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

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

CanmetENERGY
Leadership in ecoInnovation

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

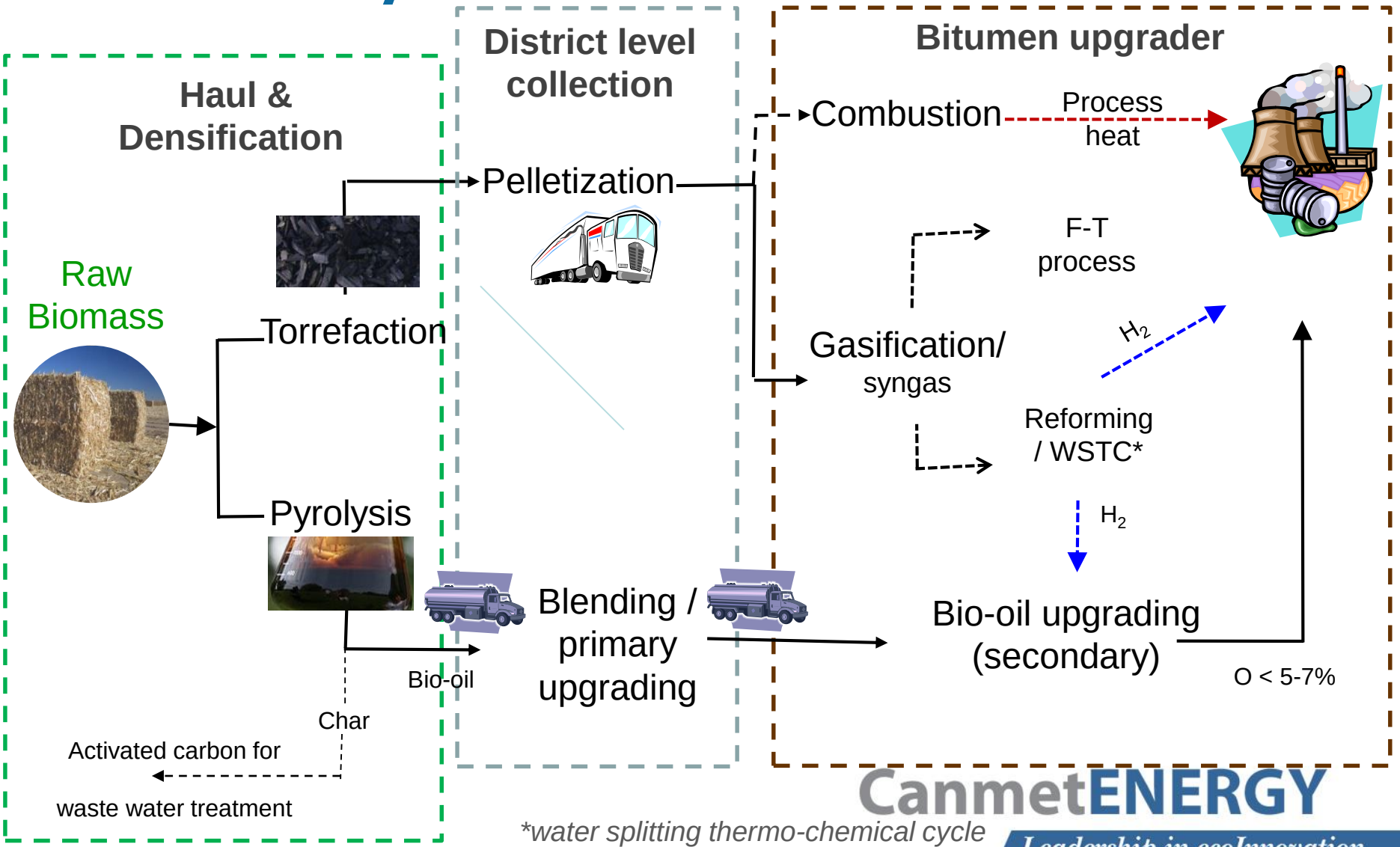
Canada's renewable agriculture and forestry resources

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

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.

