

Spring 6-12-2013

# Biomass supply and diesel requirements for co-feeding a bitumen upgrader in Alberta

Murlidhar Gupta  
*Canmet Energy*

Rene Pigeon  
*Canmet Energy*

Andy McFarlan  
*Canmet Energy*

Follow this and additional works at: [http://dc.engconfintl.org/bioenergy\\_iv](http://dc.engconfintl.org/bioenergy_iv)

 Part of the [Chemical Engineering Commons](#)

---

## Recommended Citation

Murlidhar Gupta, Rene Pigeon, and Andy McFarlan, "Biomass supply and diesel requirements for co-feeding a bitumen upgrader in Alberta" in "BioEnergy IV: Innovations in Biomass Conversion for Heat, Power, Fuels and Chemicals", Manuel Garcia-Perez, Washington State University, USA Dietrich Meier, Thünen Institute of Wood Research, Germany Raffaella Ocone, Heriot-Watt University, United Kingdom Paul de Wild, Biomass & Energy Efficiency, ECN, The Netherlands Eds, ECI Symposium Series, (2013). [http://dc.engconfintl.org/bioenergy\\_iv/35](http://dc.engconfintl.org/bioenergy_iv/35)

This Conference Proceeding is brought to you for free and open access by the Proceedings at ECI Digital Archives. It has been accepted for inclusion in BioEnergy IV: Innovations in Biomass Conversion for Heat, Power, Fuels and Chemicals by an authorized administrator of ECI Digital Archives. For more information, please contact [franco@bepress.com](mailto:franco@bepress.com).



## **Biomass Supply and Diesel Requirements for Co-feeding a Bitumen Upgrader in Alberta**

**Murlidhar Gupta, René Pigeon and Andy McFarlan**

**12 June 2013**

**Session- Biorefinery and Sustainability**

**BioEnergy IV: Innovations in Biomass Conversion for Heat & Power, Fuels and Chemicals  
Otranto, Italy**

# Oil sands

- Canada is home to largest known natural bitumen reserves ~ 400 billion cubic meters (NEB 2005).
- These resources are concentrated in three regions – Athabasca, Cold Lake and Peace River in province of Alberta.
- Oil sands are strategic resource to North American economy.



Source: Wikipedia

## CanmetENERGY

Leadership in ecoInnovation



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Canada's renewable agriculture and forestry resources

- Canada is also blessed with large quantity of renewable biomass resources. Among all G20 countries, Canada ranks 2<sup>nd</sup> in terms of per capita forestry area and one among the highest in terms of per capita agriculture production. (Layzell, 2010)

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Motivation

- Explore the possibility of sustainable co-utilization of renewable biomass resources in oil-sands operations to reduce the GHG emission intensity of HC products and to facilitate environmentally and socially responsible development of natural resources.

