Bio-Carbon for Canadian Iron and Steel Production

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Metallurgical Fuels Laboratory
Natural Resources Canada, CanmetENERGY

BioCleanTech Forum
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CanmetENERGY-Ottawa

CanmetENERGY-Ottawa leads the development of energy S&T solutions for the environmental and economic benefit of Canadians
Metallurgical Fuels Lab

- Pierre Martin, Group Manager
- 4 Research Scientists
- 1 Research Engineer
- 10 Technologists
- Over 40 years experience in coal carbonization and blast furnace ironmaking research
- Member of Canadian Carbonization Research Association (CCRA)
Canadian Carbonization Research Association

- Consortium of steel producers, coal producers and cokemakers
- Collaborative research to address industrial needs
- Met coal carbonization, Blast furnace ironmaking
GHG Mitigation by Fuel Switching

- Substitution of fossil carbon by renewable bio-carbon
  - Incorporation of bio-carbon in existing iron and steel making facilities to avoid capital investment
- Medium term goal (2030)
  - 10% substitution metallurgical coal in cokemaking by renewable bio-carbon.
  - 100% replacement of injection coal in blast furnace ironmaking by renewable bio-carbon
  - 100% replacement of injection carbon (for slag foaming) and charge carbon (for supplementary energy) in EAF steelmaking by renewable bio-carbon
Coal Mine

~1.5 t CO₂

Coal Mine

655 kg Coal

Cokemaking

495 kg Coking Coal

350 kg Coke

Ironmaking

160 kg PCI Coal

1 t HM

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Coal Mine

Biomass Collection

Pyrolysis (yield 30%)

~1 t CO2

445 kg Coal

Biomass Collection

445 kg Coking Coal

50 kg Biochar

350 kg Coke

160 kg Biochar

210 kg Biochar

1 tHM

Cokemaking

Ironmaking

Goal

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Canada

Natural Resources Canada

Ressources naturelles Canada
Bio-Char Supply Chain Pathway

Raw biomass Sources
- Saw mill residues
- Pulp mill residues
- Harvesting residues
- Demolition Wood

Pyrolysis
- Torrefaction/Slow Pyrolysis
- Fast Pyrolysis
- Hydrothermal Carbonization

Utilization
- Blast Furnace Pulverized Coal Injection
- Cokemaking
- Electric Arc Furnace Steelmaking

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Pyrolysis Technology Evaluation

- To understand the effect of various factors on bio-char properties to assist pathway selection
  - Effect of feedstock
  - Capability of pyrolysis technology in handling different feedstocks
  - Effect of pyrolysis technology and processing conditions
- Partners:
  - Ben Bronson (Bioenergy/CanmetENERGY): Fast Pyrolysis
  - Guy Tourigny (Bioenergy/CanmetENERGY): Torrefaction
  - Animesh Dutta (U of Guelph): Hydrothermal Carbonization
Test Program

- Saw Mill Residues
- Pulp Mill Residues
- Harvesting Residues
- Demolition Wood

- Torrefaction:
  - Rotary Kiln CanmetENERGY

- Fast Pyrolysis:
  - Fluidized Bed CanmetENERGY

- Hydrothermal Carbonization:
  - U of Guelph

- Bio-char properties

- PCI
- Cokemaking
- EAF
Saw Dust Torrefaction: Rotary Kiln

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>Severity Factor</th>
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<tbody>
<tr>
<td>Torr-SF5.9</td>
<td>290</td>
<td>300</td>
<td>330</td>
<td>5.9</td>
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<tr>
<td>Torr-SF6.9</td>
<td>310</td>
<td>320</td>
<td>350</td>
<td>6.9</td>
</tr>
<tr>
<td>Torr-SF7.7</td>
<td>340</td>
<td>350</td>
<td>380</td>
<td>7.7</td>
</tr>
</tbody>
</table>
Torrefied Saw Dust - Composition

H/C Atomic Ratio vs O/C Atomic Ratio

- Saw dust
- Torr-SF5.9
- Torr-SF6.9
- Torr-SF7.7
- PCI Coal
## Torrefied Saw Dust Composition