Proposed strategy for biomass co-processing in oil sands industry



**water splitting thermo-chemical cycle*

CanmetENERGY

Leadership in ecoInnovation

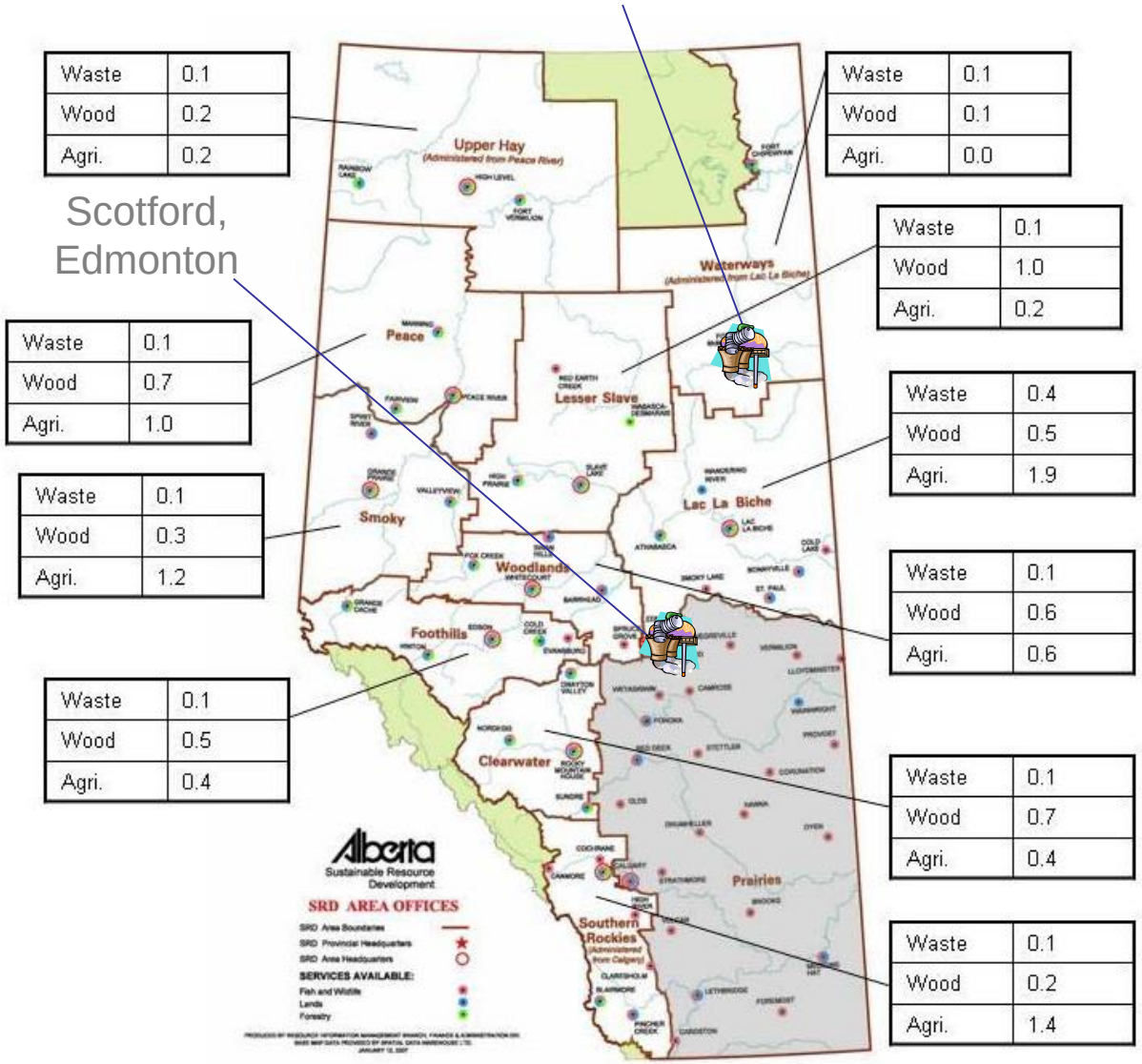
Identification of local biomass resources

- 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?

