Integrating Biocrudes into Bitumen Upgrading and Petroleum Refining via Co-processing

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CanmetENERGY Laboratories

CanmetENERGY scientists are internationally-recognized experts in key energy R&D domains.

- Fossil fuels (oil sands and heavy oil processing; tight oil and gas);
- Energy efficiency and improved industrial processes;
- Clean electricity; and
- Bioenergy and renewables.

Areas of Focus:
- Industrial processes
- Buildings energy efficiency
- Energy solutions for Northern & remote communities
- Integration of renewable & distributed energy resources

Varennes

Areas of Focus:
- Clean fossil energy
- Buildings & communities energy efficiency
- Industrial processes
- Bioenergy
- Renewables

Ottawa

Areas of Focus:
- Oil sands & heavy oil processes (incl. tailings, water management, bitumen processing, flaring, venting and emissions)
- Oil spill recovery & response
- Tight oil & gas

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R&D to **reduce the environmental impacts** and **improve competitiveness** of oil sands/heavy oil development. Understanding of fundamental science and ability to scale up technologies from bench to pilot and field scales.

- Environmental impacts
- Hydrocarbon recovery
- Hydrocarbon conversion - develop hydrocarbon conversion and end-use technologies to 1) reduce energy consumption; 2) improve air impacts, and 3) improve product quality and access to new markets.

  Areas of Focus:
  - Bitumen partial upgrading
  - Upgrading and refining process efficiency
  - Future fuels
  - Advanced/standard analytical methods
  - GHG emission assessment, life cycle assessment (LCA)
  - Biocrudes and biofuels from renewable resources

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Biocrudes and Biofuels from Renewables

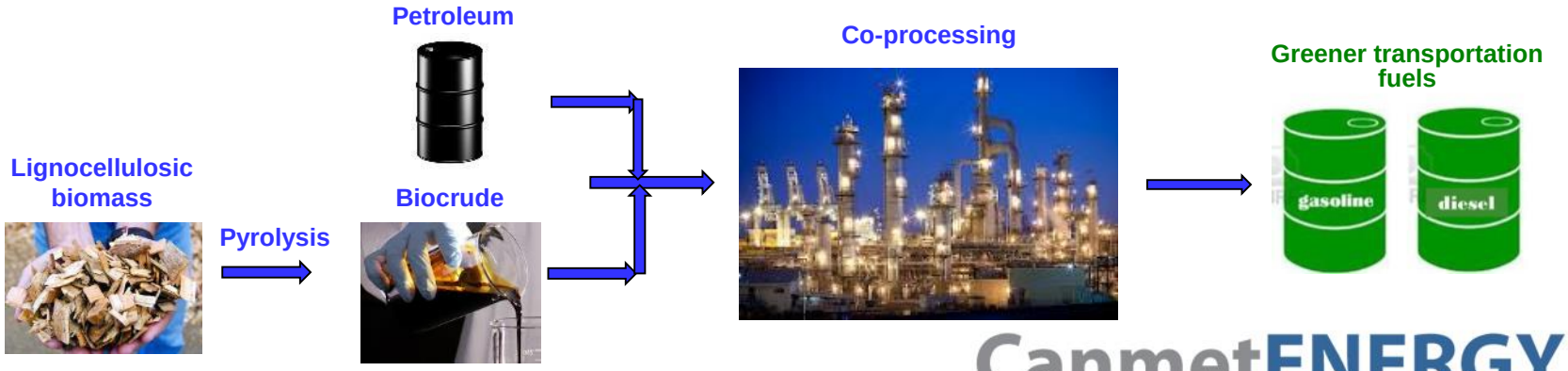
- Research Program at CanmetENERGY -Devon

- Increased production of Canadian bitumen and increased capacity of upgrading and refining.
- From life cycle point of view, the greenhouse gas (GHG) emissions related to bitumen/petroleum production, upgrading and refining to produce clean transportation fuels is higher than those related to biofuels from renewable biomass/biocrudes
- Government regulations require renewable components in transpiration fuels, 5% in gasoline and 2% in diesel. Currently most Canadian refineries imports these renewable fuels for post-blending
- Co-processing paraffinic biomass feedstocks and aromatic bitumen feedstocks may have synergy to improve gasoline and diesel quality. Using existing upgrading and refining infrastructure reduce capital and operating costs companied to standalone bio-refineries.
- Therefore co-processing biomass and petroleum/bitumen derived feedstocks has the potential to reduce carbon footprints and GHG emission associated with transportation fuel production and improve product quality.

