DEVELOPMENTS OF BIOCARBON FOR CANADIAN STEEL PRODUCTION

BioCleantech Forum
Nov 2-3, 2016

Canadian Carbonization Research Association (CCRA)

Ted Todoschuk, Board Chairman CCRA, AMDofasco

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About CCRA

Canadian Carbonization Research Association (CCRA)

- ArcelorMittal Dofasco
- SunCoke Energy
- CanmetENERGY
  - Industrial Innovation Group
  - Industrial Energy Systems
  - Metallurgical Fuels Laboratory
- Anglo American/ Peace River Coal
- USS Canada
- Boreas/ Glencore
- Teck Corp
- Start up Members
  - Ram
  - Colonial
  - Riversdale

Personnel
Dr. P. Martin

- 3 PhD Scientists
- 2 Research Engineers
- 10 Technicians

Equipment

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 CO_2 Reduction in the Steel Industry
- Energy and Environment
- Fundamental Aspects of Coal and Coke Utilization
- Database, Standards and Procedures

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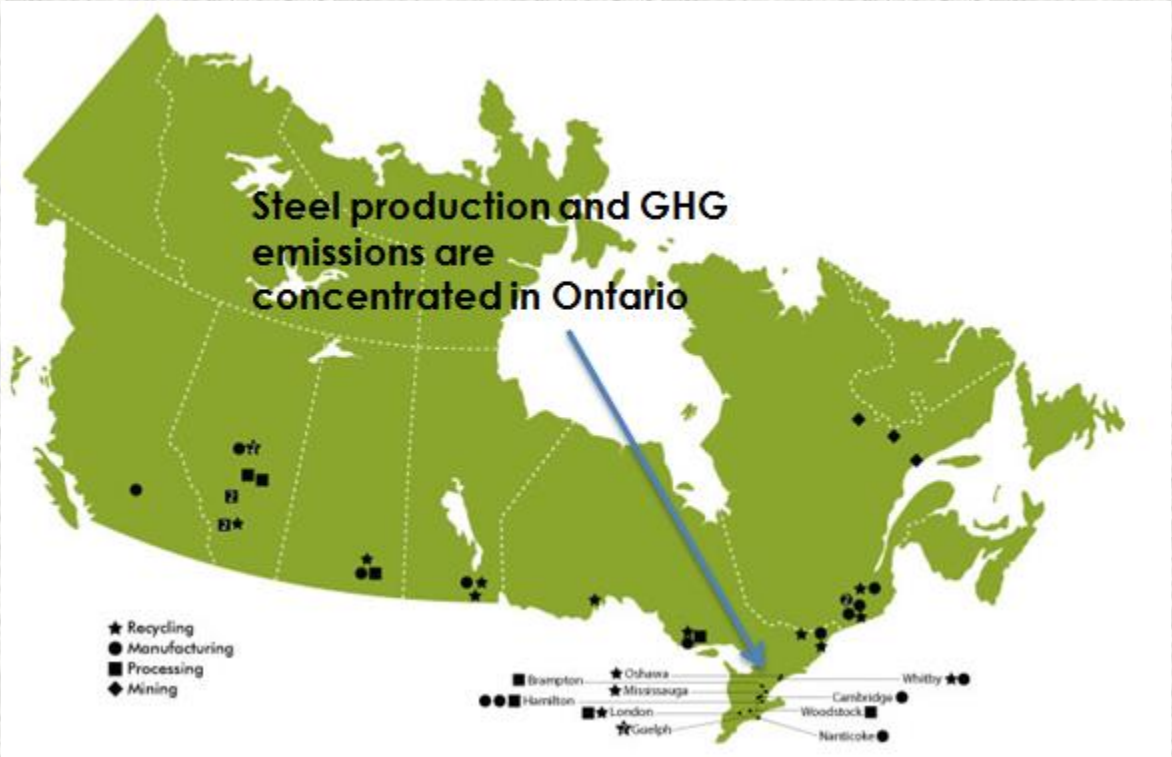
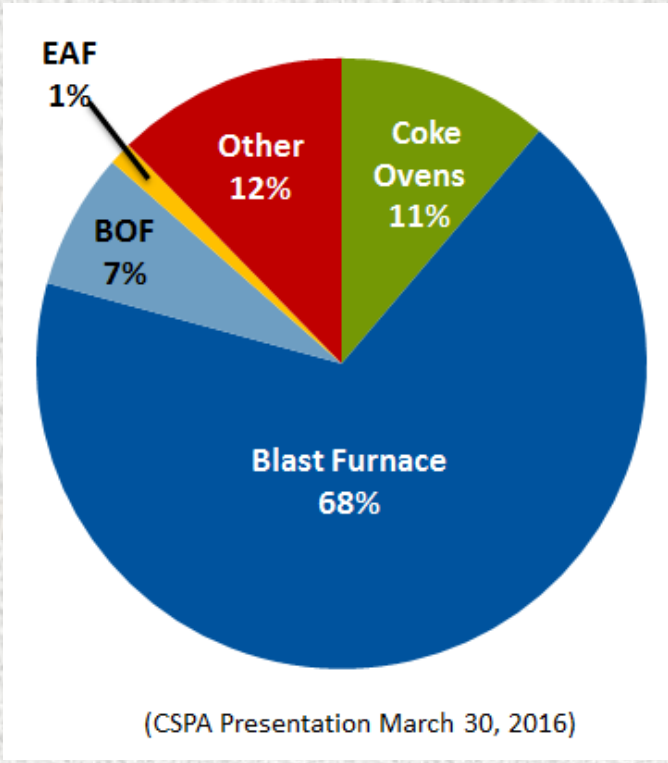
Canadian Steel Industry GHG Emissions