A district wide biomass inventory in Alberta

Fort McMurray

Levelton and Envirochem , 2008



Waste	0.1
Wood	0.2
Agri.	0.2

Scotford, Edmonton

Waste	0.1
Wood	0.7
Agri.	1.0

Waste	0.1
Wood	0.3
Agri.	1.2

Waste	0.1
Wood	0.5
Agri.	0.4

Waste	0.1
Wood	0.1
Agri.	0.0

Waste	0.1
Wood	1.0
Agri.	0.2

Waste	0.4
Wood	0.5
Agri.	1.9

Waste	0.1
Wood	0.6
Agri.	0.6

Waste	0.1
Wood	0.7
Agri.	0.4

Waste	0.1
Wood	0.2
Agri.	1.4

Prairie &

10 provincial Districts

Total: (million bdt/year)

Agriculture: ~ 20

Wood: ~ 7

Municipal Waste: ~ 1.3

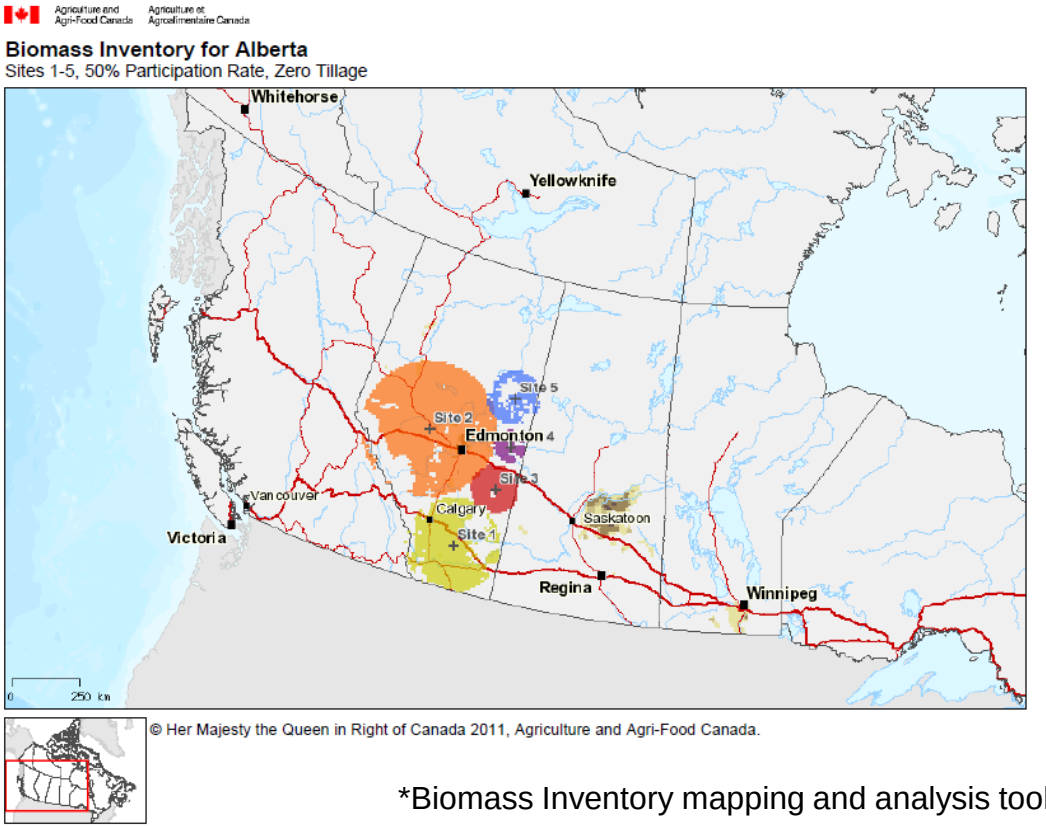
netENERGY

Leadership in ecoInnovation

Biomass hauling pathways

1-Stage pathway - circular geometry

Haul biomass from each circular field to centralized processing



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

*Biomass Inventory mapping and analysis tool

CanmetENERGY
Leadership in ecoInnovation

Prevalent biomass hauling pathways *continued…*

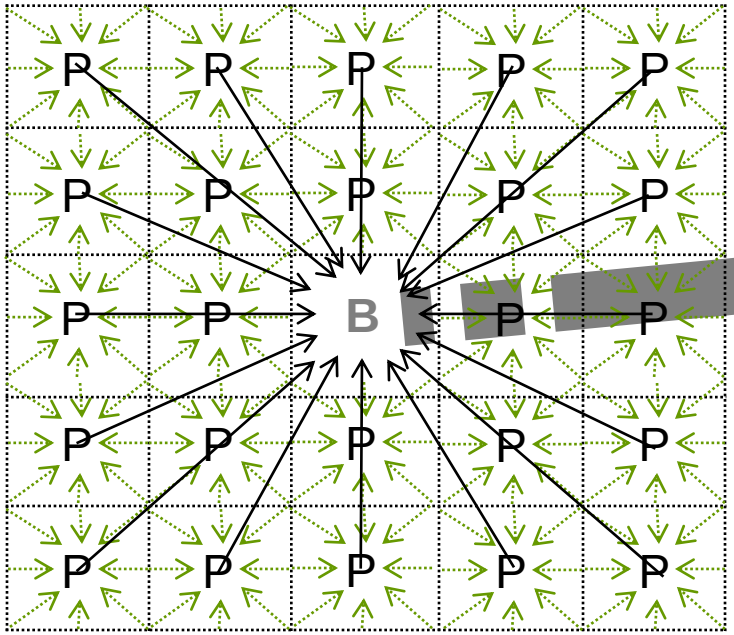
2-Stage pathway – square geometry

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)

