Covanta R&D
Developments in
MSW Gasification Technology

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Agenda

1. Gasification and MSW
2. Commercial Gasifier Demonstration
3. COVANTA CLEERGAS™ System
4. Covanta Future Gasification R&D
Gasification is the partial oxidation of the organic content of a feedstock to produce a H2 / CO containing syngas.

<table>
<thead>
<tr>
<th>PYROLYSIS</th>
<th>GASIFICATION</th>
<th>COMBUSTION</th>
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<tbody>
<tr>
<td>HCs, Tars, Char</td>
<td>H2 / CO</td>
<td>CO2, H2O</td>
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<tr>
<td>( \lambda = 0 ) (No air)</td>
<td>( \lambda &lt; 1 ) (Partial air)</td>
<td>( \lambda = 1 ) (Excess air)</td>
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<tr>
<td>Very Endothermic</td>
<td>Exothermic/Endothermic Balance</td>
<td>Very Exothermic</td>
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- Gasification is a well established process for fossil fuel and biomass feedstocks – but economics are still challenging
- Gasification process is very sensitive to the feedstock
Challenges With MSW

Gasification of MSW is technically and economically challenging

• Heterogeneous nature of MSW complicates equipment design, process design and process control
  – Broad range of physical and chemical properties
  – Heating value variability

• Gasification processes developed for coal or biomass would require significant pre-processing of MSW
  – Moving bed, fluidized bed, entrained flow reactor types

• Syngas heating value and purity dependent on many parameters
  – Gasification temperature, air or oxygen, other reactants (steam, CO2), other energy inputs (plasma), gasifier design, control system
Gasification
Heat Balance Considerations

![Graph showing the relationship between syngas adiabatic temperature and syngas heating value with stochiometric air ratio.](image)
Covanta Approach – MSW Gasification

• System designed for unprocessed, post-recycling MSW
  – Handling, shredding, processing, storing waste is expensive – especially high operations & maintenance costs
• Employ reliable solid handling equipment for feeding, gasifying, and ash removal
  – Analogous to mass-burn
• No additional sources of energy input to the process
  – Power, plasma, coal or coke
• Air based – no oxygen enrichment
  – Oxygen aids process, but cost is not recovered in product value
• Commercialize MSW gasification with syngas combustion
  – Lower excess air = smaller equipment, higher energy and lower emissions
  – Improved control of NOx and CO
Types of MSW Gasification Processes

**GASIFICATION/SYNGAS COMBUSTION** - Goal of Improved Emissions, Higher Energy Efficiency, Smaller Equipment
Commercial CLEERGAS System

- MSW
  - Gasification
  - Syngas Combustion
  - Conventional Boiler, APC, Power Gen

- Air
  - Low Quality Syngas
  - Reduced NOx, CO & gas flow

**GASIFICATION / SYNGAS RECOVERY** - Goal of Combined-Cycle Power or High Value End-Products
Ongoing Covanta R&D

- MSW
  - Gasification
  - Syngas Upgrading
  - Syngas Cleaning

- Air
  - High Quality Syngas

- Combined Cycle Power
- Liquid Fuels Production
- Hydrogen Production
Commercial Gasification Demonstration
Tulsa Unit 3

**MSW Gasification with Syngas Combustion**

- Covanta designed reciprocating platform, feed system and ash discharger
- Conventional feed system - no MSW preprocessing
- Separation of gasification and syngas combustion chambers via addition of lower furnace bullnose
- Four levels of air injection to control gasification and syngas combustion
  - Independent flow measurement and control of air to each primary, secondary and syngas combustor zone
- SNCR aqueous ammonia injection above syngas combustion zone
- Covanta designed control system – superior system stability
Commercial Gasification Demonstration
Tulsa Unit 3 Performance

• Start-up in April 2012
• Operating reliably since July 2011 with 94% availability
• Excellent emissions performance
  – NOx averaging 40 – 60 ppm
  – Short-term NOx tests < 30 ppm
  – CO held at typical low levels of ~ 20 ppm
  – Other pollutants primarily a function of emission control performance
• Reduced particulate carryover into boiler
  – Reduced fouling – boiler cleaning cost savings
  – Corrosion benefits being evaluated
Syngas Sampling and Analysis

Syngas Heating Value, Btu/SCF vs. Stoichiometric ratio

- 5500 Btu/lb MSW
- 5000 Btu/lb MSW
- 4500 Btu/lb MSW

UK ROC = 50.7 Btu/SCF
Tulsa Demonstration – Gasification Control System

Steam Flow vs. Setpoint

NOx Average = 52 ppm
Steam Stan Dev = 0.5%

Week Trend from 10/3 thru 10/10
CLEERGAS™ Gasification Process

Process improvements from Tulsa demonstration

- Separation of gasification zone from carbon burnout zone
- Burnout zone energy recovered to drive gasification process – reduced stoichiometric ratio and increased syngas heating value
- Refractory-lined gasifier to minimize energy loss – simpler design than waterwall furnace
- Cylindrical waterwall syngas combustor with staged air injection – reduces air requirement and NOx formation
- Optimal SNCR performance in turbulent syngas combustor
- Advanced control system built from Tulsa demonstration
CLEERGAS – Higher Syngas Quality

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Covanta Low Emissions Energy Recovery Gasification

COVANTA CLEERGAS™

300 TPD Modular Gasification Plant

Covanta designed and guaranteed – based on extensive EfW experience

- Modular design and fabrication to reduce field construction and capital cost
- Advanced control and monitoring system for stable and reliable operating performance
- Performance advantages vs. conventional EfW:
  - Better control of syngas combustion – lower NOx and CO generation
  - Lower air requirement – lower flue gas flow, higher boiler efficiency, lower particulate, smaller equipment

High market interest in commercially viable MSW gasification system

- Responding to multiple procurements for new and emerging technology
  - Both municipal and industrial
- Selected by St. Lucie County, FL
  - 2 x 300 TPD units
  - Combined heat and power
R&D Continues on Syngas Recovery

Goal to produce a clean renewable gas – environmentally equivalent to natural gas

• Evaluating and testing methods to upgrade syngas quality to convert residual tars
• Engineering on technologies to clean-up syngas
• Evaluating advancements in gas engine and gas turbine equipment for firing clean syngas
• Expanding pilot plant resources
Thank You!