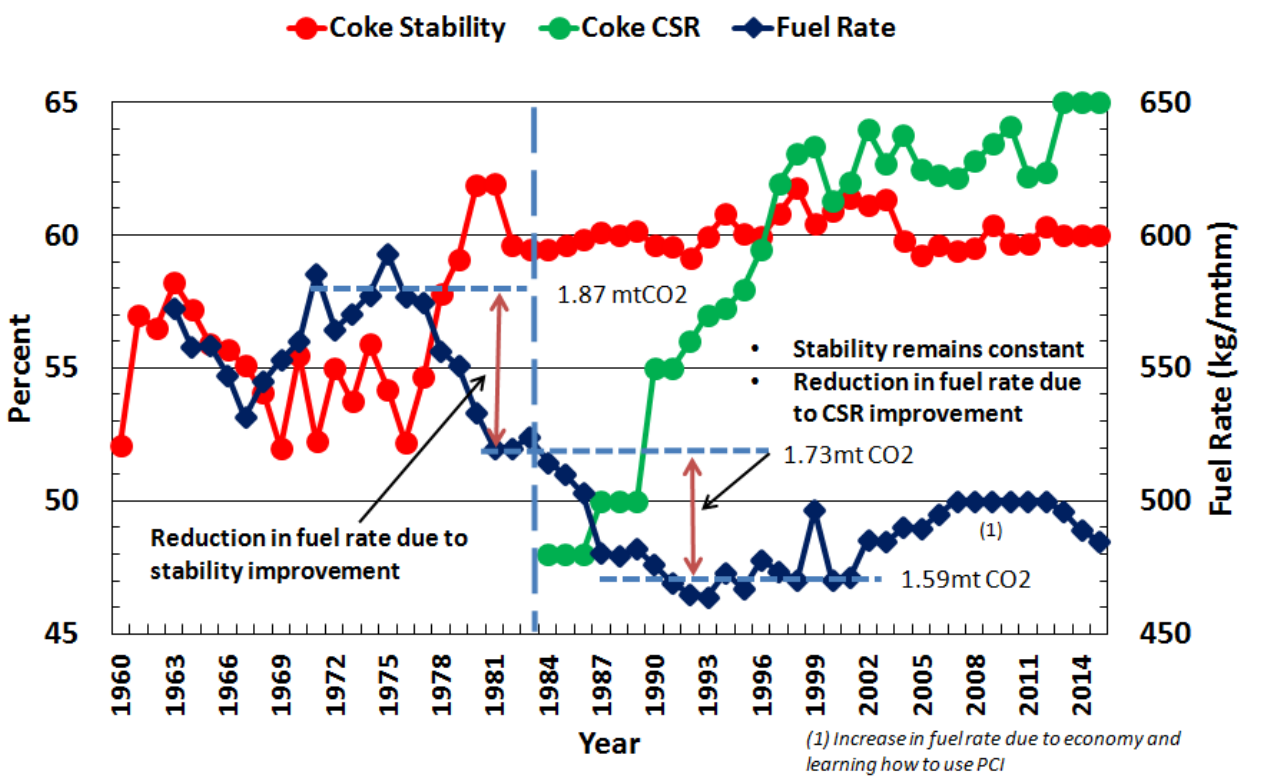
- Emitted ~14.6 MT GHG in 2013
- ~84% in Ontario