<table>
<thead>
<tr>
<th></th>
<th>Injection Coal</th>
<th>Torrefaction SF 5.9</th>
<th>SF 6.9</th>
<th>SF 7.7</th>
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<tbody>
<tr>
<td><strong>Proximate (db)</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ash</td>
<td>%</td>
<td>7.89</td>
<td>0.44</td>
<td>0.5</td>
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<tr>
<td>VM</td>
<td>%</td>
<td>36.2</td>
<td>80.8</td>
<td>74.1</td>
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<tr>
<td>FC</td>
<td>%</td>
<td>55.9</td>
<td>18.8</td>
<td>25.4</td>
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<tr>
<td><strong>Ultimate (db)</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>%</td>
<td>77.5</td>
<td>51.7</td>
<td>54.9</td>
</tr>
<tr>
<td>H</td>
<td>%</td>
<td>5.2</td>
<td>5.6</td>
<td>5.3</td>
</tr>
<tr>
<td>N</td>
<td>%</td>
<td>1.7</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>S</td>
<td>%</td>
<td>0.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>O</td>
<td>%</td>
<td>7.0</td>
<td>42.1</td>
<td>39.1</td>
</tr>
<tr>
<td><strong>Ash Chemistry (%Ash)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SiO₂</td>
<td>%</td>
<td>52.29</td>
<td>2.32</td>
<td>2.85</td>
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<tr>
<td>Al₂O₃</td>
<td>%</td>
<td>29.41</td>
<td>0.62</td>
<td>0.53</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>%</td>
<td>6.55</td>
<td>11.09</td>
<td>2.57</td>
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<tr>
<td>TiO₂</td>
<td>%</td>
<td>1.71</td>
<td>0.08</td>
<td>0.06</td>
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<tr>
<td>P₂O₅</td>
<td>%</td>
<td>0.12</td>
<td>2.94</td>
<td>3.19</td>
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<tr>
<td>CaO</td>
<td>%</td>
<td>3.25</td>
<td>29.00</td>
<td>30.02</td>
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<tr>
<td>MgO</td>
<td>%</td>
<td>0.95</td>
<td>6.30</td>
<td>6.68</td>
</tr>
<tr>
<td>Na₂O</td>
<td>%</td>
<td>0.26</td>
<td>0.58</td>
<td>0.41</td>
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<tr>
<td>K₂O</td>
<td>%</td>
<td>1.64</td>
<td>20.68</td>
<td>22.37</td>
</tr>
</tbody>
</table>
Torrefied Saw Dust - Yield

<table>
<thead>
<tr>
<th>Sample</th>
<th>Bio-Char Yield (%)</th>
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</thead>
<tbody>
<tr>
<td>Torr-SF5.9</td>
<td>84.1</td>
</tr>
<tr>
<td>Torr-SF6.9</td>
<td>82.0</td>
</tr>
<tr>
<td>Torr-SF7.7</td>
<td>46.0</td>
</tr>
</tbody>
</table>
Blast Furnace Ironmaking

C (coke/injection coal) + O2 (hot blast) → CO(g)

Heat

Metallic Fe ← Iron Ore (Fe2O3)

Molten Fe (Hot metal)

Pulverized Coal

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Replacing PCI by Torrefied Saw Dust

- Heat and mass balance modeling
- Thermodynamic modeling
- Effect on blast furnace operations
  - Fuel (coke + injectant) consumption
  - Alkaline (Na+K) accumulation
- Potential GHG reduction
- Raw biomass demand
Carbon and Energy Input

**Base Case (Coal Injection)**
- Coke rate: 350 kg/tHM
- Injection rate: 160 kg/tHM
Alkaline Accumulation

Flux rate: 70 kg/tHM

% Increase in Alkaline (Na+K) Accumulation

Pyrolysis Severity

Alkaline Accumulation

Slag Viscosity

Estimated Slag Viscosity (poise)
Alkaline Accumulation

Flux rate: 54 kg/tHM

% Increase in Alkaline (Na+K) Accumulation vs. Pyrolysis Severity

- Alkaline Accumulation
- Slag Viscosity

Estimated Slag Viscosity (poise)

Pyrolysis Severity

0% 5% 10% 15% 20% 25% 30%

5.5 6 6.5 7 7.5 8

2.10 2.20 2.30 2.40 2.50
Potential GHG Reduction
Next Step

- Comparison of combustion kinetics of biochar produced at different pyrolysis severity in CanmetENERGY injection simulation rig

Pulverized coal injection simulation rig
Future Work

- Repeat analysis with biochar produced by
  - different pyrolysis technologies
  - different raw biomass materials
- Supply information to steel producers, biochar producers and raw biomass suppliers to assist decision making
- Establishment of biochar supply chain to meet the technical needs of steel production
Acknowledgements

- Natural Resources Canada Energy Innovation Program
- Canadian Carbonization Research Association
- Canadian Steel Producers Association