Research Objectives

The ultimate objective is to reduce carbon footprints related to bitumen upgrading and petroleum refining by co-processing bitumen and biomass derived feedstocks.

- Develop and identify the optimal existing catalysts and technologies for hydroprocessing (hydrotreating and hydrocracking) and FCC that can be used to co-process bitumen/petroleum and biomass derived feedstocks.
- To provide general guidance and direction on process design and operation of co-processing.
- Assess and address impacts on total energy consumption and GHG emissions.



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Previous Research at CanmetENERGY Devon

Objectives

- Determine feasibility of co-processing with existing refinery technologies
- Understand impact of co-processing on refinery operation
- Develop advanced characterization methods for bio-feedstocks and biofuels

Processes and technologies studied:

- Hydroprocessing (hydrotreating, hydrocracking)
- Fluid catalytic cracking (FCC)
- Typical commercial operating conditions

Feedstocks studied:

- Heavy vacuum gasoil (HVGO), heavy gasoil (HGO), light cycle oil (LCO)
- Canola oil (raw & de-gummed)
- Biocrudes from pyrolysis or hydrothermal liquefaction (HTL) - preliminary

Performance and product quality:

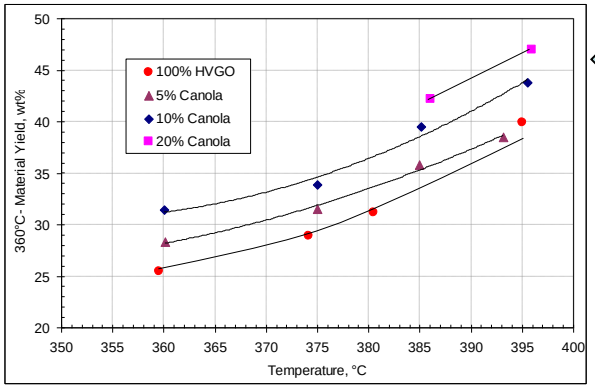
- Conversions and product yields
- Sulfur and nitrogen contents
- Hydrocarbon type compositions
- Product properties (octane, cetane, density, viscosity etc.)

Feedstock Properties

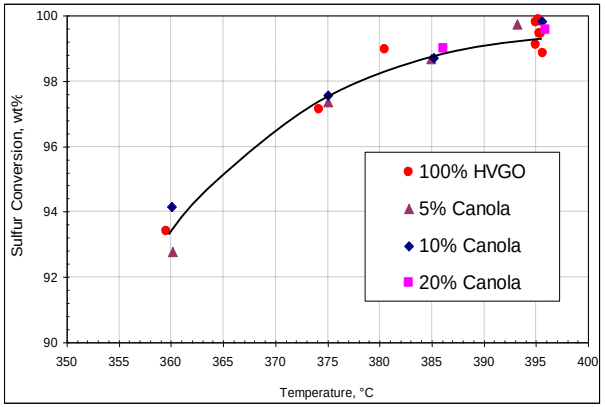
Tests	Units	100%HVGO	100% Canola oil	5% Canola + 90 HVGO Blend	10% Canola + 90 HVGO Blend	20% Canola + 90 HVGO Blend
Density	g/ml	0.9678	0.9237	0.9645	0.9628	0.9586
Carbon	wt%	84.57	77.41	84.90	84.72	83.30
Hydrogen	wt%	10.74	11.46	11.15	11.09	11.22
Sulfur	wt%	3.59	0.0208	3.36	3.09	2.81
Nitrogen	wppm	1800	192.7	1800	1718	1425
Oxygen	wt%	0.37	8.31	0.74	1.42	2.48
Hydrocarbon types	wt%					
Saturates		31.16	0.15	29.53	29.05	19.96
Aromatics		59.68	~0	55.39	52.99	53.71
Polars		8.38	99.85	13.07	17.24	25.94
Boiling range	° C	243.8~622.8	360.0~715.6	250.6~653.2	240.8~643.8	240.2~657