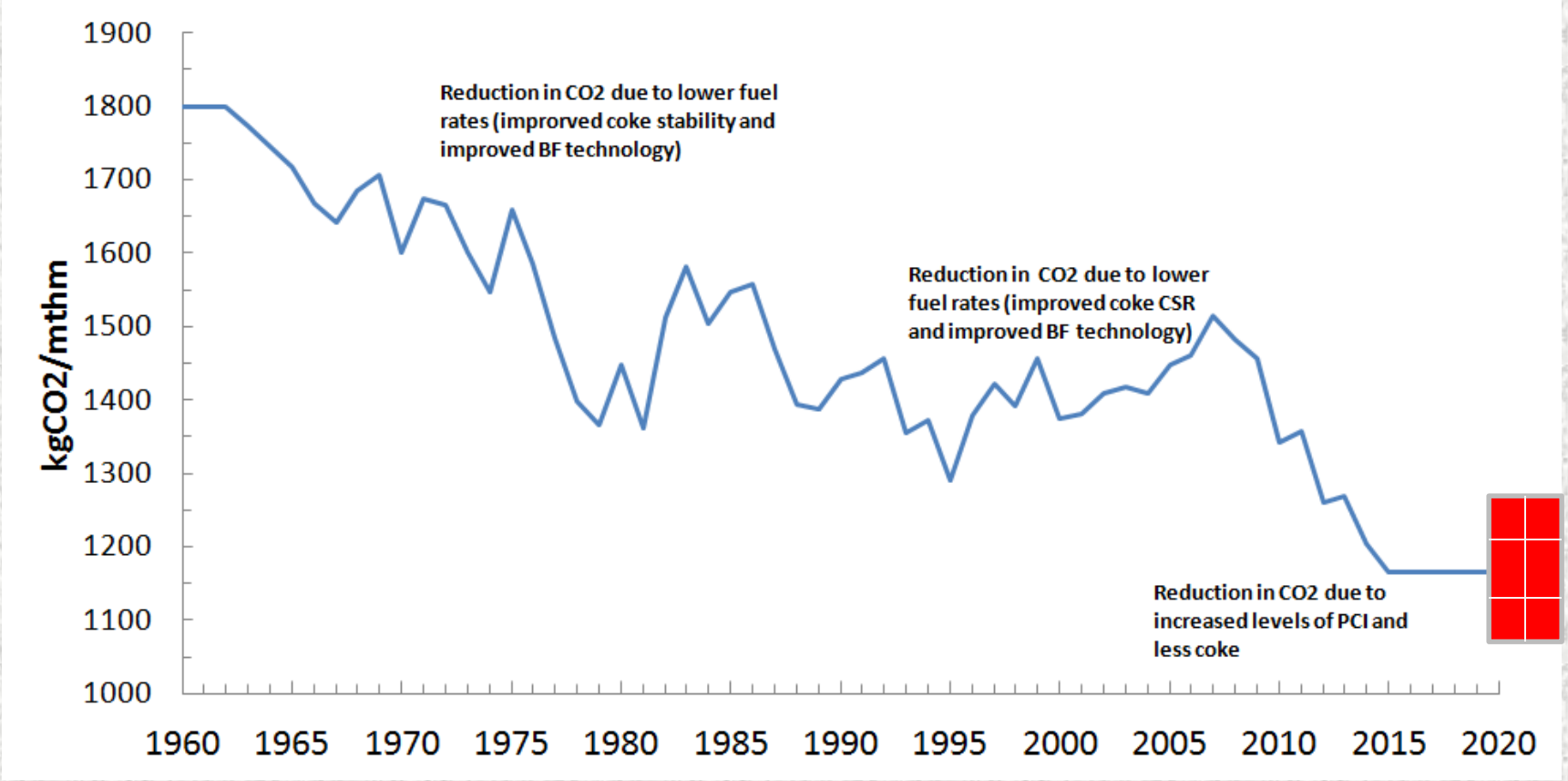
(CSPA Presentation March 30, 2016)