**CanmetENERGY**

*Leadership in ecoInnovation*

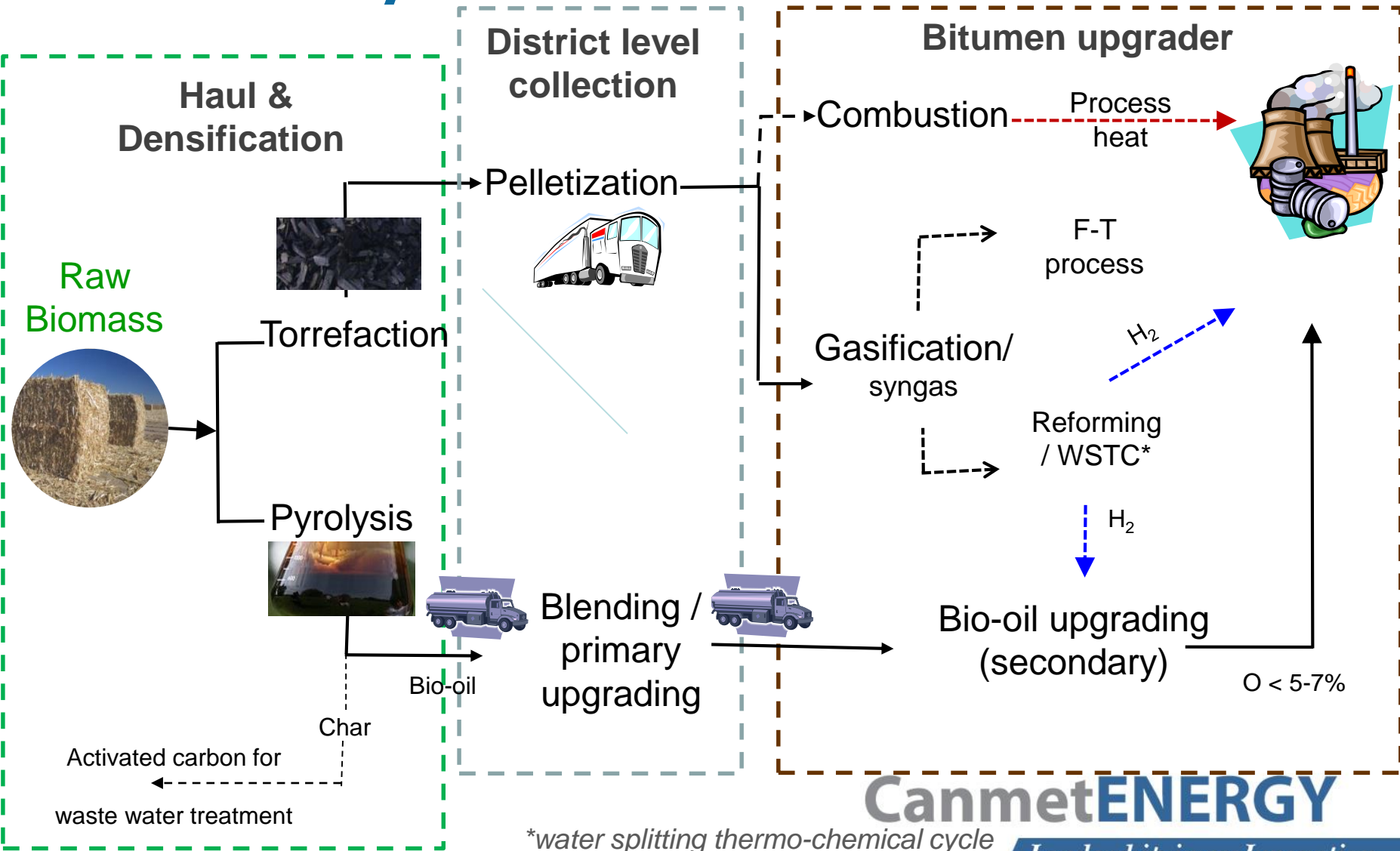


Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Proposed strategy for biomass co-processing in oil sands industry



# Identification of local biomass resources

- Can Alberta's resources supply enough biomass in a sustainable manner to help oil-sands upgrading operations to reduce their environmental impact?
- How much energy will it require to haul biomass to upgraders?