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)

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

P: Biomass pre-treatment through pyrolysis

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

CanmetENERGY

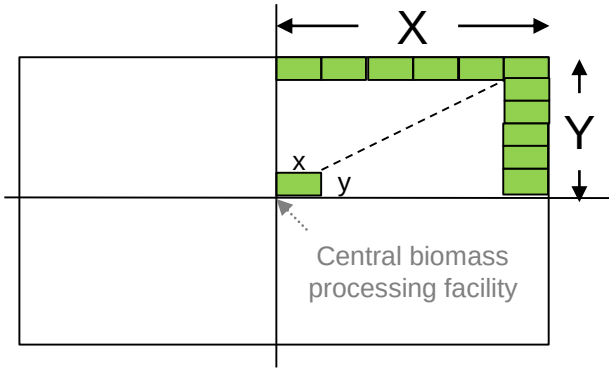
Leadership in ecoInnovation

Model for stage 1 hauling

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

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

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



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*

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

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

Model for stage 2 hauling

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

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

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

α :Biomass → Bio-oil Conversion factor (*w/w*)

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

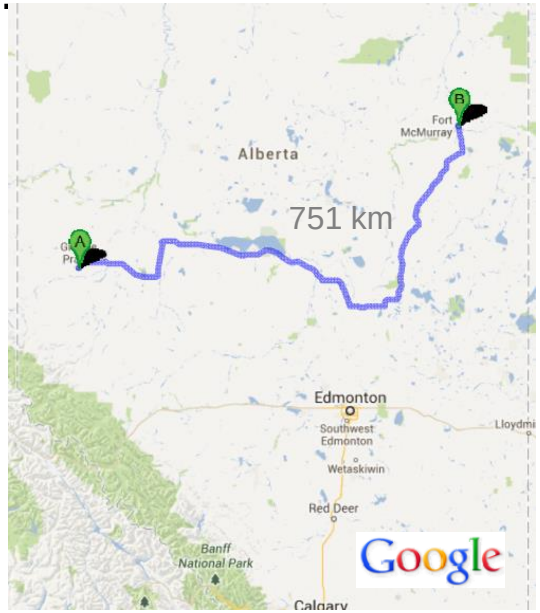
γ :Fraction of fuel consumed for return journey of empty truck/tanker

