# Biomass Gasification 101

Edmonton Waste Management Centre of Excellence

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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



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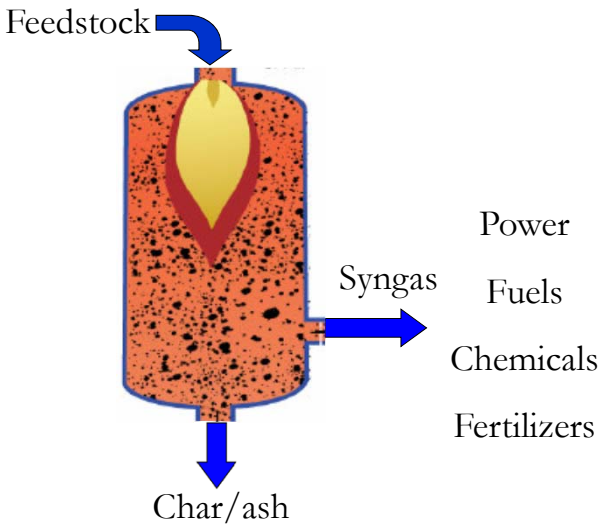
## What are Pyrolysis and Gasification?



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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 char/ash mixture remains as a residual



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# 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
- Ash/slag remains as a residual



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## What's in the Syngas?

- Syngas contains mostly hydrogen ($H_2$), carbon monoxide (CO), carbon dioxide ($CO_2$), and water ($H_2O$)
  - it's not 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



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## 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 use of natural gas



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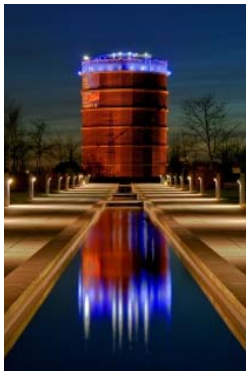
# Town Gas Holders





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# Town Gas Production
# Schwarze Pumpe, Germany



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# Biomass Gasification



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# Feedstocks

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







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# Biomass 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) |



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# Biomass Gasification vs. Combustion

- Wide range of feedstocks
- 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



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# 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



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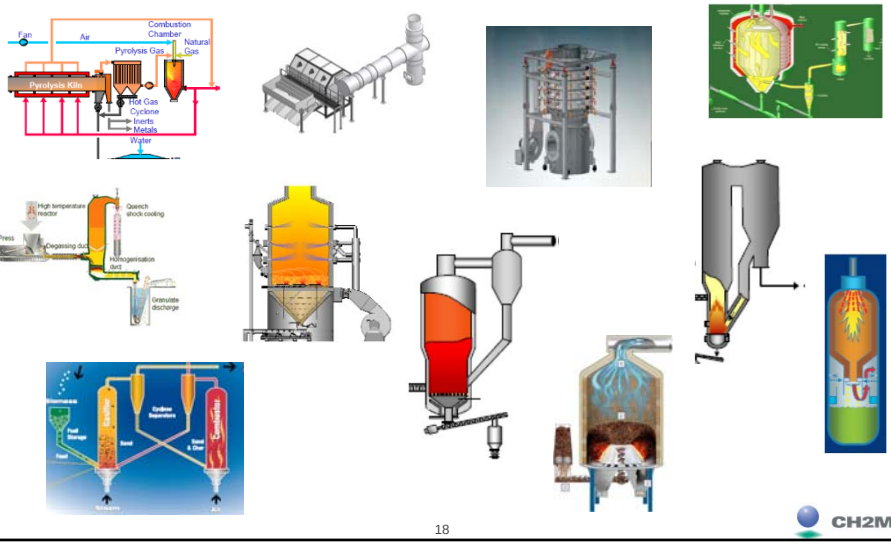
# Biomass Gasifiers – Many Types for Different Feedstocks and Applications



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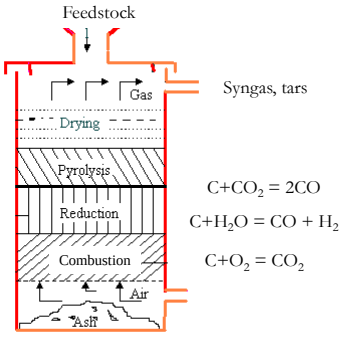
# Fixed Bed Gasifier – Updraft