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

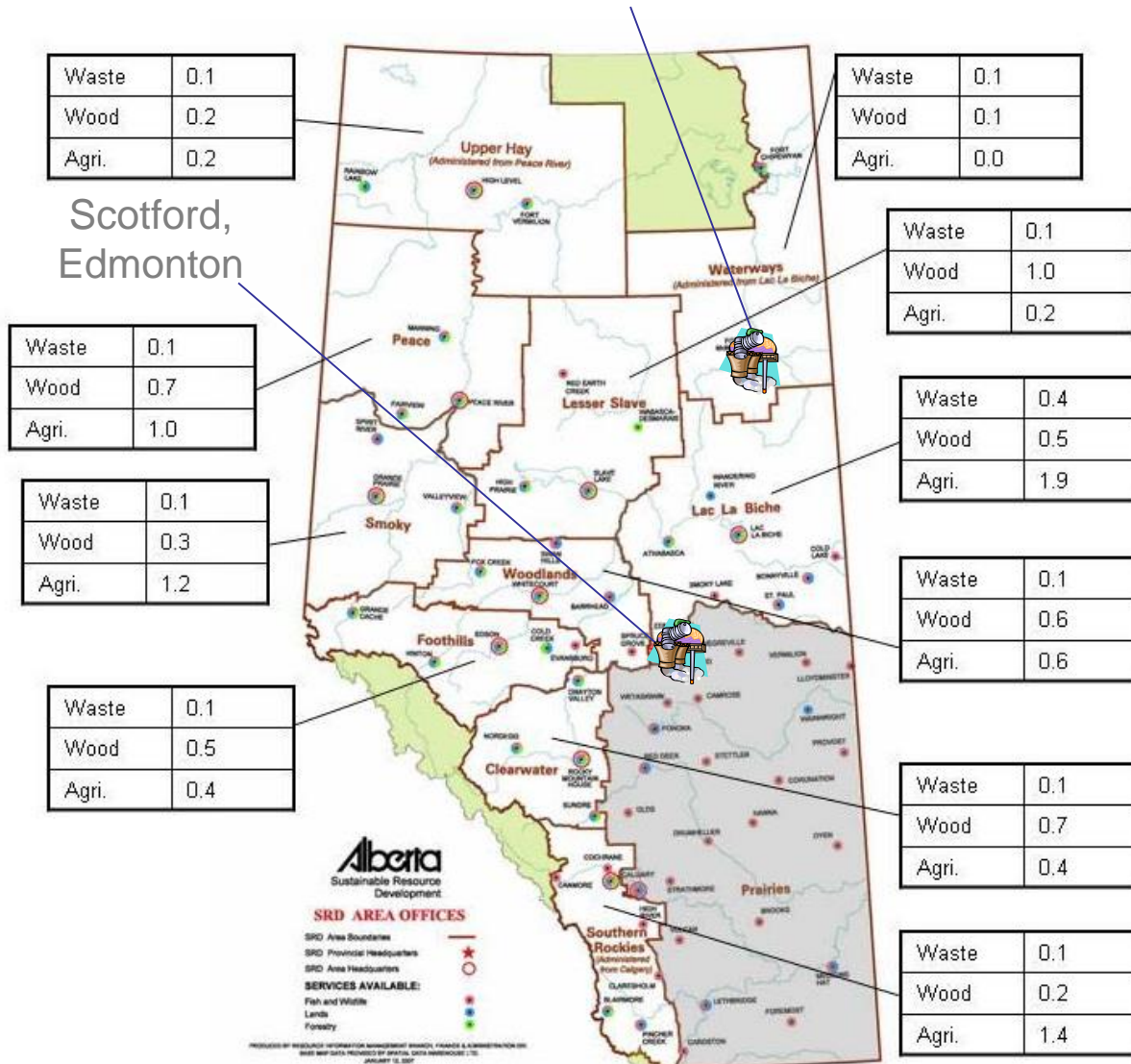
Canada



# A district wide biomass inventory in Alberta

Fort McMurray

Levelton and Envirochem, 2008



*Prairie &  
10 provincial Districts*

Total: (million bdt/year)  
Agriculture: ~ 20  
Wood: ~ 7  
Municipal Waste: ~ 1.3

**netENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada


Canada



# Biomass hauling pathways

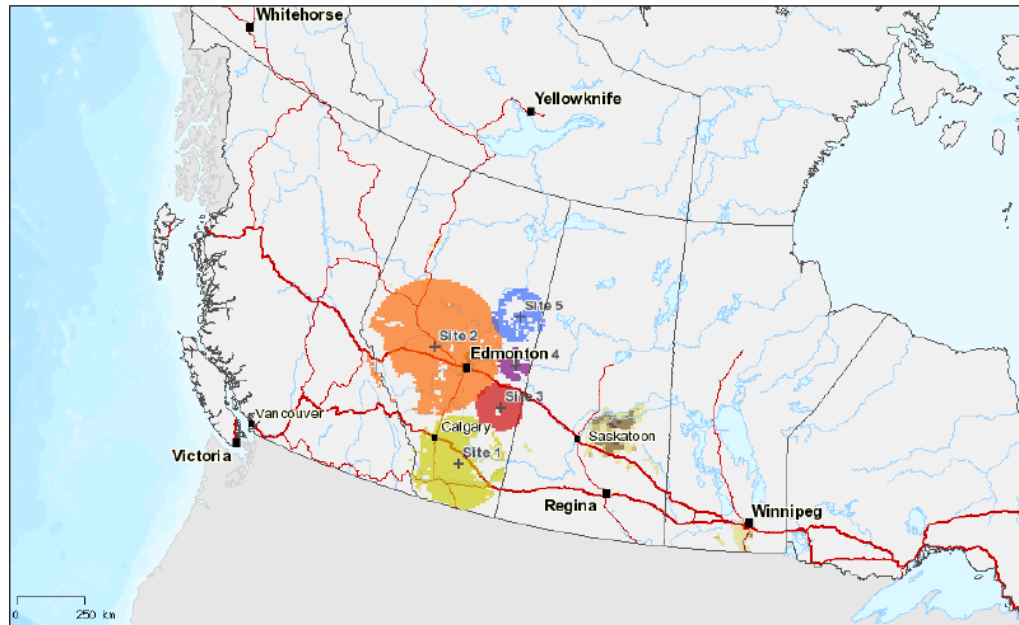
## 1-Stage pathway - circular geometry

Haul biomass from each circular field to centralized processing

 Agriculture and Agri-Food Canada Agriculture of AgriInnovative Canada

### Biomass Inventory for Alberta

Sites 1-5, 50% Participation Rate, Zero Tillage



© Her Majesty the Queen in Right of Canada 2011, Agriculture and Agri-Food Canada.



\*Biomass Inventory mapping and analysis tool

BIMAT\* and Kumar et al., 2003 used circular geometry approach (based on Overend, 1982)

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Prevalent biomass hauling pathways *continued...*

## 2-Stage pathway – square geometry

1. haul solid biomass to centre of many square fields for pyrolysis
2. haul liquid bio-oil to a central facility for final processing :

Pathway often studied but only once as a square grid by Wright *et al.* (2008)

**CanmetENERGY**

*Leadership in ecoInnovation*



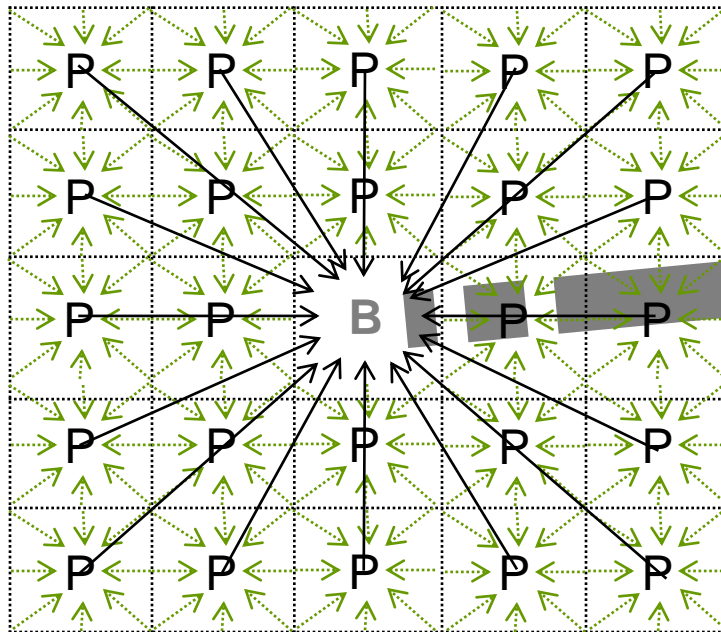
Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Proposed 3-stage biomass hauling