Stage-3 hauling

Diesel consumed in stage-3 is given by

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

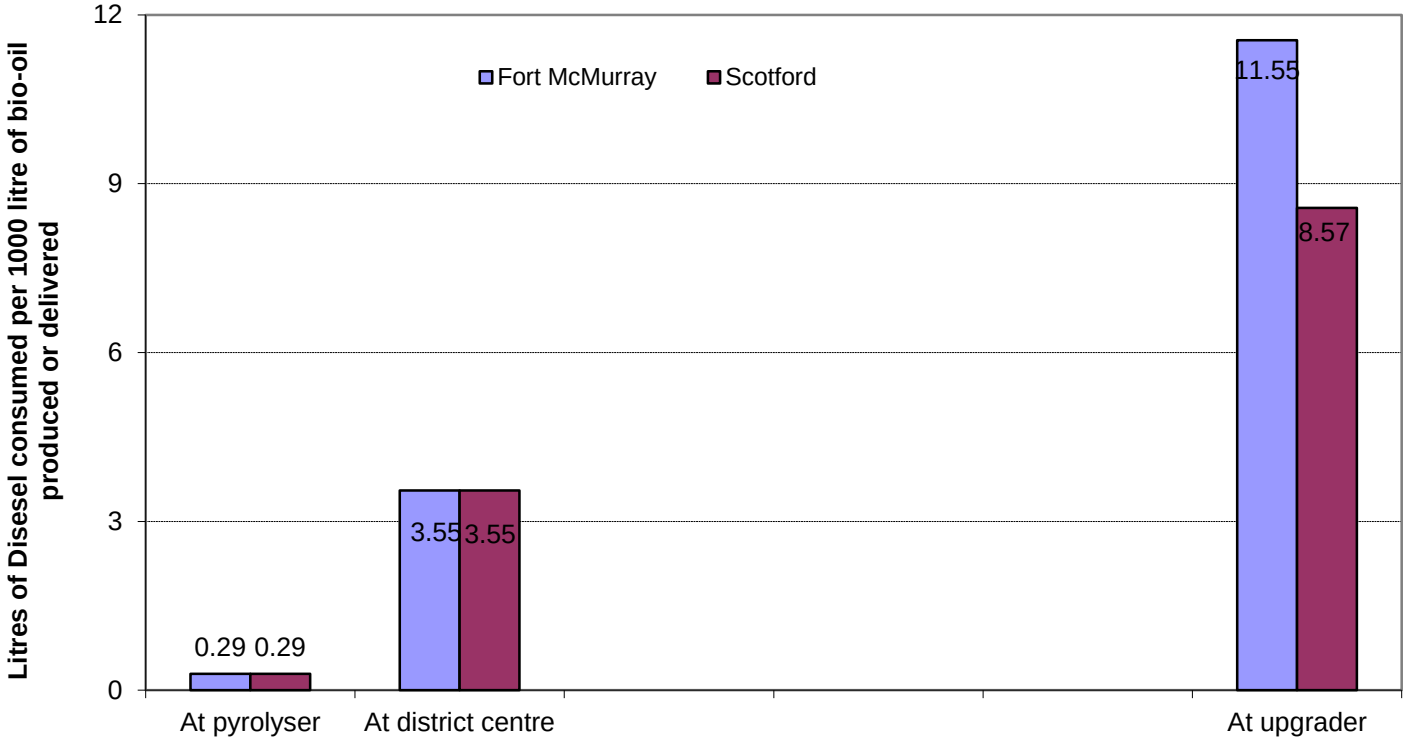
Here $D_{bio\text{-}oil,district,k->upgrader}$ is the actual road distance of an upgrader from an assigned centre in k^{th} district . This distance was estimated using fastest route through Google map.



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) to14,000 million litre (for fast pyrolyis).
- Required no. of pyrolysers @ *2 t.h*$^{-1}$ vary from 6 in Waterways to about 750 in Prairie.

