OPG Experience with Coal to Biomass Conversions

Future Perspectives of Bioenergy Development in Asia
Tokyo, Japan
September 5-7, 2018

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Overview

• OPG Profile
• Coal-Biomass Conversions
• Atikokan GS
• Thunder Bay GS
• Project Comparison
• Partners
• External Interest and Collaboration
• Summary
POWER WITH PURPOSE: Providing low cost power in a safe, clean, reliable and sustainable manner for the benefit of our customers and shareholder.

- Ontario’s Largest Clean Energy Generator Providing Half of Ontario’s Electricity
- Diversified Asset Portfolio
- Strong Community Support and Indigenous Relations
- Significant Project Management and Development Experience
- Highly trained and engaged workforce of 9,200 employees
- Over $37 billion in assets generating annual revenues of approximately $5 billion
Coal to Biomass Conversion

- Repowering PC-fired boilers with white wood pellets
  - Receiving and storage
  - Material handling
  - Mills
  - Firing system
  - BOP

Advanced wood pellets must possess specific characteristics to enable a low capital cost option.
- 220 MWe, sub-critical
- Designed for lignite
- New fuel receiving, storage and dedicated handling systems
- New burners and modifications to mills and feedwater cycle
- New ash handling systems
- Began commercial operation in July 2014
Thunder Bay GS

• 2 x 160 MWe
• Designed for Western Canadian lignite.
• Converted to NPRB coal in 1996.
• 4 corner, tangentially fired.
• 5 RP 783 mills.
• April 2014: final generation of coal-fired electricity in Ontario.
Thunder Bay Project Development

- Low capacity factor required a low capital cost solution
- 2010: OPG begins evaluation of second generation pellets
- 2013: Selection of Arbaflame pellets for detailed analysis
- Execution of full scale testing on Thunder Bay Unit 3
Thunder Bay Unit 3
Advanced Wood Pellet Conversion

- 160 MWe, sub-critical
- Designed for lignite
- Outdoor fuel storage
- Modifications to existing material handling system
- Mill modifications
- Began commercial operation in January 2015
Fuel Evaluation

Internal program to evaluate upgraded biomass pellets since 2010.

Information exchange with utility peers with refined pellet experience.

Round robin bench scale testing of all major beneficiated pellet types.

Selected steam exploded wood pellets from Arbaflame AS (Norway) based on superior safety and milling characteristics.
• Long term storage pile established in September 2013
  • Monitoring of actual impact of winter on pellet integrity
• Durability results
  • September 2013 99.3
  • October 2013 98.2
  • November 2013 98.0
  • December 2013 98.4
  • January 2014 98.2
  • February 2014 98.8
Scope of Evaluation

- **Fuel Selection**
  - weatherability
  - material handling safety
  - milling and combustion
- **Safety**
  - explosion and fire risks
  - dust generation during handling
  - dust control via suppressants
  - electrostatic ignition
  - coal handling system modifications
- **Mill Performance**
  - pilot scale mill testing to identify performance limitations
  - evaluation of operational and physical modifications
- **Full Scale Observations**
  - outdoor storage
  - handling observations
  - airborne dust measurements
  - effectiveness of wetting agents and dust collection systems
  - Pulverizer performance including start-up / shutdown, load-fineness-power relationship
  - mill drying analysis
  - unit start on biomass
  - burner stability and combustion performance
  - boiler thermal performance including steam temperatures and back end observations
  - emissions
Safety Evaluations

Electrostatic Discharge

- Bulk or cone discharges identified as a possible ignition source for fuel resistivity > $10^{10} \, \Omega \cdot m$
- Resistivity and relaxation time found to be very sensitive to relative humidity
- Threshold resistivity of $10^{10} \, \Omega \cdot m$ not exceeded for RH > 55%
- Added steam injection system to raise RH in bunkers prior to loading.

<table>
<thead>
<tr>
<th>Material</th>
<th>Volume Resistivity 15% RH ($\Omega \cdot m$)</th>
<th>Volume Resistivity 55% RH ($\Omega \cdot m$)</th>
<th>Measured Decay Time 15% RH (s)</th>
<th>Measured Decay Time 55% RH (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arbaflame Dust (&lt; 75μ)</td>
<td>$2.14 \times 10^{13}$</td>
<td>$5.34 \times 10^9$</td>
<td>1453</td>
<td>1.45</td>
</tr>
</tbody>
</table>
Visible dust only during loading of reclaim hopper

Clean conditions downstream

Personal breathing zone particulate measurements below OEL

Airborne dust monitoring also well below OEL

Dust levels for Arbaflame pellets lower than for coal
Pulverizer Modifications for White Pellet Firing