Hydroprocessing of HVGO/Canola Oil Blends

Total Product yield

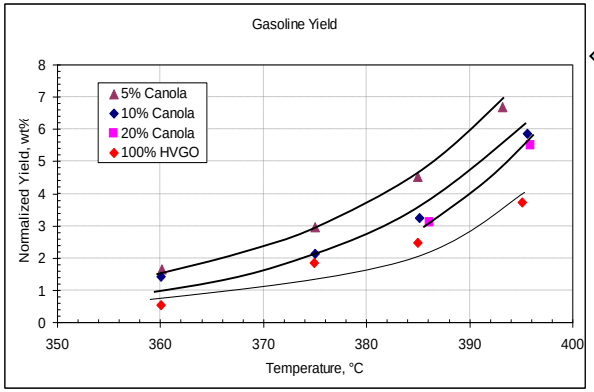


Sulfur Conversion

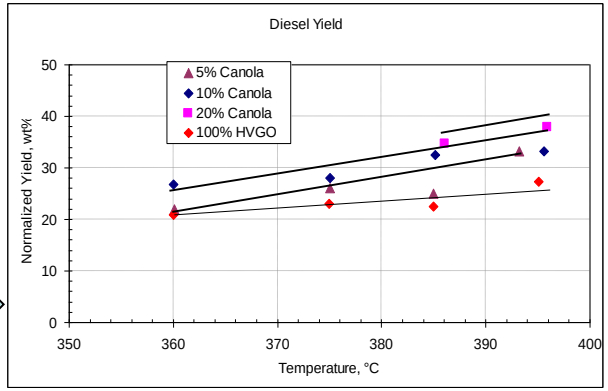


- Total product yield in creases with temperature and canola content
- Sulfur conversions is not significantly affected by the addition of canola oil

Gasoline Yield



Diesel Yield



- Gasoline yield is the greatest with 5% canola added to the feed and decreases with the addition of more canola
- Diesel yield increases with the addition of canola to the feedstock

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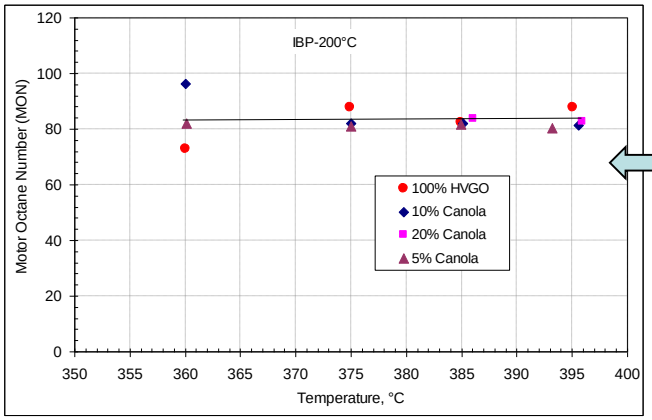
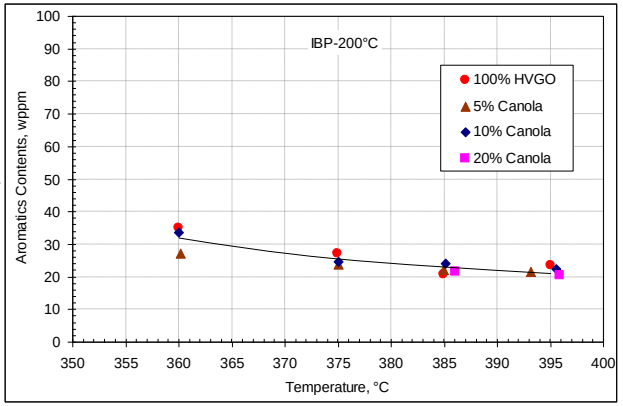
Hydroprocessing of HVGO/Canola Oil Blends

