Alberta Woody Biomass Syngas to Renewable Natural Gas/Combined Heat and Power (RNG/CHP) for Oil Sands

Summary presentation of report commissioned by NRCan (Proposal 500018271)

Sept. 2016
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Agenda

SysEne Company Background

Alberta Context

NRCan Project

- Objective 1 – Woody Biomass to RNG
- Objective 2 – Woody Biomass for CHP in the Oil Sands
- Alternatives

Conclusions

(Link to Full Report)

Company Background

Engineering and Management Consulting for Energy, Transportation, Resource, and High Tech

Systems Approach to Technology, Process, and People

Chris Norman	Craig Louie	Flyn McCarthy	Michael Eiche	Ophir Kendler	Scott Stanners

Projects in the Bioenergy Sector

FortisBC Glenmore Landfill to RNG

Community Fuels Biodiesel Plant (Calif.)

Microsoft Data Center Wyoming
Landfill to Fuel Cell

Chip, Pellet and Dust Handling
System Upgrades

Alberta Context

Natural Resources Canada | Ressources naturelles Canada

Canada

Strategic interest

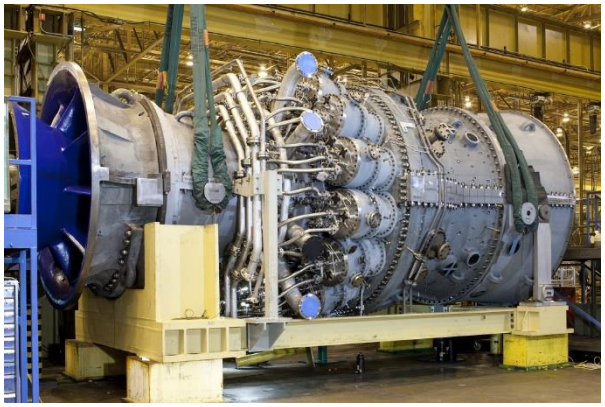
Oil Sands SAGD requirements

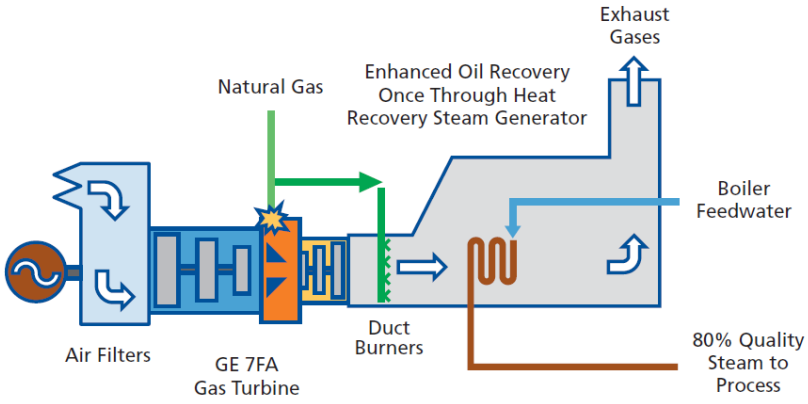
Suncor Fort McKay

- 12 MW electricity
- 345 MW steam

Conventional CHP pathway at SAGD site

- Fort MacKay
  - 172 MWe Natural Gas Gas Turbine with Steam Bottoming Cycle
  - 77% of steam in 2013
  - Excess electricity sold to grid
  - Operating since 2004

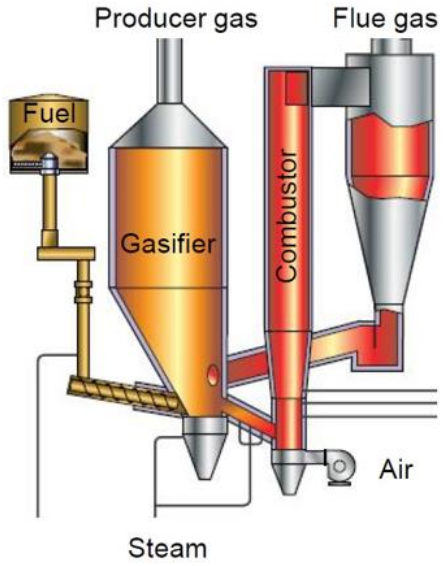




MacKay River Plant Schematic

NRCan Study - Evaluation of 2 Pathways

Woody biomass



Gasification

Renewable Natural Gas

Combined Heat and Power

RNG Cost with Current Technology

RNG Cost Summary	Biomass	Conversion to pipeline quality RNG			Delivery	Other/ Co-products	RNG to pipeline
Biomass / Case	Biomass cost $/tonne	Digestion/ Gasification $/GJ input	Upgading and cleanup $/GJ input	Yield, % of energy input	Pipeline injection $/GJ delivered	Other and credits	$/GJ
Landfill gas	Waste already collected. Some waste may require sorting and cleaning	LFG collection $0.60 to $1.50	Biogas Upgrading and clean up ($1 to $25). Costs dependent on scale and input gas quality	80-85%	Compressors, connection, monitoring equipment and pipeline costs. Depends on scale and distance to pipeline. $1 -$30	Credits for tipping fees, carbon credits for avoided emissions, value of co-products such as digestate, non RNG outputs such as heat for district heating	$6-$20
Livestock manure		Anaerobic digester $2-$25		35-45%			$10-$20
Digestible waste							$6-$20
Wastewater sludge							$6-$20
Municipal solid waste, non recycled plastics, and solid recovered fuel (MSW, NRP, SRF)		Thermochemical conversion (e.g. gasification and methanation with clean up ($12-$35/GJ) depends on scale and fuel difficulty		50-70%			$12-$30
Woody Biomass	$30-$200 including collection costs						$23-39

