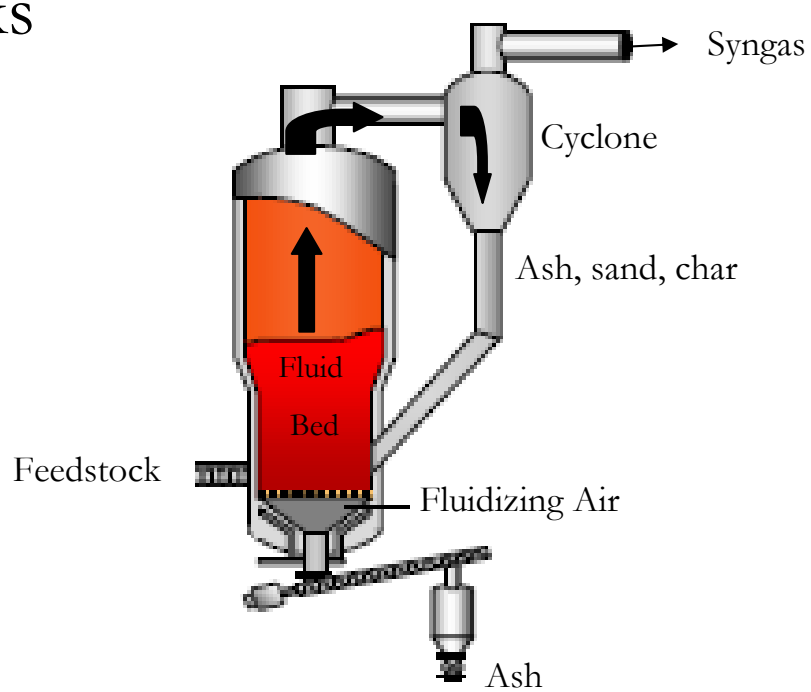
Fluid Bed Gasifiers

- Good for low reactivity feedstocks
- Good for fines
- Air/sand bed mixture is fluidized
- Moderate temperatures
- Provides high turbulence and residence time
- High carbon conversion
- Syngas/ash/sand mixture exits to cyclone
  - Ash/sand mixture is returned to bed
- Low tars in syngas



MSW Pyrolysis and Gasification

- MSW typically requires significant pre-processing
  - Removal/recovery of metals, paper, and glass, plastics plus shredding and sizing
  - Enhances existing recycling programs
- Same/similar technologies as used for biomass
  - Some use pyrolysis
  - Plasma gasification may have advantages in some applications

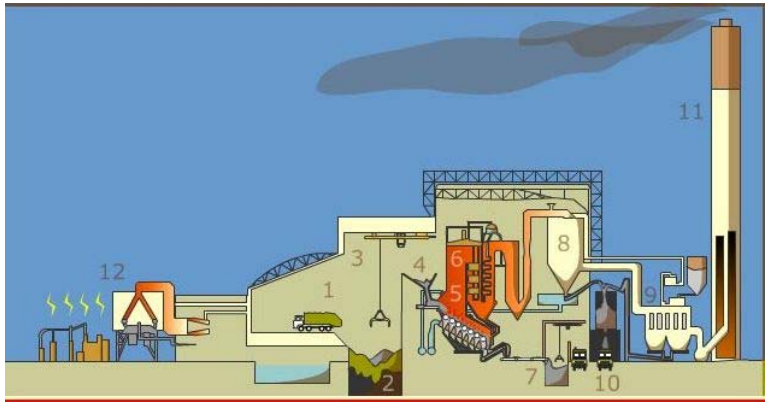
Plasma Gasification

- Uses plasma torch or carbon arc to supply heat/energy to initiate gasification reactions or to improve quality of syngas produced from a conventional gasifier
- Plasma gas injected at up to 5,500°C
- Used for decades to destroy wastes and melt incinerator ash into slag
- Good for hard to gasify materials
- Operating plants in Canada and Japan

MSW Gasification vs. Mass-burn Incineration

Mass-burn Incineration

- Incineration literally means to *render to ash*
  - Incineration uses MSW as a *fuel*
  - It burns with large amounts of air to form heat and CO_2
  - Hot exhaust gases are used to make steam, which is then used to generate electricity
  - Emissions can only be removed *after* combustion



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MSW Gasification

- MSW is *not a fuel*, but a *feedstock* for the gasification process
- The MSW itself is *not* combusted
- Gasification converts MSW to a usable syngas

– The MSW reacts with little or no oxygen and is converted to syngas

– The syngas (not the MSW) can be combusted to produce steam or electricity

– Or the syngas can be used to make higher valuable commercial products such as transportation fuels, chemicals, and fertilizers