Gasoline Octane Number

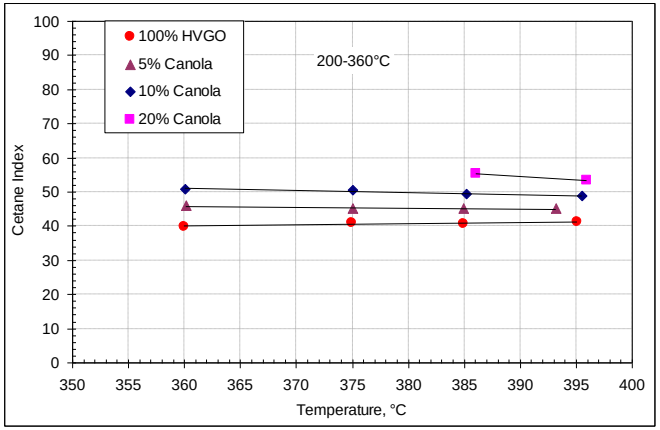


Gasoline Aromatic Content



- Aromatics content and octane number in gasoline do not change significantly with the addition of canola oil

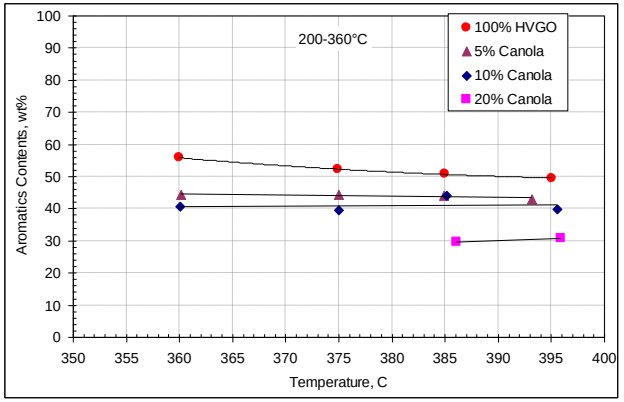
Diesel Cetane Index



- Diesel cetane index increases with the addition of canola oil

- Aromatics content in diesel decreases with the addition of canola oil

Diesel Aromatic Content



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Selected Publications

Hydroprocessing:

1)Chen, J., Farooqi, H., Fairbridge, C., “Experimental Study on Co-hydroprocessing Canola Oil and Heavy Vacuum Gas Oil Blends”, Energy & Fuels, 27,3306-3315, 2013
2)Wang, H., Farooqi, H., Chen, J., “Co-hydrotreating light cycle oil-canola oil blends”, Front. Chem. Sci. Eng., 9(3), 336-348, 2015

FCC:

1)S. Ng, Y. Shi, L. Ding, S. Chen. Proc. 2010 AIChE Annual Meeting 2010, Paper 192037
2)S. Ng, C. Lay, S. Bhatt, B. Freel, R. Graham. Proc. 2012 AIChE Annual Meeting 2012, Paper 779b

On-going Research:

Integrating Biocrudes into Bitumen Upgrading and Petroleum Refining via Co-processing

NRCan-US DOE Research Collaboration on Advancing Clean Technologies for Producing Green Fuels from Biomass

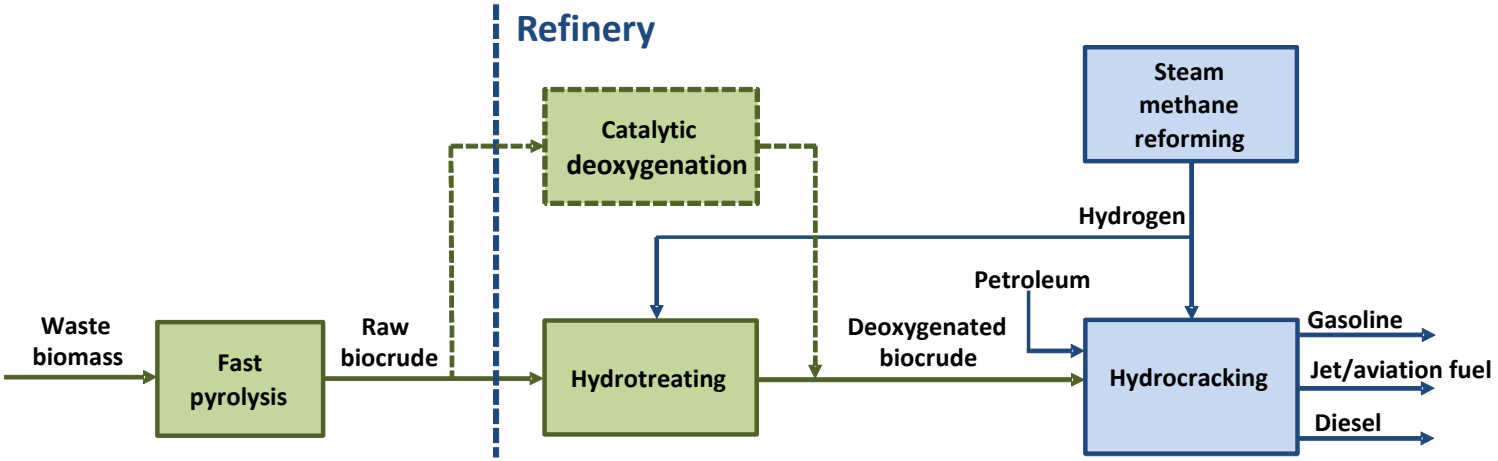
- Start-up funding
  - 150K/year over 2 years (FY 2016-17 and 2017-18) from OERD's International Clean Technology Initiative
  - 150K/year (FY 2016-17) from CFS's Forest Innovation Program
- Main collaborators
  - Pacific Northwest National Laboratory (PNNL) of US DOE
  - Alberta Innovates
- Partners/Sponsors
  - Academia - Aalborg University
  - Industry - Steeper Energy, Canadian Natural Resources Limited (CNRL), The Boeing Company, Genifuel ……
  - Government - CanmetENERGY-Ottawa, NRC-Ottawa