Natural Gas Wholesale Alberta ~ $2/GJ

$ CAD

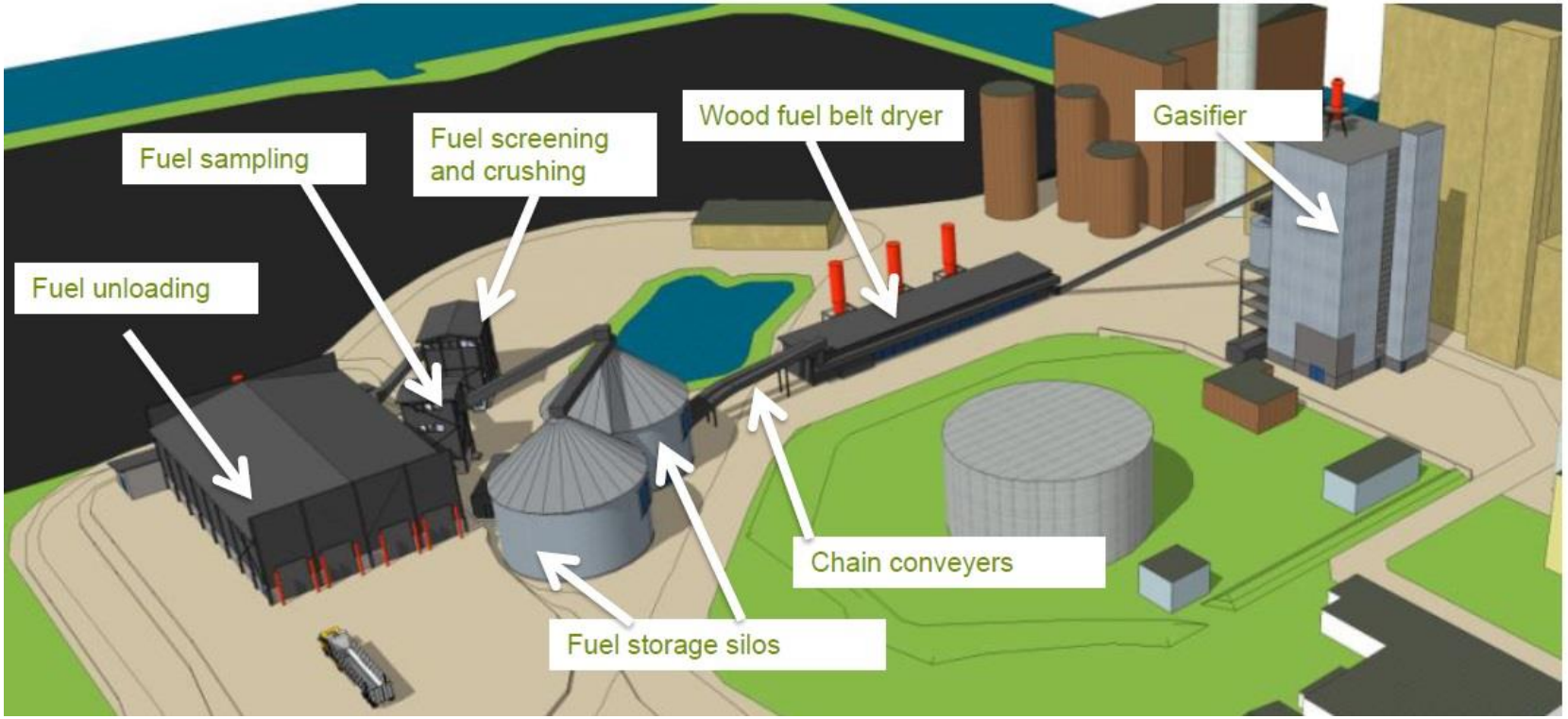
Woody biomass characteristics vary and are difficult to convert