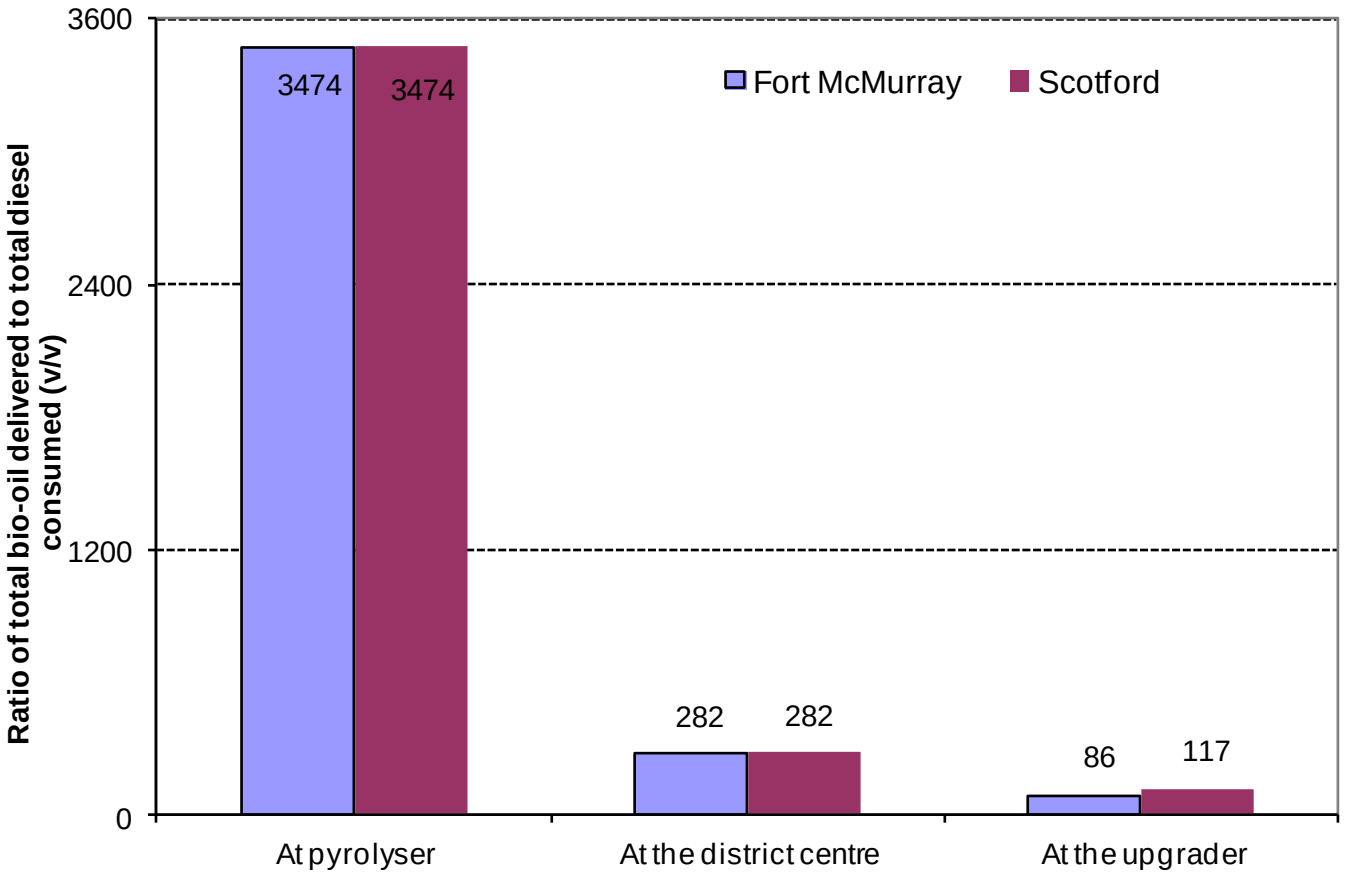
Ratio of diesel consumed to hauled bio-oil



