DEVELOPMENTS OF BIOCARBON FOR CANADIAN STEEL PRODUCTION

BioCleantech Forum
Nov 2-3, 2016

Canadian Carbonization Research Association (CCRA)

Ted Todoschuk, Board Chairman CCRA, AMDofasco
Louis Giroux, Technical Committee Chairman CCRA, Natural Resources Canada/CanmetENERGY
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About CCRA

Canadian Carbonization Research Association (CCRA)

ArcelorMittal Dofasco
SunCoke Energy
CanmetENERGY
Anglo American/Peace River Coal
Boreas/Glencore
Teck Corp

Industrial Innovation Group
Industrial Energy Systems
Metallurgical Fuels Laboratory

Start up Members
Ram Colonial Riversdale

Personnel
Dr. P. Martin

3 PhD Scientists
2 Research Engineers

Equipment

10 Technicians

Coal

Chemistry
Petrography
Rheology
Physical
Movable Wall Oven
Sole Heated Oven

Coke

Chemistry
Size
Strength
Density
Porosity
Coke Carbon Forms
CCRA Research Program

- Energy and CO₂ Reduction in the Steel Industry
- Energy and Environment
- Fundamental Aspects of Coal and Coke Utilization
- Database, Standards and Procedures
Canadian Steel Industry GHG Emissions

- Emitted ~14.6 MT GHG in 2013
- ~84% in Ontario

Steel production and GHG emissions are concentrated in Ontario

(CSPA Presentation March 30, 2016)
Previous CCRA Research Achievement

- Improve coke quality
- Reduce fuel consumption
- Reduce GHG emissions
- Limited room for further energy efficiency improvement
- Need an alternative approach to achieve drastic GHG reduction: Bio-carbon
Bio-carbon Research Focus

- Coal replacement in coal blend which makes coke for BF
- Coal replacement for PCI applications
- Fossil carbon replacement in EAF

Role of Coke in Blast Furnace
- Source of Reducing Gas
- Source of Heat
- Burden Support
- Gas Distribution

Hot and cold strength of particular coke determines its suitability for blast furnace ironmaking.
Research Target: Short Term Goals (2020)

- **Integrated Ironmaking**
  - 5 - 10% substitution metallurgical coal in cokemaking by renewable bio-carbon in slot ovens
  - 100% replacement of injection coal in blast furnace ironmaking by renewable bio-carbon
  - *Corresponds to ~25% reduction in GHG emission associated with both cokemaking and ironmaking*

- **Integrated Steelmaking**
  - Small impact and what is developed for EAF could translate for the BOF

- **EAF Steelmaking**
  - 100% replacement of injection carbon (for slag foaming) and charge carbon (for supplementary energy) in EAF steelmaking by renewable bio-carbon
  - *Corresponds to >50% reduction in direct GHG emission associated with EAF steelmaking*
Future CO2 Reduction in the Canadian Steel Industry

[Graph showing % GHG Reduction and Intensity tCO2/thM over years from 2010 to 2055]
Technological Gap: Stable Supply of Suitable Bio-Char

• Current Canadian hot metal production: 8.4 Mt/yr
• Bio-char demand: 1.7 Mt/yr
• Raw biomass demand: 5.7 Mt/yr (assuming bio-char yield is 30%)
• Challenges:
  • Sustainable supply of raw biomass
  • Lack of pyrolysis capacity in Canada to produce bio-char with suitable properties for steel production
### Potential Raw Biomass Supply: Forestry Residues

<table>
<thead>
<tr>
<th></th>
<th>BC</th>
<th>Prairies</th>
<th>ON</th>
<th>QC</th>
<th>Maritimes</th>
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<td>403,902</td>
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<td>896,329</td>
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<td>Softwood Roadside</td>
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<td>Urban Waste</td>
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<td>3,900,176</td>
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<td><strong>Total</strong></td>
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<td>6,710,421</td>
<td>9,603,219</td>
<td>11,736,718</td>
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*(Source: Canadian Wood Fibre Centre Presentation March 30, 2016 Meeting)*

- Forestry residues in ON and QC has the potential to meet the demand
  - Residues and waste available in ON and QC: ~20M ODT
  - Raw biomass required to support Canadian blast furnace iron production: ~ 6Mt/yr

- Efforts in collection, transportation and may be pre-processing of residues affect:
  - $Cost-->affect biochar price
  - GHG emissions-->offset carbon neutrality

- Require optimization in logistics and processing
Bio-Char Demand by Steel Industry

Short Term Goals

- 5 - 15% substitution metallurgical coal in cokemaking by renewable bio-carbon. The use of Western Canadian Coals a must for CSR.
- 100% replacement of injection coal in blast furnace ironmaking by renewable bio-carbon
- 100% replacement of coke in BOF 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

Bio-char demand to achieve short term goals:

- Total potential demand: 1.7 Mt Bio-char/yr
  - 1.2 Mt Bio-char/yr for direct injection in ironmaking
  - 0.4 Mt Bio-char/yr for cokemaking
  - 0.1 Mt Bio-char/yr for EAF and BOF

- Demand substantially exceeds the bio-char production capacity!
- Need to work with possible suppliers to engineer the bio-char that meets the steel industry needs – both integrated and EAF
- Provincial and Federal governments need to join the team

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Research Target: Long Term Goals (+2030)