Worldwide woody biomass RNG plants

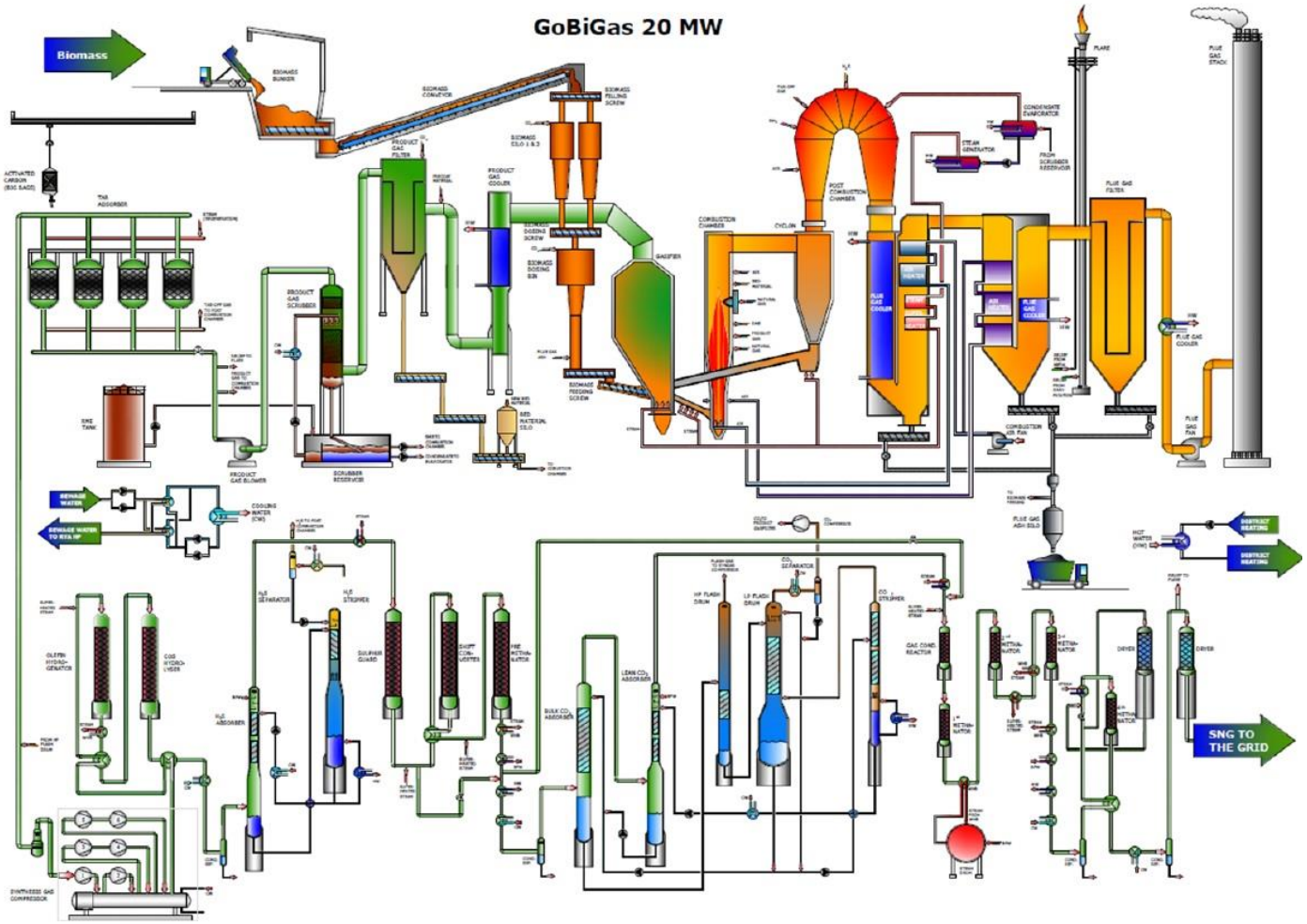
Location/Technology	Usage type	Fuel/Product (MW/MW)	Start-up	Status
Guessing, Austria, FICFB	Gas engine; bio-RNG demo	8_{fuel} / 2_{el} 1 MW_{RNG}	2002 2009	Operational Demo over
GoBiGas, Sweden FICFB	Bio-RNG	32_{fuel} / 20_{RNG}	2013	Commissioning, project stop?
Alkmaar, Netherlands MILENA	Bio-RNG	4_{fuel}/2.8_{RNG}	2017?	Planned
Petten, Netherlands MILENA	Bio-RNG R&D	0.8_{fuel}	2008	Pilot plant, Operational
Gothenburg, Sweden FICFB	Bio-RNG R&D	2_{syngas}	2009	Pilot plant, Operational
Koping, Sweden WoodRoll	Bio-RNG R&D	0.5_{fuel}	2015	Pilot plant, Operational

- FICFB = Fast Internally Circulating Fluidized Bed
- MILENA = ECN brand name for their indirect gasifier technology
- WoodRoll = Cortus Energy brand name for their biomass-to-syngas technology