Previous CCRA Research Achievement

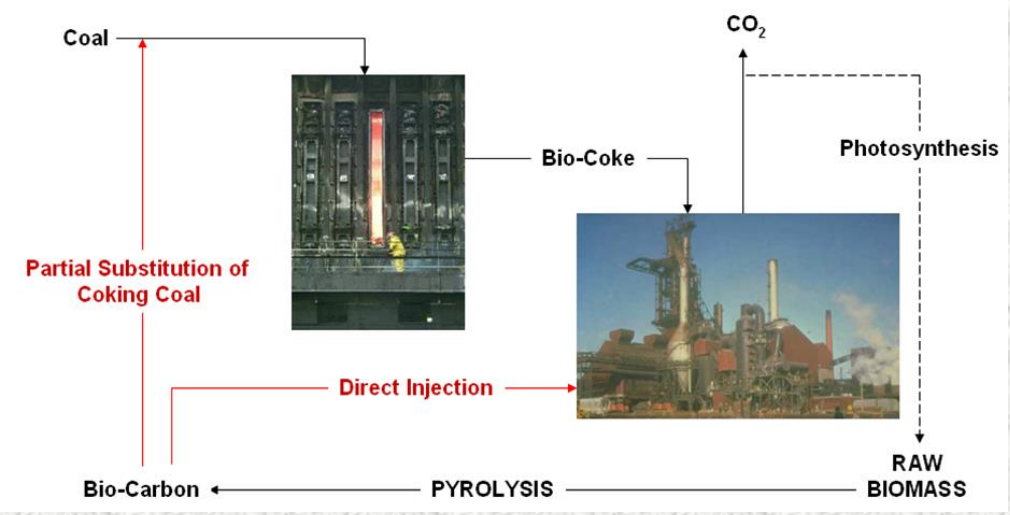


- Improve coke quality
- Reduce fuel consumption
- Reduce GHG emissions
- Limited room for further energy efficiency improvement
- Need an alternative approach to achieve drastic GHG reduction: Bio-carbon