- High efficiency
- Feedstock is pre-dried before it gets to gasification zone
- Can handle high moisture biomass
- Heat source is combustion of char
- Operates at low temperatures
- High amount of tar in syngas



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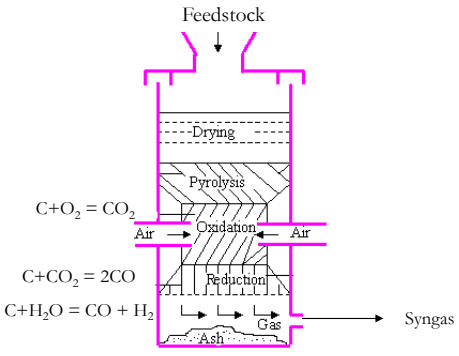
# Fixed Bed Gasifier – Downdraft

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



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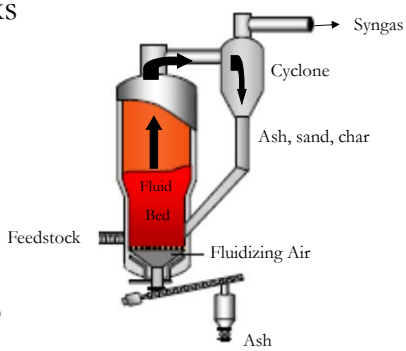
# Fluid Bed Gasifiers

- 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



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# 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



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## Plasma Gasification

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



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## Gasification vs. Incineration



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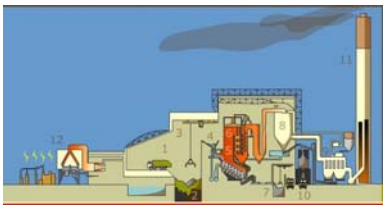
## Mass-burn Incineration

- 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



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## MSW Gasification

- Gasification does not compete with recycling, it actually *enhances* it
  - Metals and glass are removed from the waste stream prior to being sent into the gasification process
  - 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







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## Dioxins and Furans

- Large organic molecules (like plastics) are decomposed into syngas in the high temperatures of a gasifier
- Dioxins/furans need sufficient oxygen to form, and the 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



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## 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, hog fuel, bark
  - Agricultural wastes
  - Grasses
  - Municipal solid waste
  - WWTP sludge or dried biosolids
  - Animal "stall wastes"

## Biomass and MSW Gasification Plants




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## Edmonton Waste Management Centre

- 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



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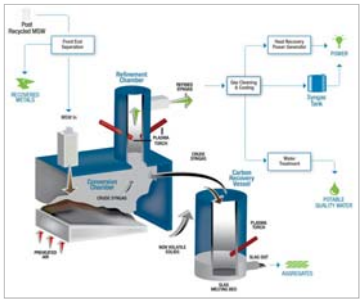
# Plasco Trail Road Facility Ottawa

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





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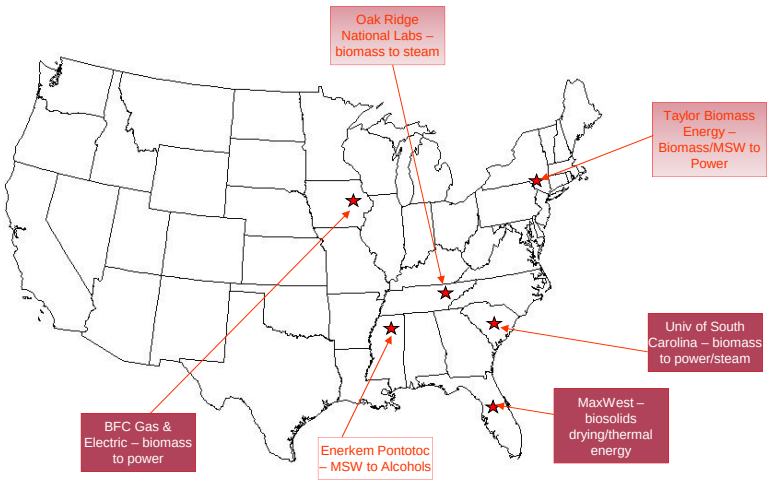
# Biomass and MSW Gasification Plants



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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



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## MaxWest Environmental Systems

- WWTP biosolids gasification facility in Sanford, FL
- 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 used to dry incoming biosolids
- Significant reduction in use of natural gas for drying
- Small amount of ash for disposal



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## Questions?



## Contact Info

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