MSW Gasification

- Gasification does not compete with recycling; it actually *enhances* it
  - Metals and glass are removed from the waste stream prior to being fed into the gasifier
  - Many plastics and cardboard boxes cannot by recycled, and would otherwise end up in a landfill
    - They make excellent high energy feedstocks for gasification, reducing the amount that would otherwise end up in a landfill





Dioxins and Furans

- Large organic molecules (like plastics) are decomposed into syngas in the high temperatures of the gasifier
- Dioxins/furans need sufficient oxygen to form, and the oxygen-efficient atmosphere in a gasifier *does not* provide the environment needed for that to occur
- Dioxins need fine metal particulates in the gas to reform; syngas from gasification is typically cleaned of particulates *before* being used

Dioxins and Furans

- When syngas is used to produce fuels, chemicals and fertilizers, the syngas is quickly quenched, so that there is not sufficient residence time in the temperature range where dioxins/furans could re-form
- When the syngas is primarily used as a fuel for making heat, it can be cleaned as necessary *before* combustion; this cannot occur in incineration, which requires *post-combustion* clean-up

Biomass Gasification Projects

- Many new biomass gasification projects are being developed
- Government incentives for bio-energy production
- Typically for power production in 5-50 MW range
- Some will produce alcohols or transportation fuels
- Feedstocks include:
  - Wood chips, bark
  - Agricultural wastes
  - Grasses
  - MSW
  - WWTP sludge or dried biosolids
  - Animal "stall wastes"

Biomass and MSW Gasification Plants

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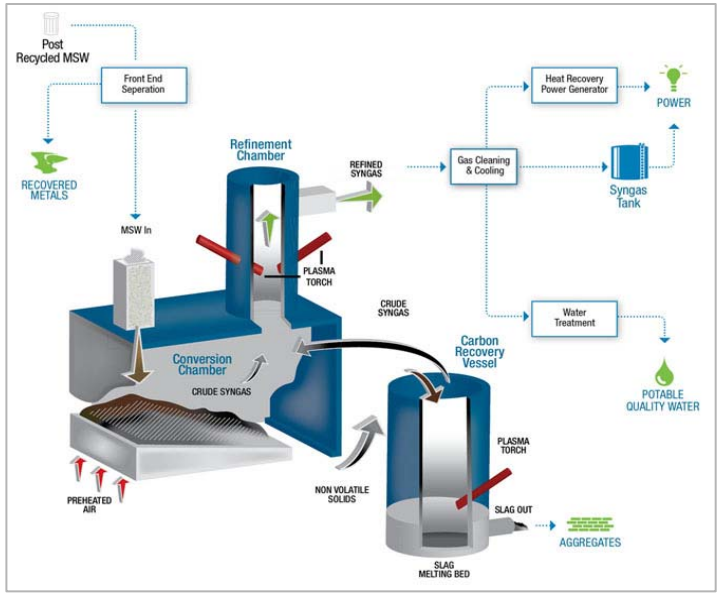
- Waste-to-Biofuels Facility
- MSW processed to "refuse-derived fuel" quality
- Enerkem - 100,000 tonnes/year RDF fed to gasification system
- RDF converted to syngas
- Syngas cleaned and converted to 36 million litres/year of alcohols

Plasco Trail Road Facility
Ottawa

- Demonstration facility at 75 tonnes/day since 2006
- Developing full-scale facilities in Canada and U.S. at 300-400 tonnes/day to generate 15-20 MW electricity to the grid