CanmetENERGY

Leadership in ecoInnovation

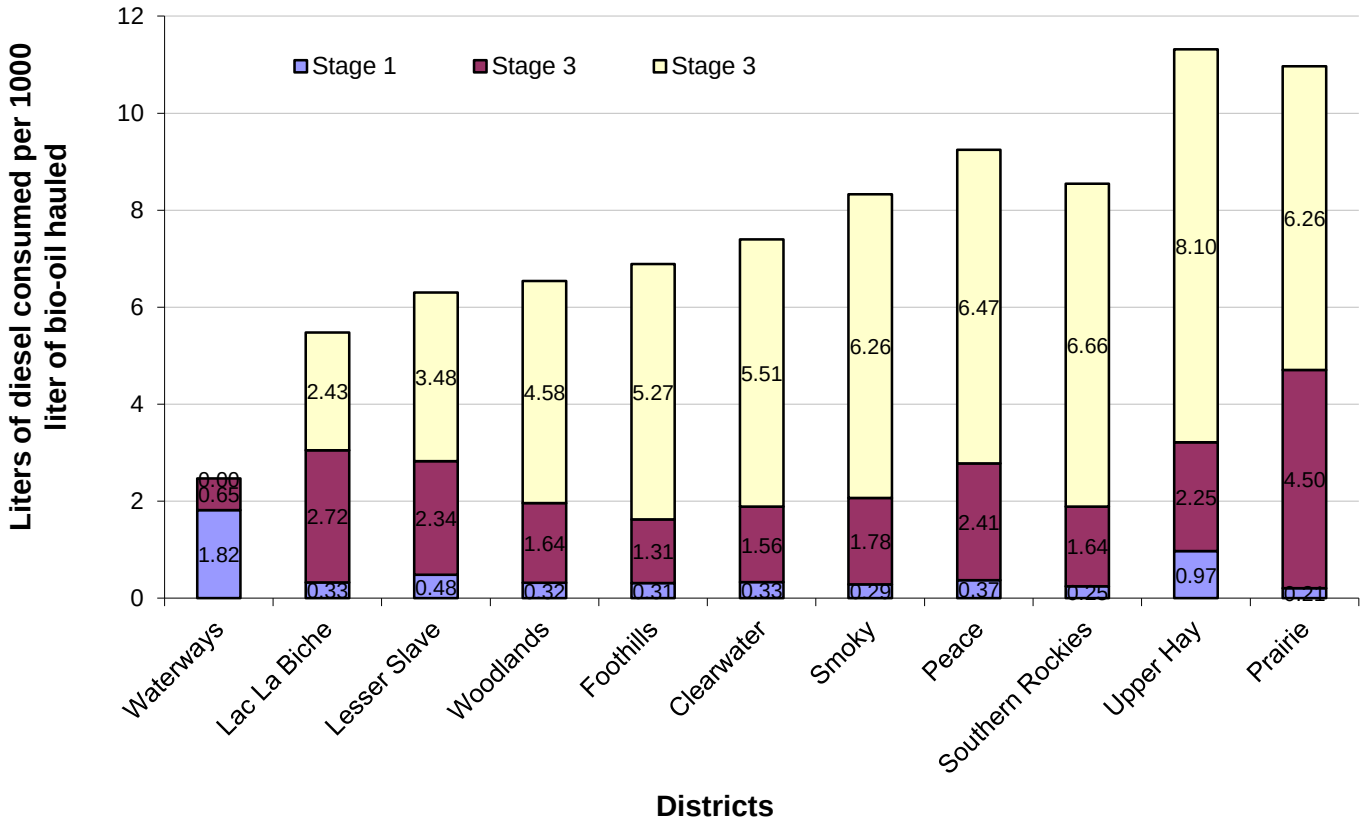
Ratio of hauled bio-oil to diesel consumed



CanmetENERGY

Leadership in ecoInnovation

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



CanmetENERGY

Leadership in ecoInnovation

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 3rd 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 β, tortuosity factors (τ) for forestry and agriculture.

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 1st 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.