Historical CO2 Reduction in a Typical Canadian BF



Bio-carbon Research Focus

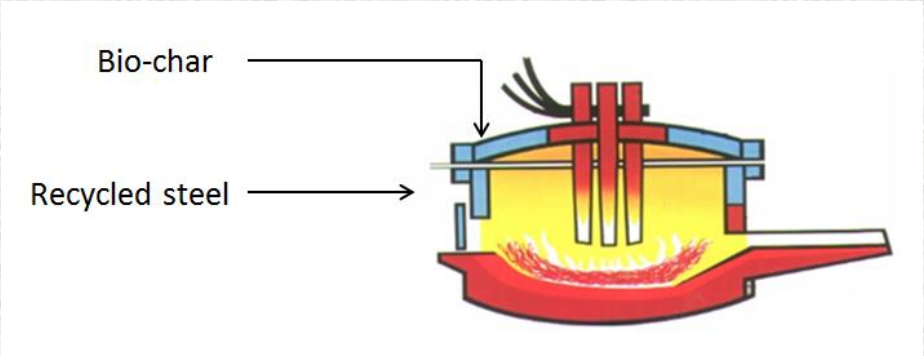


Role of Coke in Blast Furnace

- 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

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



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*

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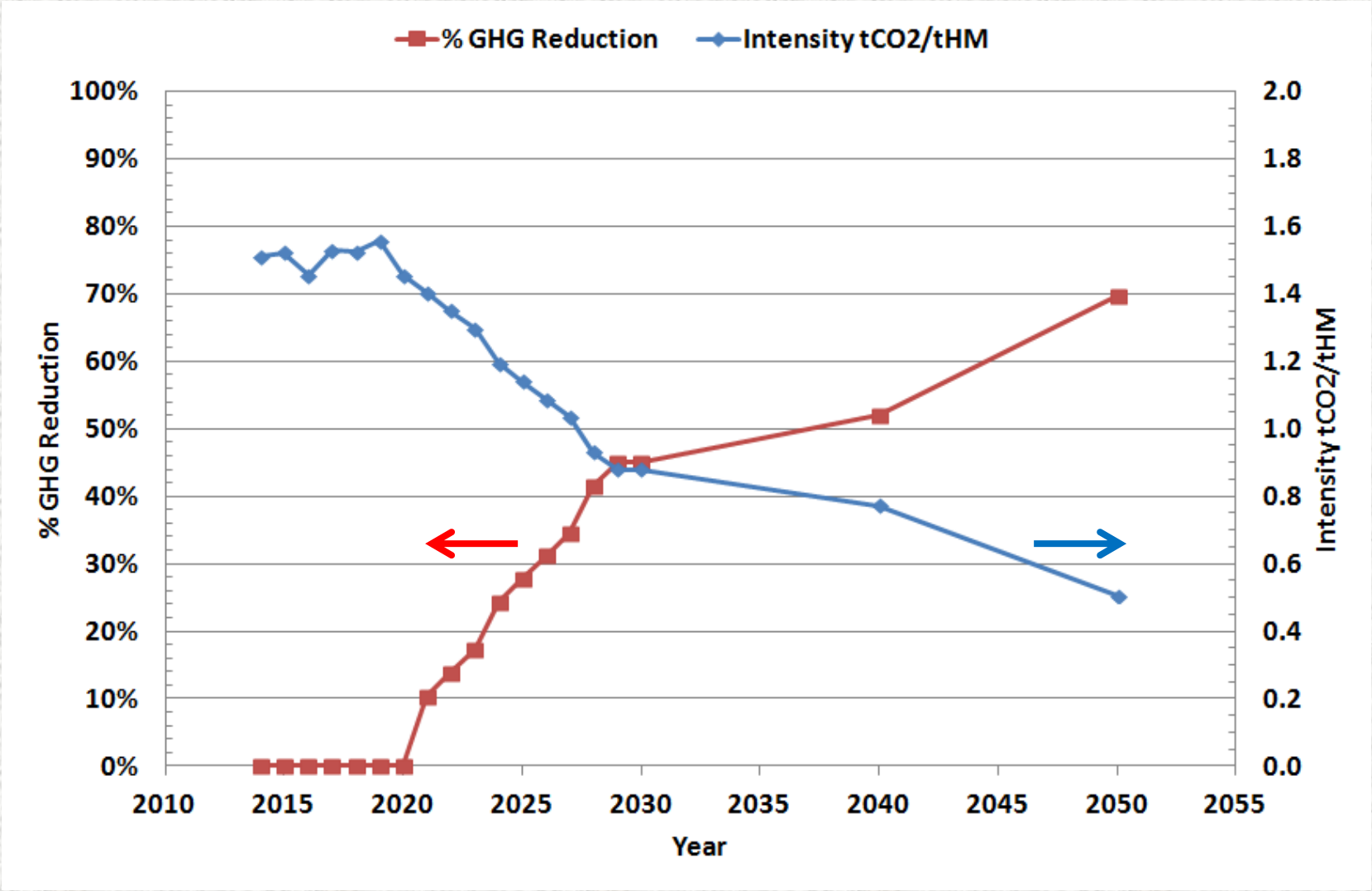
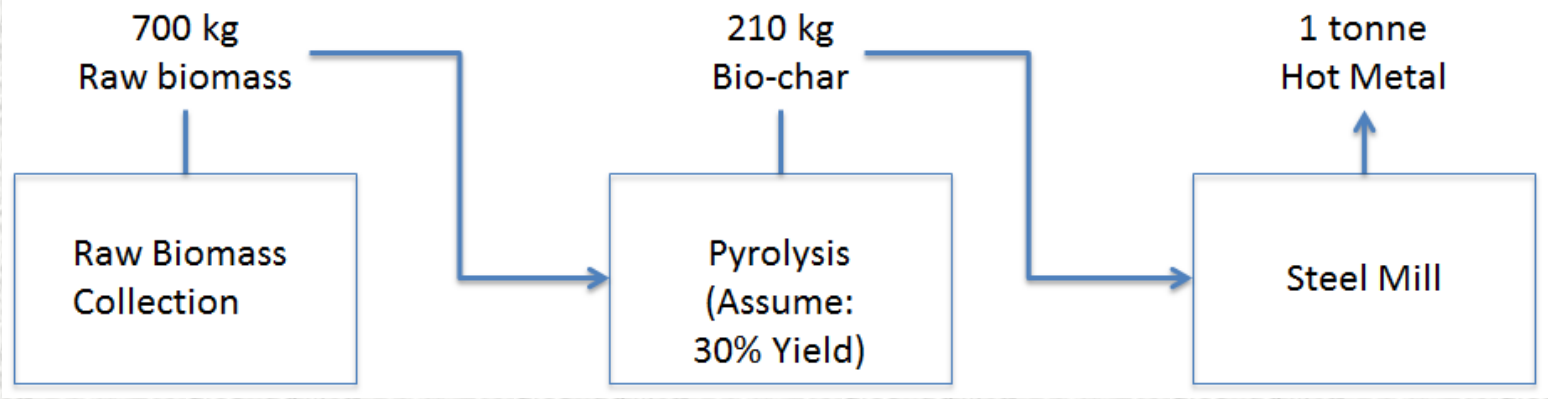
Future CO2 Reduction in the Canadian Steel Industry



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

	BC	Prairies	ON	QC	Maritimes
Hardwood Roadside	403,902	1,735,900	896,329	1,366,950	196,094
Softwood Roadside	13,331,800	2,704,032	3,484,810	5,446,830	1,275,246
Hardwood Mill	86,727	124,886	392,389	626,017	98,896
Softwood Mill	2,722,930	572,896	929,515	1,807,200	475,028
Urban Waste	1,302,787	1,572,707	3,900,176	2,489,721	368,003
Total	17,848,146	6,710,421	9,603,219	11,736,718	2,413,267