A sample district composed of square harvesting fields

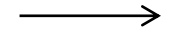


Bitumen upgrader

stage 1: Raw biomass (solid)



stage 2: Bio-oil (liquid)



stage 3 : Blended / upgraded bio-oil

to bitumen upgrader (liquid)



$$D_{Total} = D_{Biomass \rightarrow Pyrolyser} + D_{Bio-oil \rightarrow DistrictCentre} + D_{Bio-oil, district \rightarrow Upgrader}$$

P: Biomass pre-treatment through pyrolysis

B: Bio-oil blending or primary upgrading at district level

**CanmetENERGY**

Leadership in ecoInnovation



Natural Resources  
Canada

Ressources naturelles  
Canada

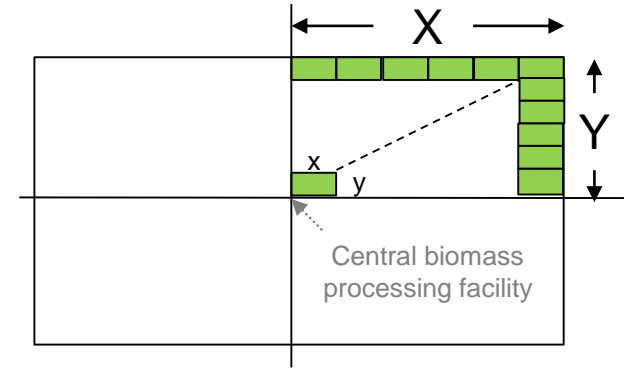
Canada

# Model for stage 1 hauling

The total haul derived using rectangular geometry (Jenkins, 1997):

$$D(\text{km}\cdot\text{y}^{-1}) = 4\pi n \sum_{i=0}^{m-1} \sum_{j=0}^{m-1} (ix + jy)$$

$$= \frac{1}{2} \tau \frac{Q}{w} (X + Y) \left( 1 - \frac{1}{m} \right)$$



For a square harvest field:  $X=Y$  and  $x = y$ ; Thus for all the grids, in a district, the total annual one way hauling of solid biomass in a district can be given by

$$D_{\text{biomass,district},k} (\text{km}\cdot\text{y}^{-1}) = 44.497 \cdot \tau_{\text{biomass,grid}} \frac{\sqrt{A_{\text{district},k} \cdot Q_{\text{biomass,district},k} \cdot C_{\text{pyrolyser},k}}}{w_{\text{biomass}}} \left( 1 - \frac{1}{m_{\text{biomass,grid}}} \right)$$

Where number of sub regions, in each grid for hauling solid biomass is given by  $m = X/x = Y/y$

**CanmetENERGY**

Leadership in ecoInnovation



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Model for stage 2 hauling

$$D_{bio-oil,district,k} (km.y^{-1}) = \frac{1}{2} \alpha \cdot \tau_{bio-oil,district} \frac{Q_{biomass,district,k} \cdot \sqrt{A_{district,k}}}{w_{bio-oil}} \left( 1 - 178 \sqrt{\frac{C_{pyrolyser,k}}{Q_{biomass,district,k}}} \right)$$

Total diesel consumed for hauling biomass and bio-oil in stage 1 and 2.

$$F_{biomass+bio-oil,district,k} (l.y^{-1}) = \beta_{biomass} \cdot (1 + \gamma_{biomass}) \cdot D_{biomass,district,k} + \beta_{bio-oil} \cdot (1 + \gamma_{bio-oil}) \cdot D_{bio-oil,district,k}$$

$\alpha$  :Biomass  $\rightarrow$  Bio-oil Conversion factor (w/w)

$\beta$  :Average diesel consumption for hauling biomass ( $l.t^{-1}.km^{-1}$ )

$\gamma$  :Fraction of fuel consumed for return journey of empty truck/tanker

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

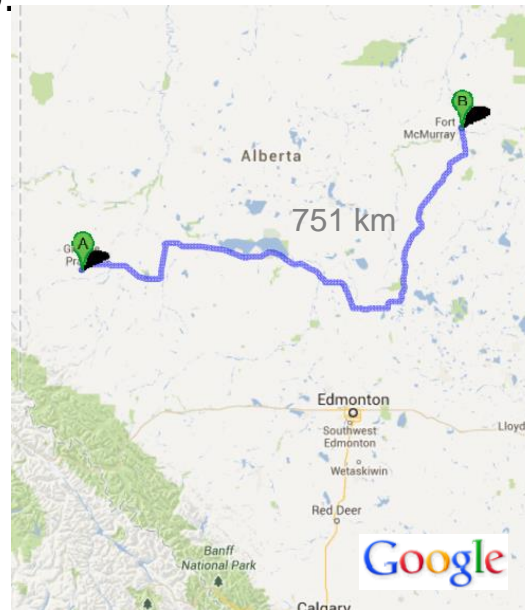
Canada

# Stage-3 hauling

Diesel consumed in stage-3 is given by

$$F_{bio-oil,district,k \rightarrow upgrader}(l.y^{-1}) = \beta_{bio-oil} \cdot (1 + \gamma_{bio-oil}) \cdot D_{bio-oil,district,k \rightarrow upgrader}$$