Acknowledgement

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

CanmetENERGY

Leadership in ecoInnovation

Questions and Comments

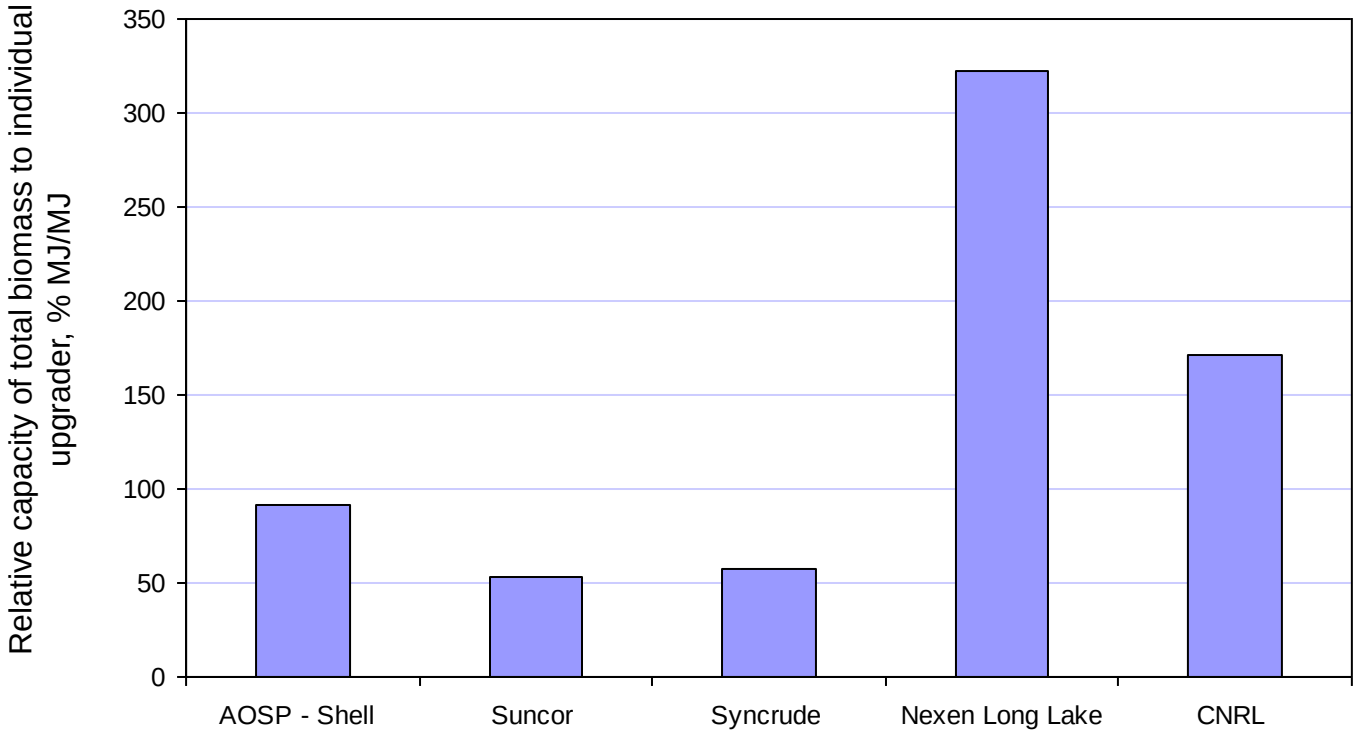
CanmetENERGY

Leadership in ecoInnovation

Supplementary slides

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

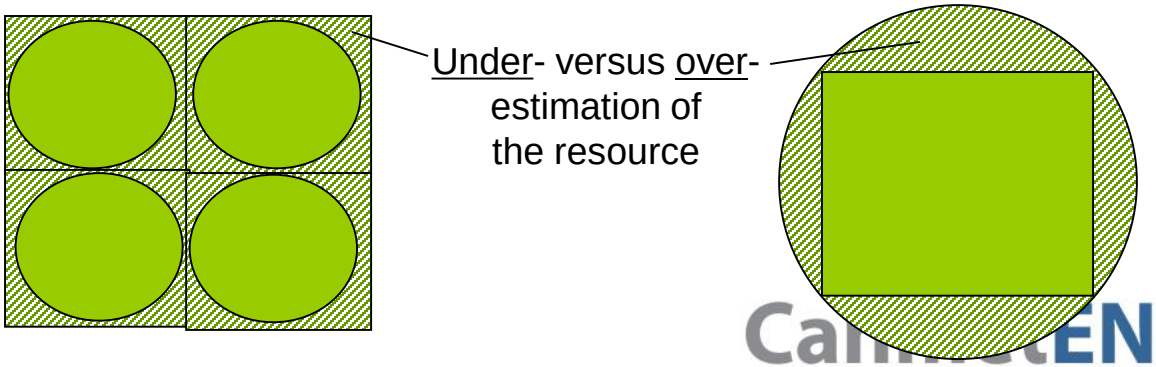
CanmetENERGY

Leadership in ecoInnovation

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.



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.

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 11th district and has kept at the same distance as Grande Prairies*

CanmetENERGY

Leadership in ecoInnovation