Research Objectives

Develop and demonstrate biomass processing technologies that can be implemented in the oil sands upgrading and petroleum refining industry for producing greener transportation fuels

- Demonstrate that novel pre-treatment concept (catalytci deoxygenation) for removing contaminants in biocrudes prior to co-processing
- Conduct pilot plant studies to understand and optimize biocrude co-processing with petroleum-derived feedstocks

Proposed refinery -integrated pathway



Tasks to Meet the Goals

Task 1: Biocrude sample acquisition and preparation

- Obtain biocrude samples
- Prepare biocrude feed samples for pilot plant tests
- Analytical characterization of biocrude samples

Task 2: Biocrude deoxygenation tests

- Deoxygenation catalyst preparation/development
- Pilot plant setup and commissioning
- Exploratory pilot plant tests

Task 3: Biocrude co-processing tests

- Pilot plant setup and commissioning
- Parametric pilot plant study on co-processing biocrude with bitumen
- Analytical characterization of co-processing products

Supporting tasks required to achieve objectives (not part of scope of work):

- Advance characterization methods to better understand biocrude and biofuel chemistry
- Develop modelling and simulation approaches for process development

Benefits

- Advancing the technology readiness level (TRL) from 3 to 5 (demonstration ready) for biocrude processing technologies that can be integrated into upgrader or refinery infrastructure
- Proven feasibility of these technologies will help influencing oil sands and refining industry to produce upgraded bitumen and transportation fuels with renewable resources
- Reduced GHG emissions from the oil and gas sector
  - If 10% of the petroleum streams in refineries and upgraders is replaced with biocrudes (with 50% lower GHG intensity), then the proposed technologies could lead to 1% of total GHG reduction in Canadian oil and gas sector
- Cost-effective solution to meet Canada's regulation for renewables content in gasoline, diesel, and potentially jet fuel
- Establishing close collaborations between NRCan and other government agencies, industries, and academia from priority countries (US and Denmark)

Performance Indicators

- Successful proof of concept/pilot plant tests with good mass balance
  - High catalytic activity for biocrude deoxygenation to produce cleaner biocrudes for co-processing
  - Optimized conditions for co-processing biocrude with bitumen and petroleum in upgraders and refiners
- Scientific productivity – reports, presentations and publications
- Project expansion to large RD&D program with increased budget, scope, and duration
- Engaging more partners and collaborators from governments, industry, and academia
- Closer interactions with oil sands upgrading and petroleum refining industry

Acknowledgement

- Canadian interdepartmental Program of Energy Research and Development (PERD 1.1.3)
- Office of Energy Research and Development (OERD) of NRCan - International Clean Technology Initiative
- Canadian Forest Service - Forest Innovation Program
- Alberta Innovates (AI)
- Pacific Northwest National Laboratory (PNNL) of US DOE
- All collaborators, partners and sponsors
- CanmetENERGY pilot plant
- CanmetENERGY analytical lab

Thank you!