(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

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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

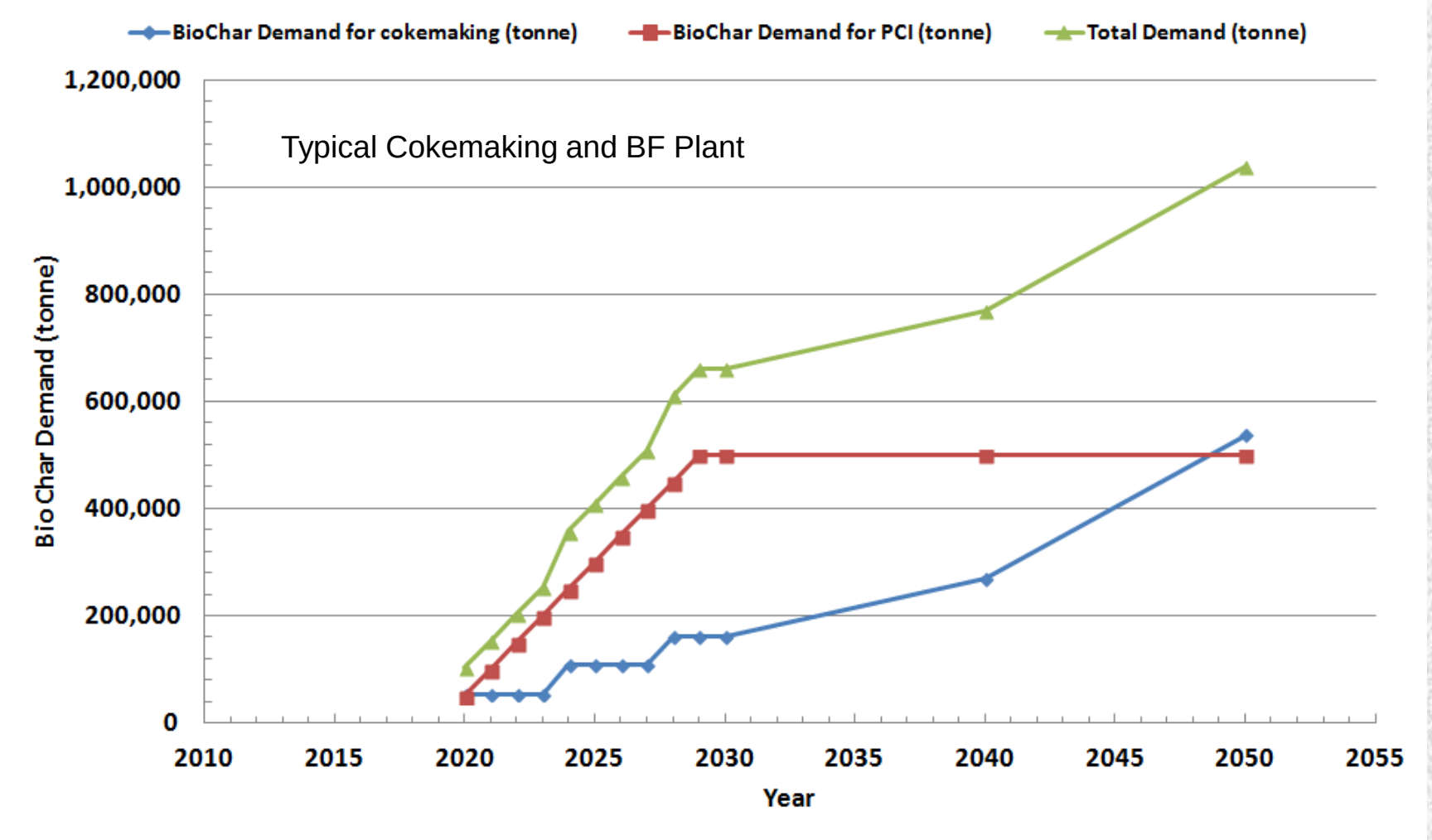
Bio-char demand to achieve short term goals:

- 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

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*

Future Bio Char Demand for the Canadian Steel Industry



Bio-Char Characteristics Demand by Steel Industry

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

		Coal	Bio-char			
		PCI	Fast Pyrolysis	Slow Pyrolysis	Torrefaction	Hydrothermal Carbonization
Proximate	Ash	7.89	9.8	2.18	1.18	0.05
	VM	36.2	4.92	15.71	50.47	51.74
	FC	55.91	85.27	82.12	48.35	48.21
Ultimate	C	77.5	86	87.2	67	71.6
	H	5.15	0.95	2.63	4.45	4.85
	N	1.71	1.27	0.57	0.19	0.18
	S	0.78	0	0.05	0	0.0054
	O	6.98	2.01	7.4	27.2	23.4
Ash Chemistry	SiO_2	52.29	54.95	2.38	7.41	2.38
	Al_2O_3	29.41	0.6	0.48	2.08	0.48
	Fe_2O_3	6.55	0.72	0.97	3.4	0.97
	CaO	3.25	15.99	61.67	37.17	61.67
	MgO	0.95	9.88	7.28	5.97	7.28
	P_2O_5	0.117	4.98	4.13	1.99	4.13
	Na_2O	0.26	0.2	1.76	0.7	1.76
	K_2O	1.64	7.45	8.12	15.59	8.12

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

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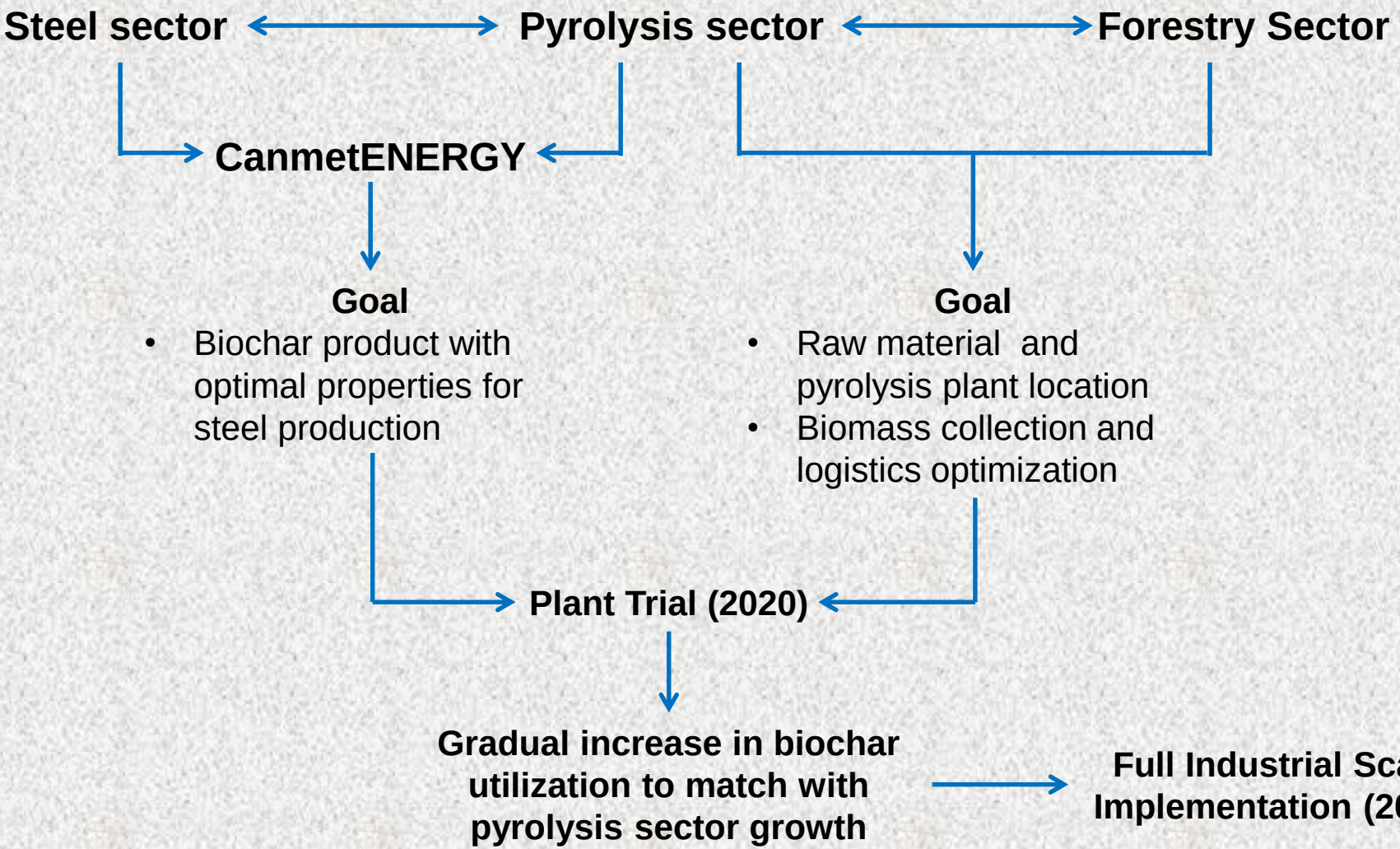
Timeline of Development