Here  $D_{bio-oil,district,k \rightarrow upgrader}$  is the actual road distance of an upgrader from an assigned centre in  $k^{th}$  district . This distance was estimated using fastest route through Google map.



**CanmetENERGY**

Leadership in ecoInnovation



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



# Preliminary results

- Two case scenarios:
  - Haul bio-oil to Fort McMurray
  - Haul the bio-oil to Scotford
- Total bio-oil produced in the province varies from 8,000 (for slow pyrolysis) to 14,000 million litre (for fast pyrolysis).
- Required no. of pyrolysers @  $2 \text{ t.h}^{-1}$  vary from 6 in Waterways to about 750 in Prairie.

CanmetENERGY

*Leadership in ecoInnovation*

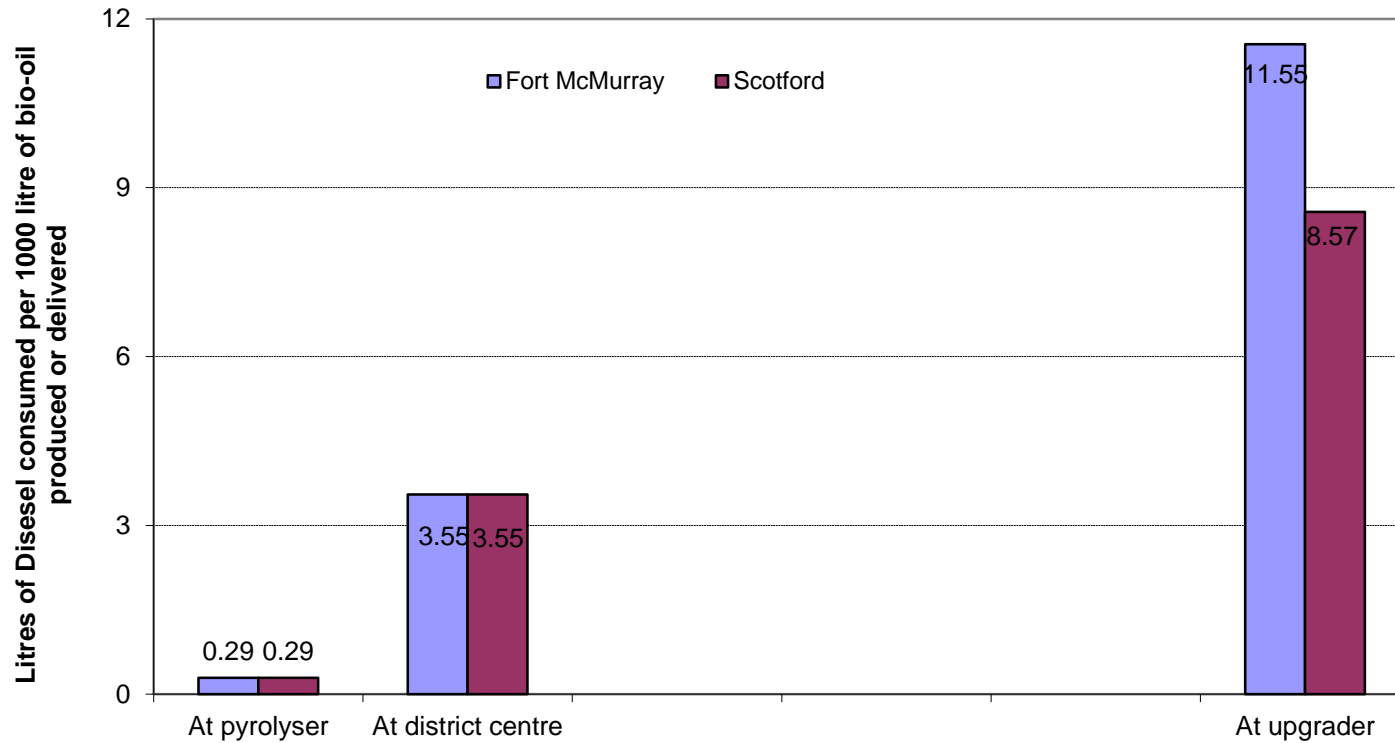


Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Ratio of diesel consumed to hauled bio-oil