- **Integrated Ironmaking**
  - 50% substitution metallurgical coal in cokemaking by renewable bio-carbon (determine the maximum amount in both slot ovens and energy recovery ovens)
  - 100% replacement of injection coal in blast furnace ironmaking by renewable bio-carbon
  - Corresponds to ~70% reduction in GHG emission associated with both cokemaking and ironmaking

- **Integrated Steelmaking**
  - 100% replacement of nut coke by renewable bio-carbon
  - Corresponds to 100% reduction in GHG emission in the BOF

- **EAF Steelmaking**
  - 100% replacement of injection carbon (for slag foaming) and charge carbon (for supplementary energy) in EAF steelmaking by renewable bio-carbon
  - Corresponds to >50% reduction in direct GHG emission associated with EAF steelmaking

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Future Bio Char Demand for the Canadian Steel Industry

Typical Cokemaking and BF Plant

Canadian Carbonization Research Association www.cancarb.ca
### Bio-Char Characteristics Demand by Steel Industry

- Direct injection – chemistry is key
- Cokemaking – chemistry and physical characteristics are key
- EAF steelmaking – chemistry is key

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Bio-char</th>
<th>Fast Pyrolysis</th>
<th>Slow Pyrolysis</th>
<th>Torrefaction</th>
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<td>Ash</td>
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<td>8.12</td>
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<td>8.12</td>
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(C)
Bio-Char Characteristics Demand by Steel Industry

• Transparent to production process
  • Allow switch between bio-char and coal to cope with bio-char availability
  • Implement without modifying existing process to avoid major capital investment

• Bio-char for Substituting Coal in Cokemaking
  • Low in CaO, MgO, K2O, Na2O, P2O5
  • High in Carbon >80%
  • Not create cokemaking issues (wall pressure, handling, grinding, etc)
  • Resultant Bio-Coke must have:
    • Adequate size
    • Adequate chemical properties
    • Adequate cold strength
    • Adequate hot strength and reactivity with CO2

• Bio-char for Substituting Injection Coal:
  • High combustion kinetics
  • Adequate coke replacement potential
  • Low in K2O, Na2O and P2O5

• Bio-char for EAF Steelmaking:
  • Properties would be more chemical than physical and could be from coke oven as opposed to a separate product
Timeline of Development

Steel sector  ➔  Pyrolysis sector  ➔  Forestry Sector

CanmetENERGY ➔

Goal
• Biochar product with optimal properties for steel production

Plant Trial (2020)

Gradual increase in biochar utilization to match with pyrolysis sector growth

Goal
• Raw material and pyrolysis plant location
• Biomass collection and logistics optimization

Full Industrial Scale Implementation (2030)
Forestry, Pyrolysis and Steel Sector Collaboration

- 2 meetings were held in Ottawa on 30 March 2016 and 8 June 2016 for establishing the collaboration between the forestry, pyrolysis and steel sectors

- Participants:
  - **Steel sector**: CCRA, CSPA
  - **Pyrolysis sector**: Agri-Tech Producers, AIREX Énergie inc
  - **Forestry sector**: Canadian Forestry Services, Canadian Wood Fibre Center
  - **Academic**: McMaster U, Carleton U and U of Guelph
  - **Provincial government**: Ontario Ministry of Economic Development, Employment and Infrastructure, Ontario Centers of Excellence, Centre for Research and Innovation in the Bio Economy
  - **Federal government**: CanmetENERGY/MFL and CanmetENERGY/Bioenergy

- Outcomes:
  - Engagement of different sectors in R&D
  - Industrial support for applying Federal Government funding
**Federal Government Support**

**Goal:** Develop the steel industry as a major consumer of bio-carbon to encourage expansion of bio-char production capacity in Canada

**Approach:**
- Establish steel industry as the target market
- R&D in incorporation of biochar in steel production process
- Evaluate the suitability of biochar products for steel production
- Provide feedback to pyrolysis sector
- Assist further development of existing pyrolysis technologies (Fast pyrolysis, Torrefaction and Hydrothermal Carbonization) for producing suitable bio-char that meets the needs of steel industry

### Natural Resources Canada Energy Innovation Program (EIP)

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<th>2018-19</th>
<th>2019-20</th>
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<td>530</td>
<td>433</td>
<td>650</td>
<td>538</td>
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</tbody>
</table>

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Funding Gap

Woody Biomass
- Saw mill, Pulp mill, Harvesting, Municipal Waste

Funding needed to cover:
- Raw biomass feedstock supply chain
- Scenario study: Life cycle and economic analysis

R&D covered by EIP:
- Optimization of pyrolysis technology
- Pilot scale demonstration of biochar utilization

Fast Pyrolysis → Torrefaction → HTC → Bio-char
Substituting coal in steel production (PCI, Cokemaking, EAF)
**Funding Gap**

- **Natural Resources Canada EIP funding:**
  - Cover R&D activities at CanmetENERGY Met Fuels Lab
  - Does not cover work on raw biomass materials supply
  - Does not cover industrial scale development of biocarbon production technologies.

- Require additional financial support from the Government of Ontario
  - Training of Highly Qualified Personnel (HQP) to accelerate technology development
  - Plant trial in steel mills
  - Support pyrolysis sector development
  - Support raw biomass materials collection and logistics development