- Modified Classifier Vanes
  Reduce Classifier Revolution
- Double Wall
- Explosion Suppression System
- Additional Coverage Housing Openings
- Mod. Central Raw Coal Conus
- Increase Grinding Bed Height
- Increase Gear Outlet Speed
Full Scale Results – Combustion

• Operation up to original unit MCR on 100% Arbaflame pellets
• Stable 100% wood fires
• No significant fuel drop out or burning carryover
• LOI generally well less than 5%
• Testing included start up on wood
• Steam temperatures similar to coal performance
• CO concentration ~ 20 ppmv
• NOx emissions 45% lower than sub-bituminous coal
- Atikokan GS
  - 205 MWe – White Pellets
  - Project Duration
    - • 18 months (9 month outage)
  - Conversion CapEx
    - • $170M ($830 / kW)

- Thunder Bay GS Unit 3
  - 150 MWe – Advanced Biomass
  - Project Duration
    - • 7 months (2 month outage)
  - Conversion CapEx
    - • $3M ($20 / kW)
Advanced Solid Biofuels Research Program at CanmetENERGY

CanmetENERGY-Ottawa
Bioenergy Systems Group

IEA Task 32 Workshop
Japan, September 2018
About CanmetENERGY

CanmetENERGY is the science and technology branch of Natural Resources Canada and operates three labs across Canada with over 450 scientists, engineers and technicians.

The Bioenergy Program at CanmetENERGY-Ottawa assists industry to develop cleaner, more energy-efficient biomass conversion processes.
CanmetENERGY Advanced Solid Biofuels Research Program

Convert low value Canadian forest and agricultural residues into a consistent and commercially viable fuel or carbon sources for the power, metallurgical, cement and other sectors:

- Identify/assess pathways to produce quality advanced pellets/briquettes from thermally treated biomass
- Develop procedures/recipes to reduce the cost and improve product qualities
- Define optimal process conditions for conversion and densification
- Support development of standards for advanced solid biofuels
- Develop specifications for handling & storage of advanced solid biofuels
CanmetENERGY - Advanced Solid Biofuel Pilot Plants

Steam explosion & HTC units

Electrical kiln (continuous operation), 10 kg/hr

Single pellet/briquette press

Flat die pellet mill

Ring die pellet mill

Briquette machine
Advanced Solid Biofuels Evaluation Program

• Collaborative Initiative between CanmetENERGY-Ottawa and OPG

• Goal is to objectively rank advanced solid biofuels regarding their relative performance for handling and combustion
  – Develop standardized protocols / methods to measure fuel properties
  – Assess key fuel criteria required by industrial end users
New procedures developed by CanmetENERGY-Ottawa for pellets and briquettes:

- Weathered durability and water uptake;
- Rain emulation and leachate analyses;
- Grindability (modified HGI);
- Freeze/Thaw;
- Dust profiling and explosivity.

CanmetENERGY Scope

Physical & Chemical Properties:

Durability (ISO 17831); Ash (ASTM D4326); Halogens (pyrohydrolysis - in-house method); Ultimate: C/H/N/S/O (ISO 16948 and 16994); Moisture (ISO 18134-3); Volatile Matter (ISO 18122); Fixed Carbon (ASTM D7582); Calorific value (ISO 14918)
CanmetENERGY Project lead

Guy Tourigny
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Pellet Quality Advancements

Progress with Weatherability Metric

<table>
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<tr>
<th>Year</th>
<th>Weathered Durability (%)</th>
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<tr>
<td>Torr. 2010</td>
<td>70</td>
</tr>
<tr>
<td>Torr. 2010</td>
<td>80</td>
</tr>
<tr>
<td>Torr. 2010</td>
<td>80</td>
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<tr>
<td>Torr. 2018</td>
<td>90</td>
</tr>
<tr>
<td>Torr. 2018</td>
<td>90</td>
</tr>
<tr>
<td>SE 2010</td>
<td>100</td>
</tr>
<tr>
<td>SE 2018</td>
<td>100</td>
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OPG has assisted a number of other utility clients with their evaluation and testing of advanced biomass fuels, including:
  
  • Southern Company, Portland General Electric, Capital Power, Électricité du France, Engie and J-Power

In addition, OPG has hosted many technical tours of industry groups seeking to learn more about the two biomass conversion techniques applied at OPG:
  
  • USA and Canada
  • Europe (UK, France, Netherlands, Norway, Finland)
  • Asia (Korea and Japan)
Key Points

• OPG has executed successful coal-biomass conversions using both traditional white wood pellets and advanced biomass pellets.

• Leveraging the excellent handling properties of the selected pellets has enabled a low capital cost solution for a total coal-biomass conversion.

• Cooperation between suppliers, researchers and utilities is encouraged to further develop this new opportunity for our industry.
Thank you

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