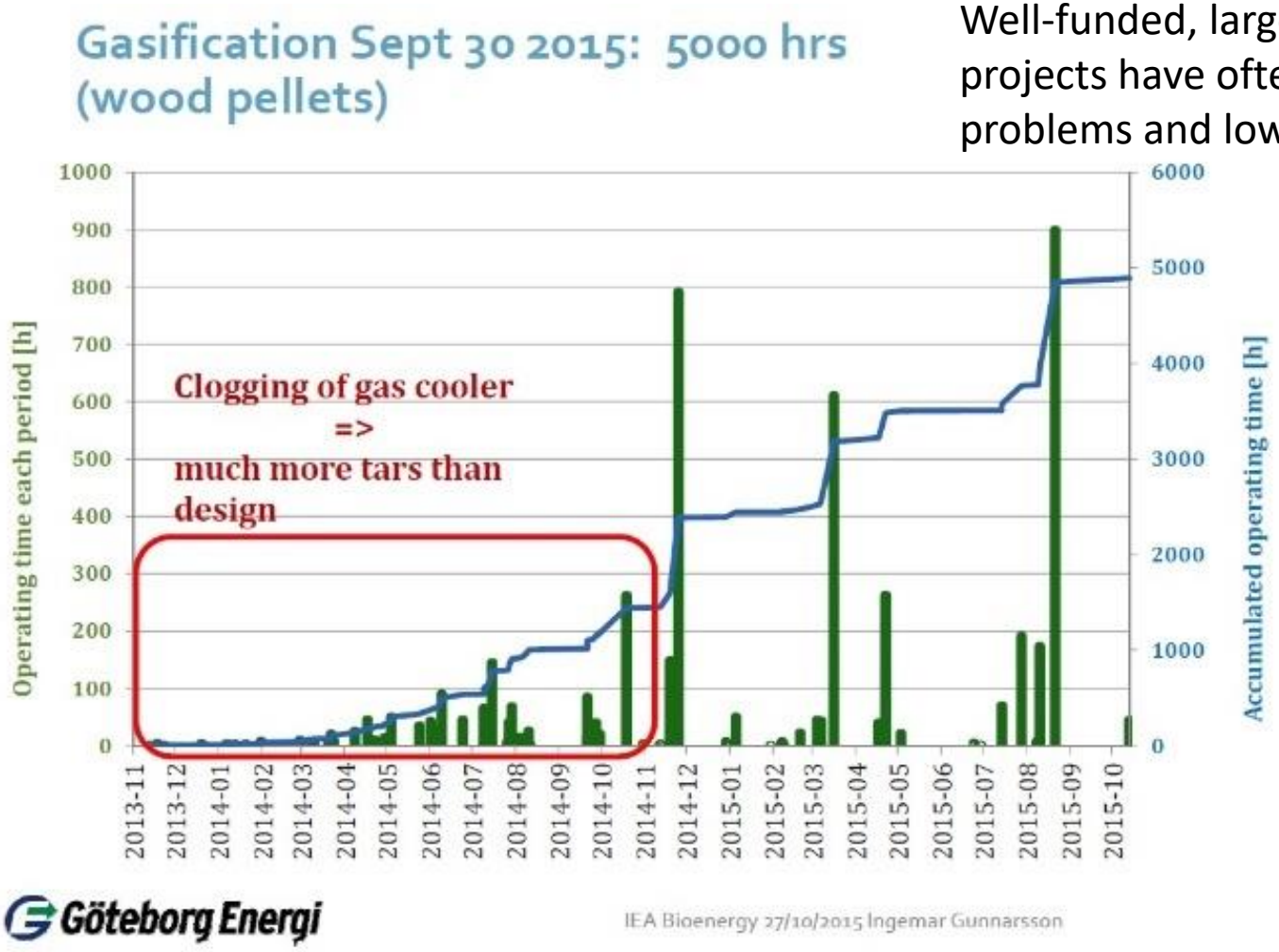
Fuel feeding system



Current technology is complex with many reactors



Technology maturity is still low



Well-funded, large scale (20 MW) demo projects have often experienced many problems and low availability.

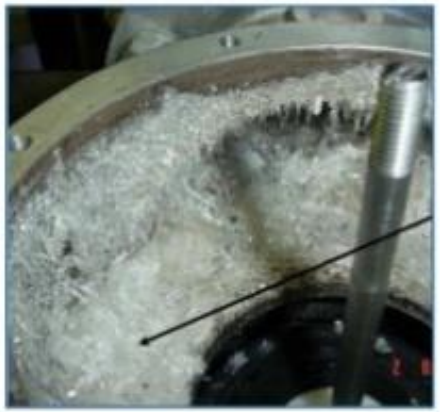
There are many technology challenges

Tar removal: the most important step

Deactivation of catalyst

Fouling of equipment

Plugging an intercooler



Naphthalene crystals

The "Achilles Heel" of biomass gasification

GoBiGas cost breakdown ($USD)

Gasifier

- Fuel feeding
  9 M$
- Gasifier
  12 M$
- Product gas cooler/filter and Scrubber
  5 M$
- Flue gas cleaning including flare
  9 M$
- **Total**
  35 M$

Syngas Cleaning and Methanization

- Carbon beds
  15 M$
- Hydronisation/sulfur removal
  8 M$
- CO2 separation
  8 M$
- Shift and pre-methanization
  11 M$
- Methanization 4 stages + drying
  15 M$
- **Total**
  57 M$

Syngas Compression

- Compressor
  15 M$
- **Total**
  15 M$

Building and civil constructions

- Base
  17 M$
- Explosion wall
  6 M$
- **Total**
  23 M$

Aux Systems
10 M$
Commissioning
40 M$
Total
180 M$

8.3 SEK = 1 $

tcbiomass2015
THE INTERNATIONAL CONFERENCE ON THERMOCHEMICAL CONVERSION SCIENCE

Pilot and prefeasibility example

Outline of demonstration

Chalmers lab reactor

Chalmers
2-4 MW Raw Gas
Pilot Plant

1.6 M$

GoBiGas Phase 1 Hisingen
20 MW Biomethane
Demonstration Plant
Göteborg Energi

180 M$

GoBiGas Phase 2
Hisingen
80-100 MW Biomethane
Commercial Plant
Göteborg Energi

420 M$

2008 2013 2017

Bio-RNG Pipeline interconnect costs

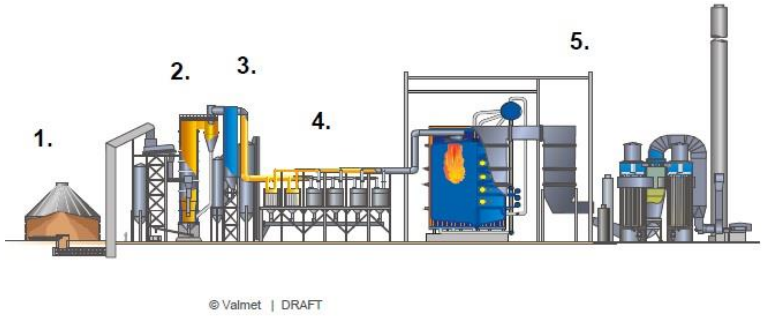
Site	Size (RNG output)	Plant Cost	Interconnect Costs $CAD
Seabreeze, Delta, BC	1.5 MW	Not published	$1.2 million ($800/kW)
Lachenaie, Montreal, Que.	104 MW	$44 million ($423/kW)	$2.3 million ($22/kW)