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

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Federal Government Support

Natural Resources Canada Energy Innovation Program (EIP)

	2016-17	2017-18	2018-19	2019-20	2020-21	Total
EIP	440	500	403	620	208	2471
CCRA	30	30	30	30	30	150
Total	470	530	433	650	538	2621

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

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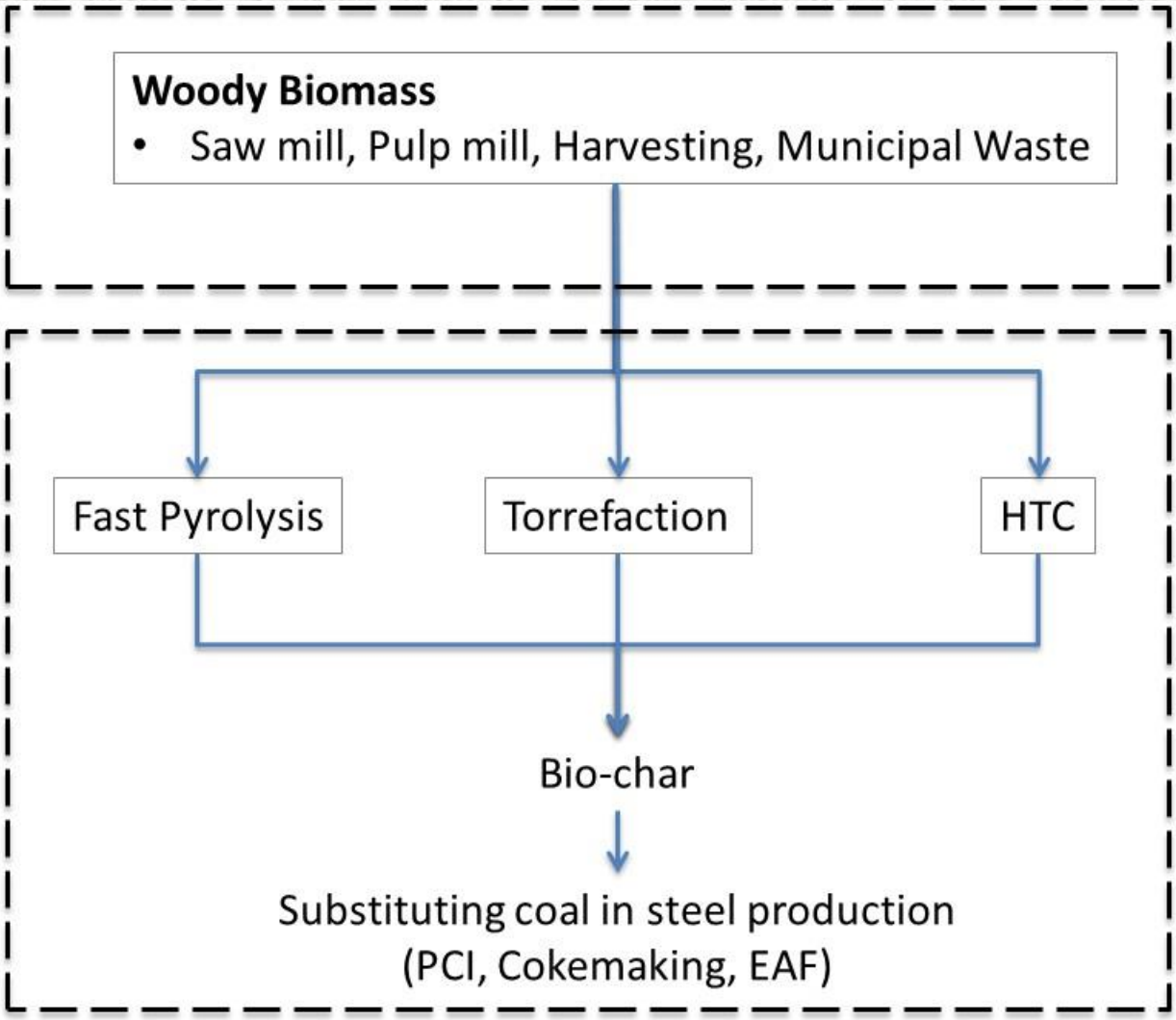
Funding Gap



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

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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

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