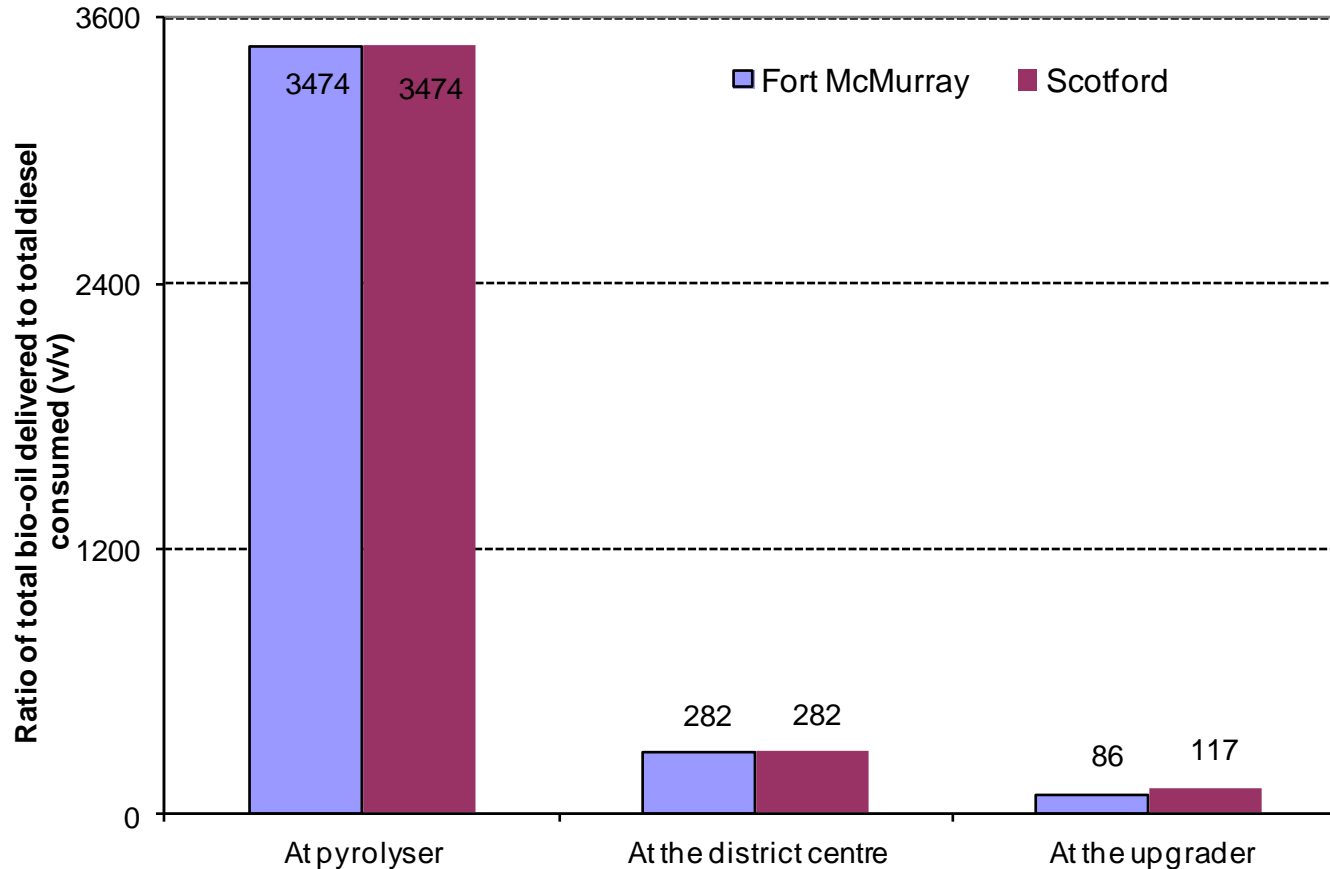


CanmetENERGY

Leadership in ecoInnovation



# Ratio of hauled bio-oil to diesel consumed

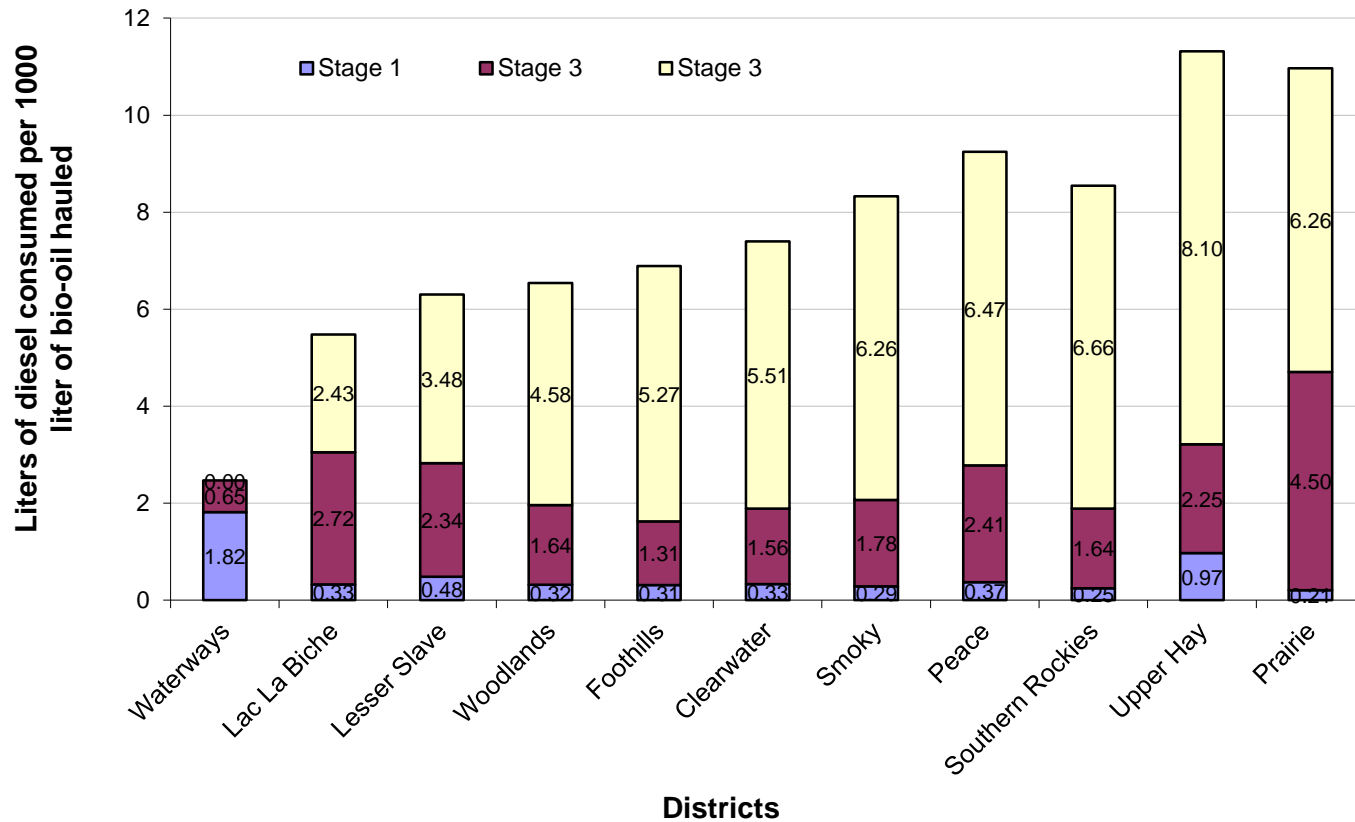


**CanmetENERGY**

*Leadership in ecoInnovation*



# Ratio of hauled diesel consumed to bio-oil hauled for each district



CanmetENERGY

Leadership in ecoInnovation



Natural Resources  
Canada

Ressources naturelles  
Canada



# Conclusions

- A 3-stage biomass densification and hauling methodology has been proposed by
  - Splitting solid and liquid hauls
  - Applying square grid method for stage 1 and 2 and using geometric tool e.g. Google Map to calculate actual haulage for 3<sup>rd</sup> stage.
- Model parameters need to be refined to reflect the local conditions at each district as well at harvest region, e.g. size of pyrolyser for each district  $C_{pyrolyser, k}$ , the efficiency of diesel consumption of trucks and tankers  $\beta$ , tortuosity factors ( $\tau$ ) for forestry and agriculture.

CanmetENERGY

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Conclusions

- The model will evaluate the overall parasitic GHG emissions caused by hauling of biomass to upgraders.
- The methodology will be used to optimize the output for multiple scenarios:
  - What will be impact of moisture content\*, especially in the 1<sup>st</sup> stage of hauling?
  - What if we choose more than one upgrader of preference?
  - What degree of primary upgrading of bio-oil at the pyrolysis unit or at the district level is needed?

\*In the present study only oven dry biomass has been used.

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



# Acknowledgement

- Funding support from *Clean Energy Fund and PERD funding program, Natural Resources Canada* is greatly appreciated.