Preferred options for Alberta conditions

Established large suppliers

Valmet

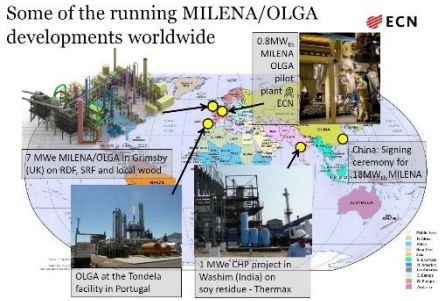
- Full scale 10-200 MW
- Capable company
- Successful projects



1. Fuel handling
2. Gasifier
3. Gas cooling
4. Gas filter
5. Gas boiler and flue gas cleaning

Valmet

New Technology companies



ECN

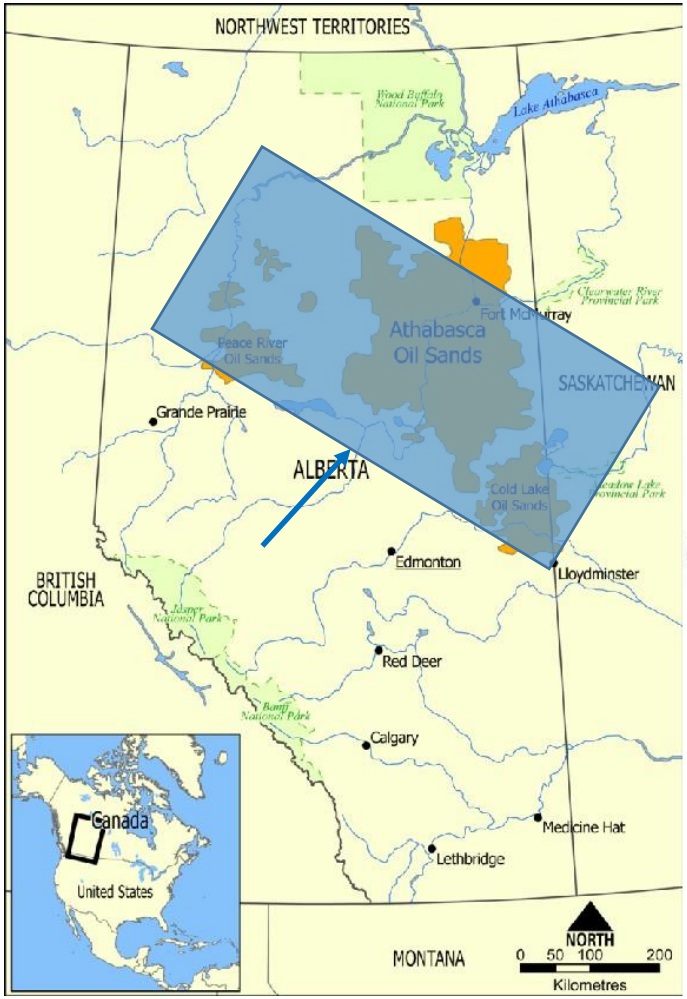
- Promising technology
- High efficiency
- Reasonable momentum

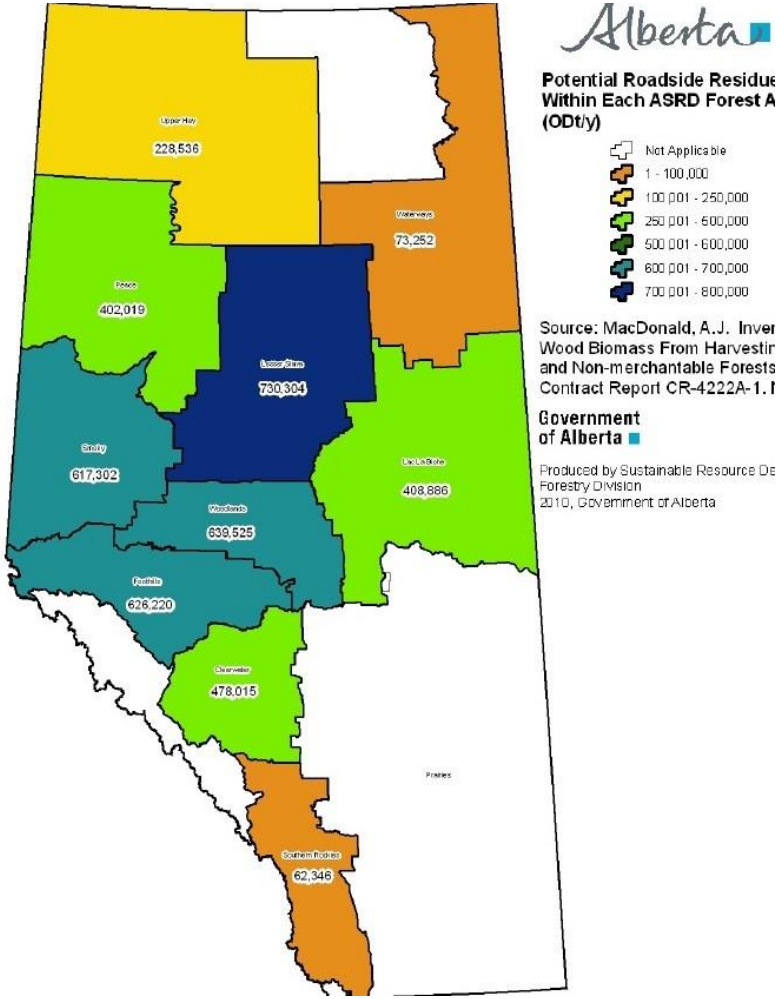
Cortus Energy

CORTUS ENERGY

- Promising technology
- Modular plant design
- Reasonable momentum

Mapping Alberta Biomass to Oil Sands



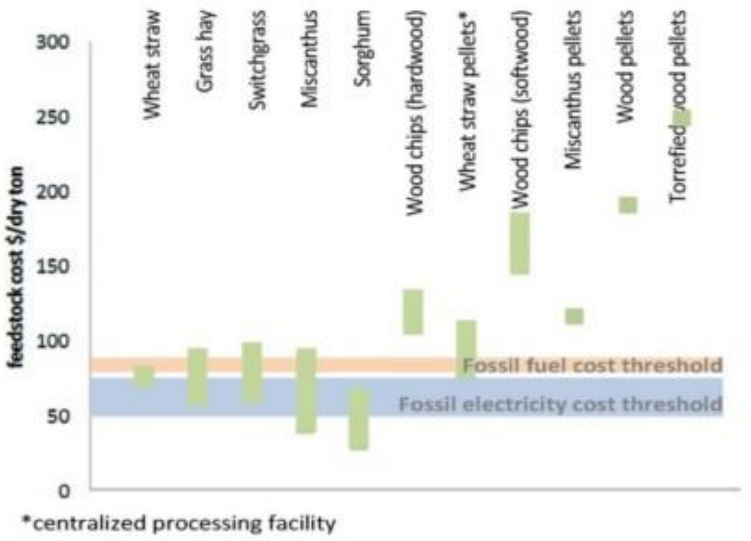


Supply challenges

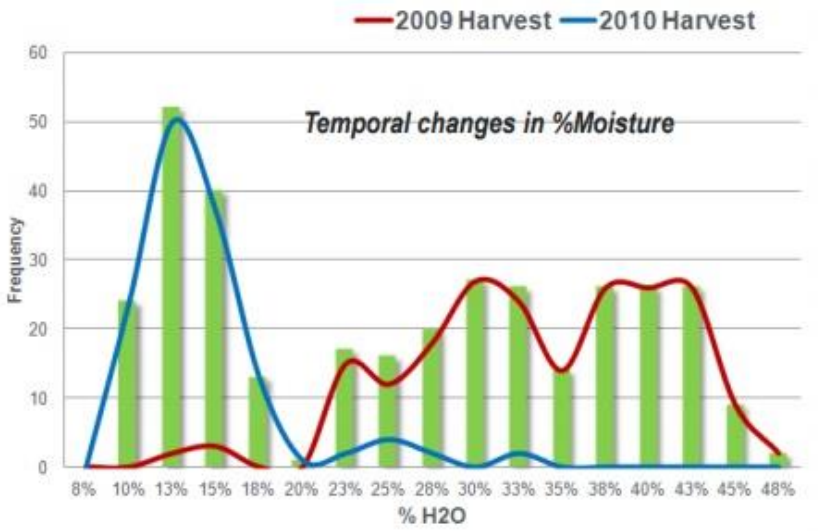
Key challenges in feedstock supply

IEA Bioenergy

Supply Costs & Quantity



Variability (Quality)



Wood chip costs

Unsubsidized	
Operation	**Cost per green ton, $USD**
Harvesting	$81
Chipping	$18
Transportation	$15
Total	**$114**

$114/ton = $20/GJ RNG for fuel

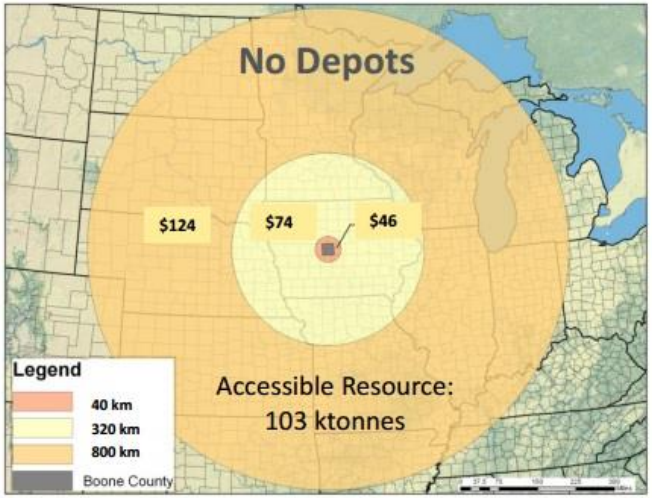
Subsidized	
Operation	**Cost per green ton, $USD**
Harvesting	$0
Chipping	$18
Transportation	$15
Total	**$33**

Example: depot strategy

Overall supply chain benefits

IEA Bioenergy

Example: Boone County, Iowa



Vertically integrated supply system

- Lower average feedstock supply costs BUT elevated risk
  - Quantity risk
  - Quality risk
  - Cost risk

Depot based supply system

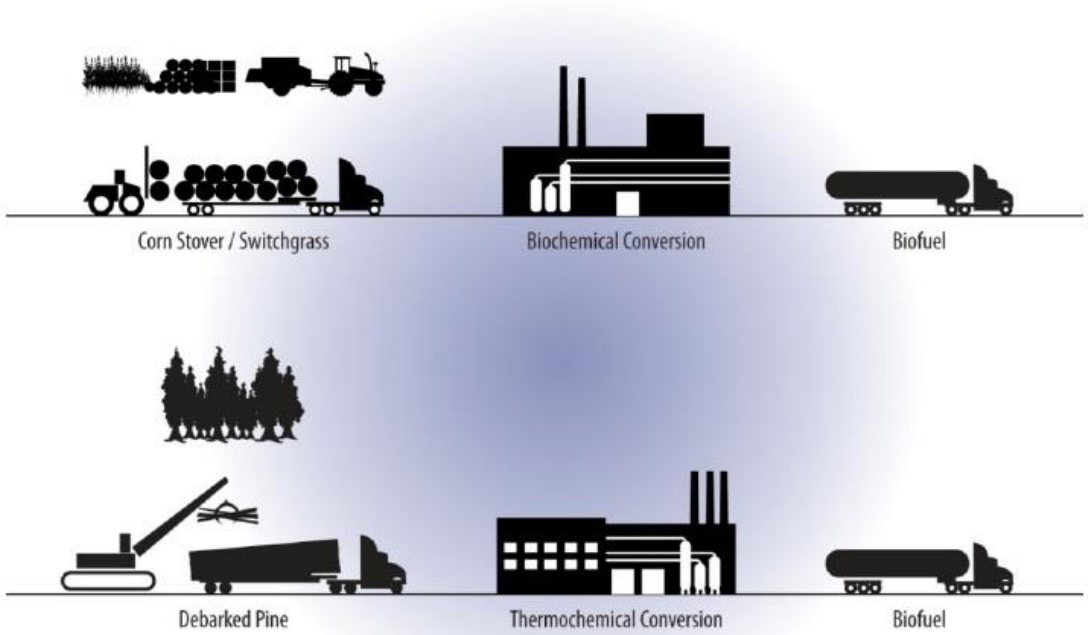
- Higher average supply costs but
  - Stable quantities
  - Stable quality specs
- Reduces business risks → reduces WACC
- Enables economies of scale
- Conversion efficiency improvements
- Reduced equipment at the biorefinery

Source: INL 2015

Current supply chain

Today: vertically-integrated

IEA Bioenergy



Vertically integrated supply systems

Designed around:

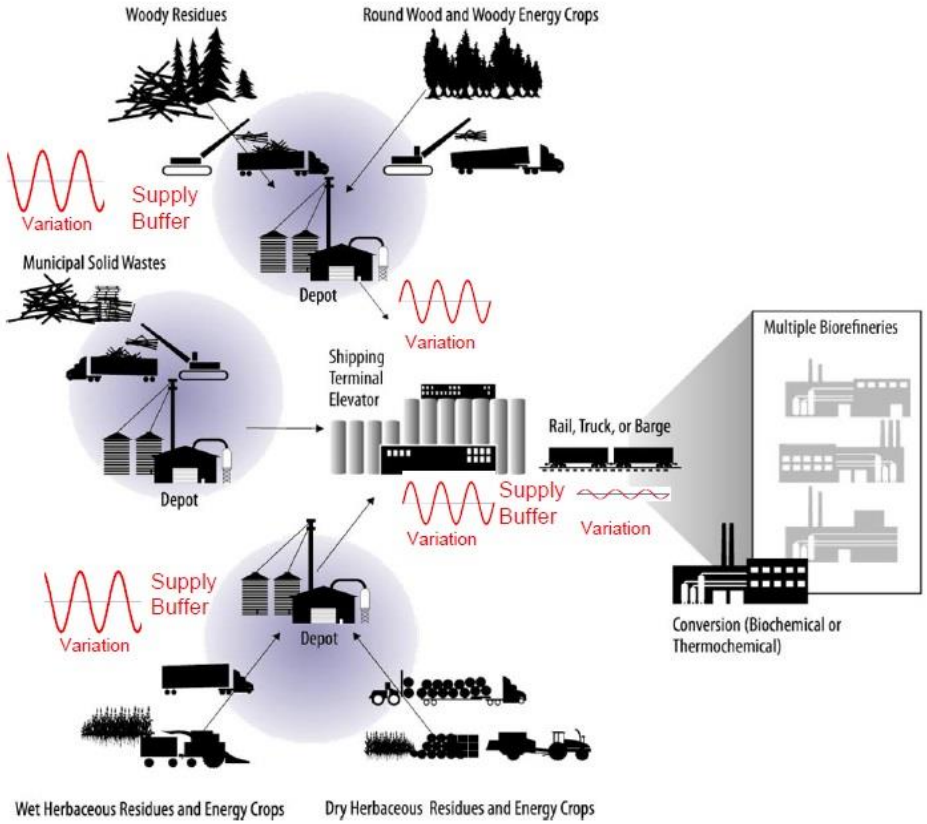
- **Limited markets**
- **Specific feedstock**
- **Specific conversion facilities**
- **Specific supply radius**

- High risk
- High costs
- Uncertain future
- Difficult to make high capital plant investment decisions

A preferred future

Future: Commodity supply system

IEA Bioenergy

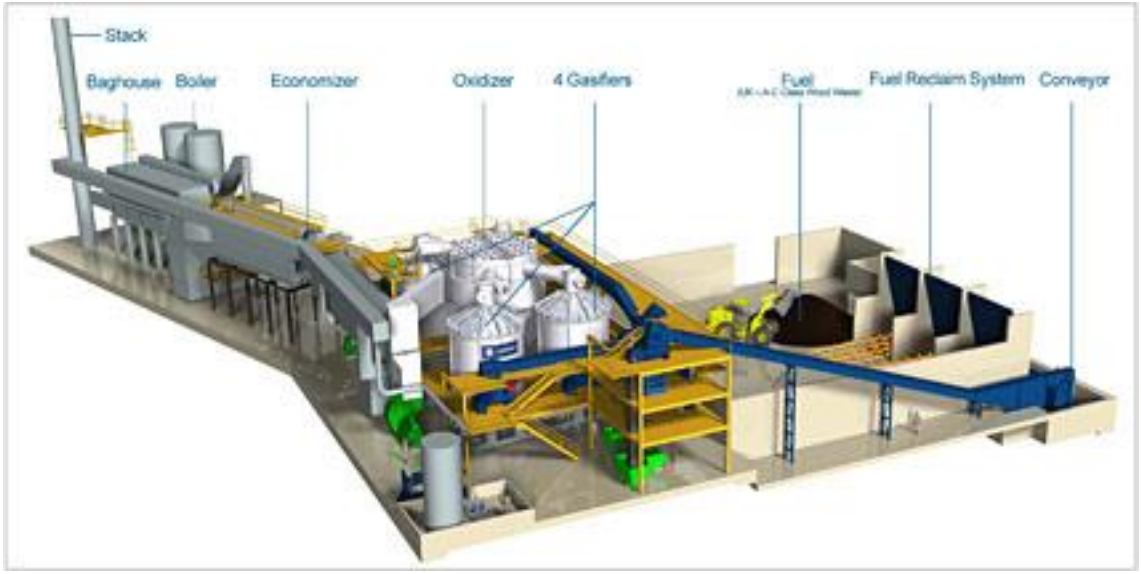


High-density, stable, commodity feedstocks

- **Manage feedstock variability & uncertainty**
- **Reduce supply chain risk**
- **Blend resources to meet cost, quantity, quality specifications of end-markets**
- **Access low-grade and diffuse resources**

Source: INL 2015

Nexterra business case in UK



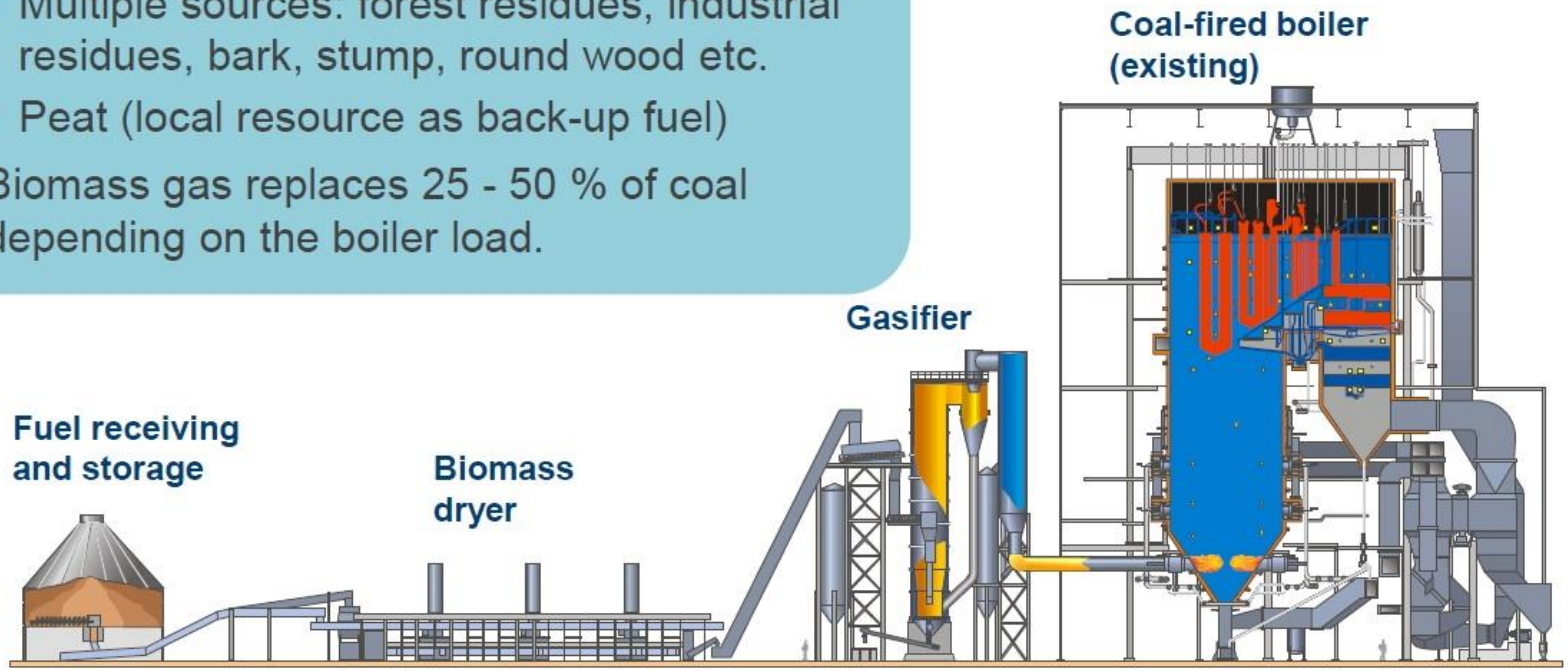
- 10 MWe
- $100 million
- “Free” wood
- Renewable Obligation Certificates
- 25 cents/kWh

Biomass co-firing: partial gasifier (140 MW), partial coal (560 MW)

Biomass feed 140 MW

- Chipped or crushed wood biomass
- Multiple sources: forest residues, industrial residues, bark, stump, round wood etc.
- Peat (local resource as back-up fuel)

Biomass gas replaces 25 - 50 % of coal depending on the boiler load.



Case study: Lachenaie Landfill, Montreal

Progressive Wastes

104 MW RNG Landfill to pipeline injection

Commissioned 2015

Project cost $44 million

$6/GJ RNG production cost

Alternate pathway biomass combustion to heat

Valmet CYMIC Boiler

Conclusions

1. Biomass combustion to heat (steam)
2. Biomass co-firing (but coal)
3. Waste-to-RNG
4. Supply chain modernization
5. Government strategy/policy adjustments

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