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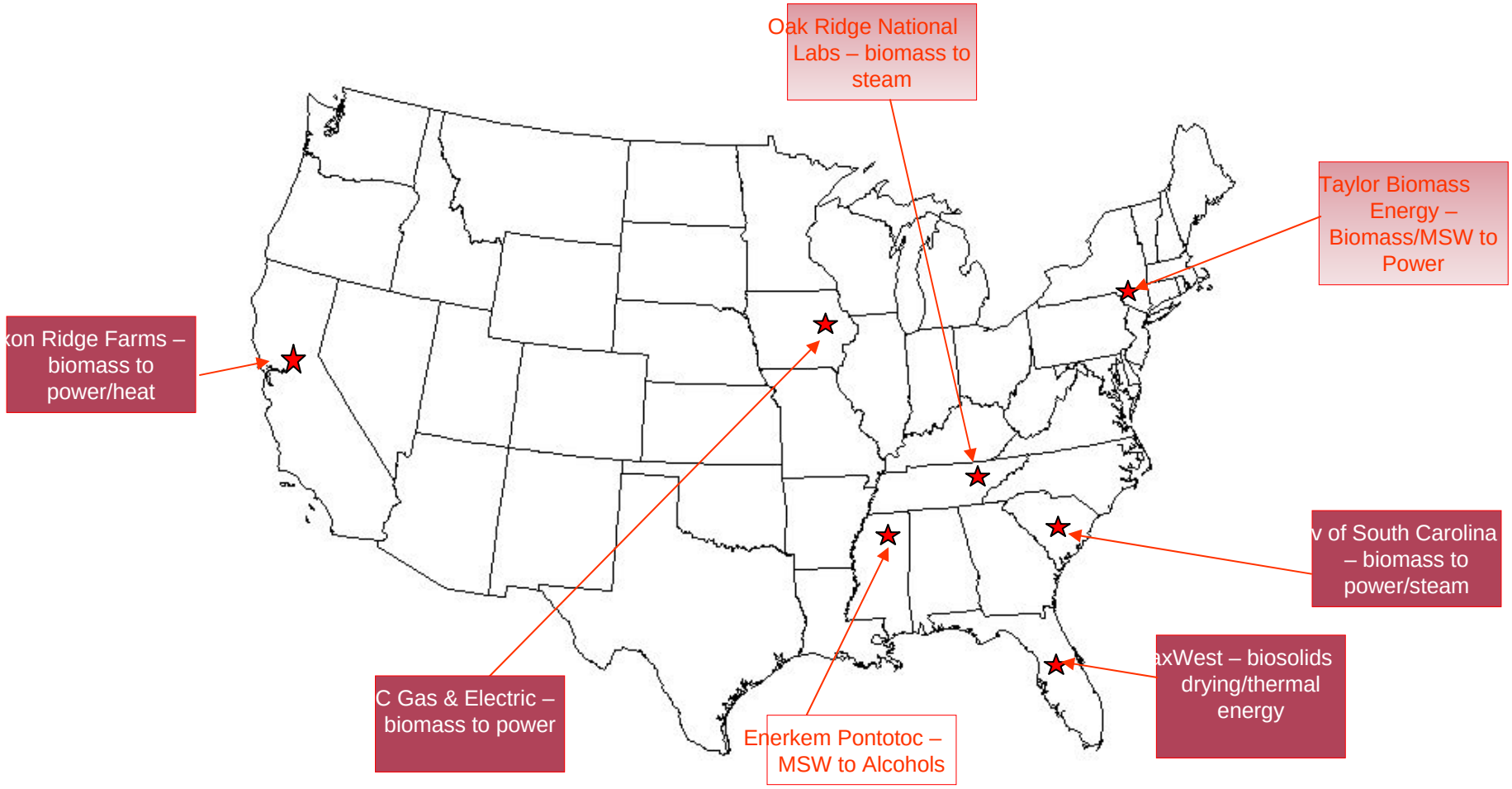
Biomass and MSW Gasification Plants



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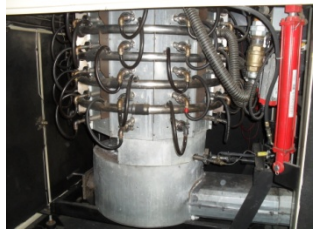
Dixon Ridge Farms

- Walnut farm near Sacramento, CA
- Used significant amount of propane to dry the walnuts
- Now use 45 kg/hr walnut shells as feedstock for a biomass gasifier
- Syngas is used for 50 kW power generation
- Heat from engine is used for drying the walnuts
- Offsets 20% of electricity use
- Offsets 40% of propane use



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Wastewater Treatment Plant Biosolids

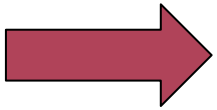
- WWTPs want to use biosolids gasification to meet internal heat and power requirements
- Biosolids can be a good feedstock for gasification
  - High moisture content is challenging
  - Dried biosolids provide higher quality for biomass gasifiers
  - Opportunities to use waste process heat to dry the inlet biosolids
- High ash content and unique ash chemistry make ash handling a challenge

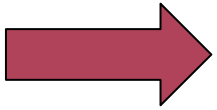
MaxWest Environmental Systems

- WWTP biosolids gasification facility in Sanford, FL
- City WWTP needed to reduce use of natural to dry sludge to meet Class A biosolids for land application
- MaxWest system installed their facility at the WWTP
  - Heat from combustion of syngas is used to dry incoming biosolids
- Significant reduction in use of natural gas for drying
- Small amount of ash for disposal

Waste-to-Biofuels?

Waste-to-Biofuels?





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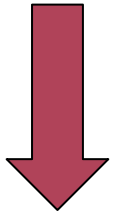

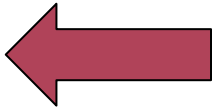

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Waste-to-Biofuels?

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Questions?

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