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



# Questions and Comments



**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Supplementary slides

**CanmetENERGY**

*Leadership in ecoInnovation*



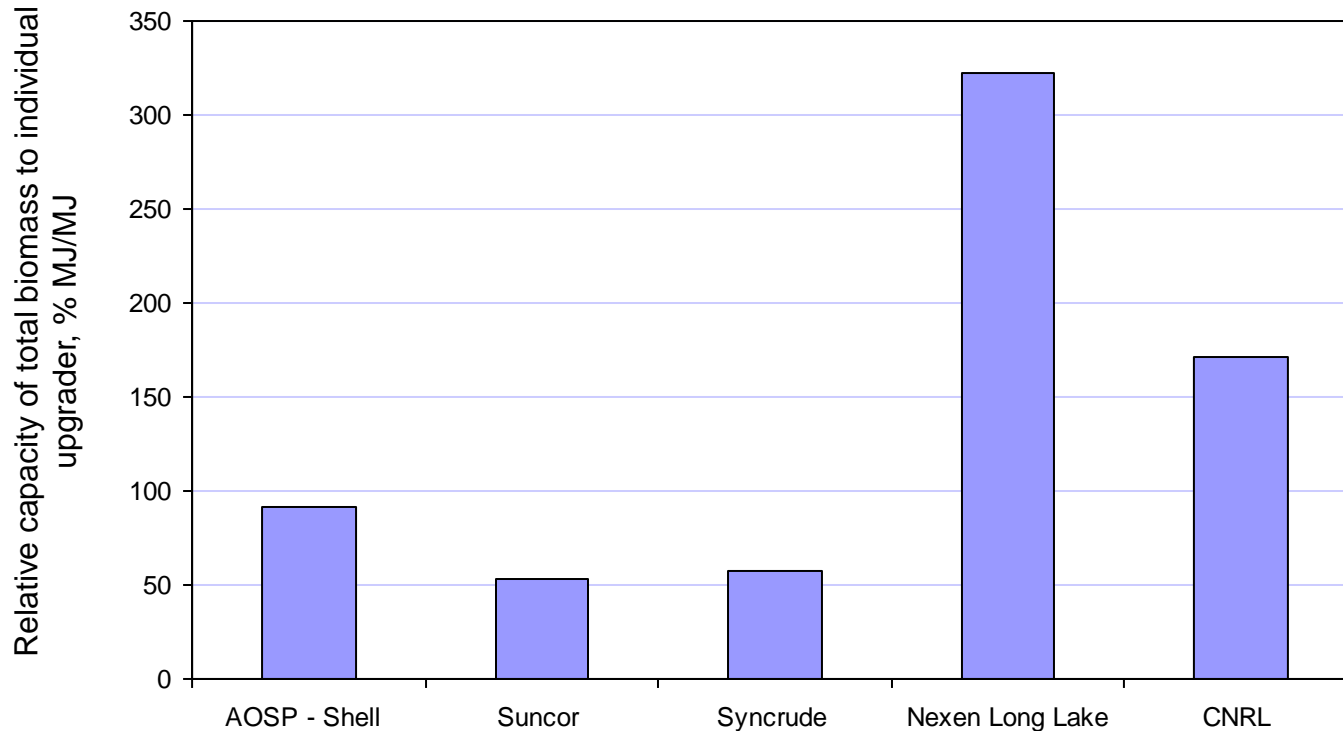
Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# Current operating up-grader in Alberta

- In 2010, Oil-sands patch has 5 operating up-graders



*Total renewable biomass available in Alberta is equivalent to 18 % of total bitumen processing capacity (in terms of energy equivalence)*

Numbers do not include process efficiency/energy loss

Source: [www.energy.alberta.ca](http://www.energy.alberta.ca)

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

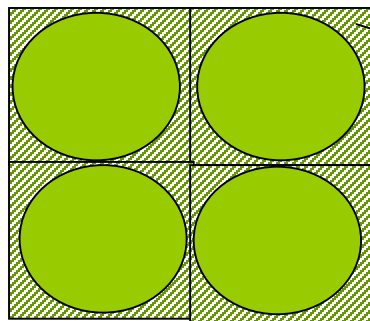
Ressources naturelles  
Canada

Canada

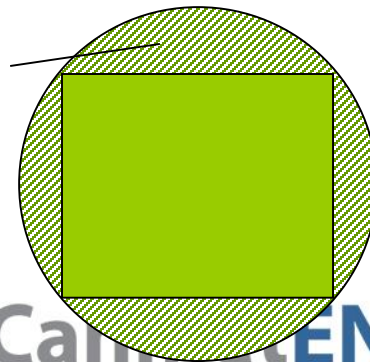
# Do Biomass Estimation Methods Reflect Actual Industry Production Methods ?

## Circular versus Square Fields ?

- Many bioenergy studies minimize haul by harvesting biomass that grows over a circular or a square field and by processing it at the center of the circle or square.
- Production of biomass on many circular fields simultaneously suffers one drawback :
  - Biomass that lies between the circles will likely remain unused within the life of the investment.



Under- versus over-  
estimation of  
the resource



Canada ENERGY

Leadership in ecoInnovation



# Circular versus Square Fields ?

- Thus this study assumes that biomass is harvested over many square areas in order to ensure complete utilization of resources available over an entire province while avoiding under- or over-estimation.

CanmetENERGY

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



# Stage-3 hauling

District	Central Town	Postal Code	Distance to upgrader (km)	
			Scotford	Fort McMurray
Waterways	Fort McMurray	T9H 1L2	399	0
Lac La Biche	Lac La Biche	T0A 2C0	184	291
Lesser Slave	Webasca Desmarais	T0G 2K0	335	417
Woodlands	Swan Hills	T0G 2C0	256	550
Foothills	Edson	T7E 1N7	238	632
Smoky	Grande Prairies	T8V 0R7	473	751
Peace	Manning	T0H 2M0	600	776
Southern Rockies	High River	T1V 1N5	406	799
Upper Hay	High Level	T0H 1Z0	796	972
Prairies*	Grand Prairies	T8V 0R7	473	751

*\*Prairies has been assumed to be equivalent to 11<sup>th</sup> district and has kept at the same distance as Grande Prairies*

**CanmetENERGY**

*Leadership in ecoInnovation*



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada