# BIOMASS DRYING AS A PROMISING SOLUTION FOR EFFICIENT BIOMASS BOILERS


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# Outline

- CanmetENERGY
- Context
- Typical dryer in P&P industry and their specifications
- Dryer model
- Case study
- Potential for Canada
- Conclusions

# CanmetENERGY

## *Three Scientific Laboratories across Canada*

CanmetENERGY is the principal performer of federal non-nuclear energy science & technology (S&T):

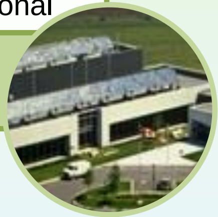
- Bioenergy, renewables, and energy efficiency


**Areas of Focus:**
- Oil sands & heavy oil processes
- Tight oil & gas
- Oil spill recovery & response

Devon

**Areas of Focus:**
- Buildings energy efficiency
- **Industrial processes**
- Integration of renewable & distributed energy resources
- RETScreen International

**Varennes**



**Areas of Focus:**
- Buildings & Communities
- Industrial processes
- Clean fossil fuels
- Bioenergy
- Renewables

Ottawa

# CanmetENERGY
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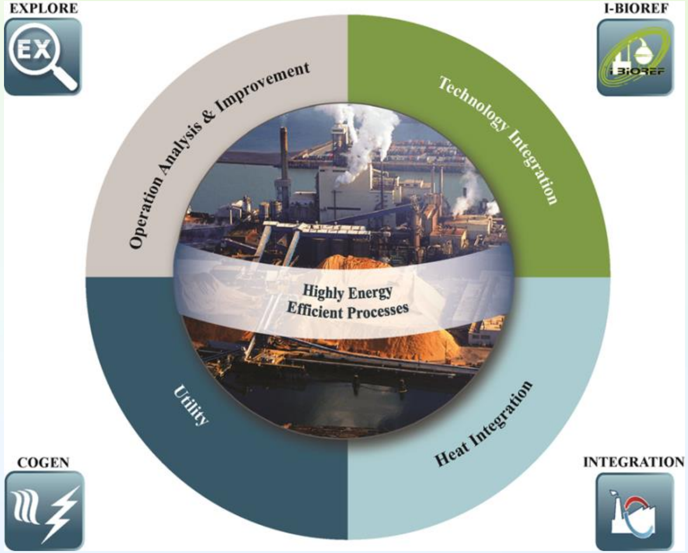
- CanmetENERGY's ISO Program focuses on innovative **facility-wide optimization** techniques (i.e. systems approach):
  - **Improve plants design and operation**
  - Effective introduction of new technologies
  - Achieve efficient use of energy and natural resources with reduced environmental impacts
  - **Pulp and paper**, refineries, oil sands, agri-food
  - Four main areas:
    - Heat Management
    - Cogeneration Optimization
    - Advanced Data Analytics
    - Biorefinery



# Context

- Biomass feedstock moisture content is one of the most important parameters influencing biomass boiler efficiency, steam production, fossil fuel consumption, and flue gas emissions
- High moisture biomass results in unstable combustion, increased stack losses and consequently decreased boiler efficiency. It also leads to increased fossil fuel consumption
- Boiler efficiency rapidly drops as biomass moisture content increases
- Low efficiency combustion will not sustain the biomass price surges that are expected in the future

# Drying Technology Advantages and Disadvantages

## Advantages

- Increased flame temperature
- More complete combustion
- Less excess air
- Less ash and fly ash

→

- Improve boiler efficiency by 5-15%
- Increase steam and power production
- Lower GHG emissions
- Lower co-firing
- Hotter flue gas in the furnace

## Disadvantages

- Fly ash reaching fusion temperature, melting and forming slag inside the boiler
- During dryer downtime, co-firing might be required
- Cooler flue gas leaving the boiler will result in sulfuric acid formation and could cause corrosion in the ductwork and stack
- Drying is an energy intensive process
- High capital and footprint

# Dryer Types

**Commercially available dryers**

- ***Rotary dryer***
- ***Belt dryer***
- Fluidized dryer
- Flash dryer
- Superheated steam dryer
- Cascade dryer
- Disk dryer

Feeco: http://feeco.com/photo-of-the-week-mechanical-construction-of-a-rotary-dryer-in-3d/

Alvan Blanch: http://www.alvanblanchgroup.com/driers-other-materials

# Rotary Dryer

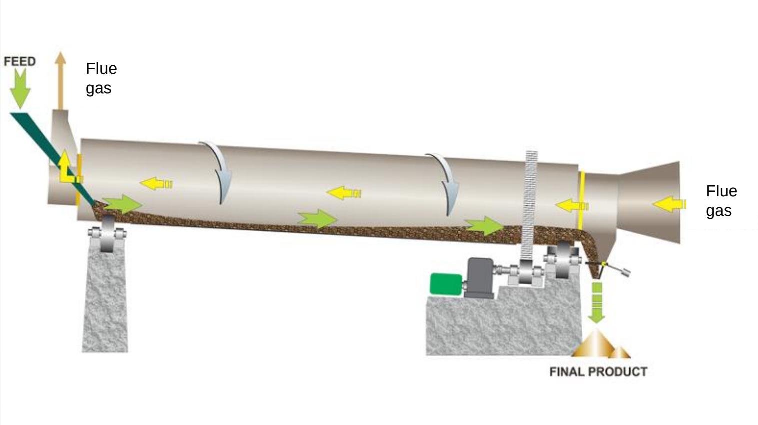
- Material rotates in a drum while it's being heated either directly or indirectly
- Commonly used to dry hog
- It could use flue gas or hot air as heat source

**Advantages**

- Low OPEX
- Moderate CAPEX
- Less sensitive to particle size
- High capacity

**Disadvantages**

- Relatively high heat source temperature is required
- High retention time results in high risk of fire
- Large footprint
- Hard to control moisture content




GEA: https://www.gea.com/en/products/rotary_dryer.jsp

# Belt Dryer

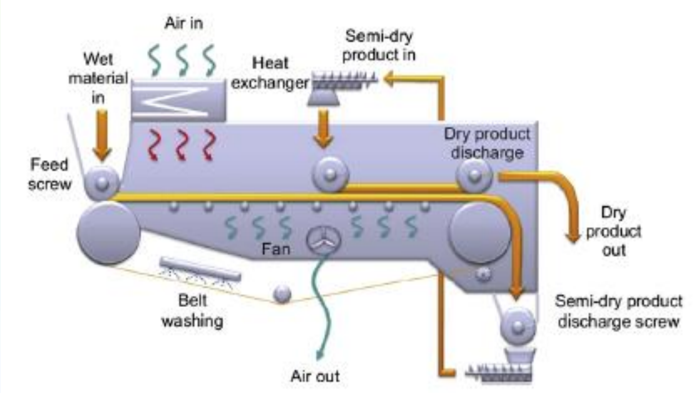
- Material is spread on perforated conveyors while the drying medium blows cross-sectionally
- It could use LP steam, hot water or flue gas as heat source

**Advantages**

- Low inlet temperature allows to utilize waste heat
- Low risk of fire hazard
- Low emissions due to low temperature

**Disadvantages**

- Large footprint → multi-pass has smaller footprint
- Slightly higher CAPEX compared to rotary dryer
- Slightly higher OPEX compared to rotary dryer




Valmet: https://www.valmet.com/pulp/wood-handling/bark-handling/biomass-drying/

National Renewable Energy Laboratory (NREL), "Report on Biomass Drying Technology," November 1998

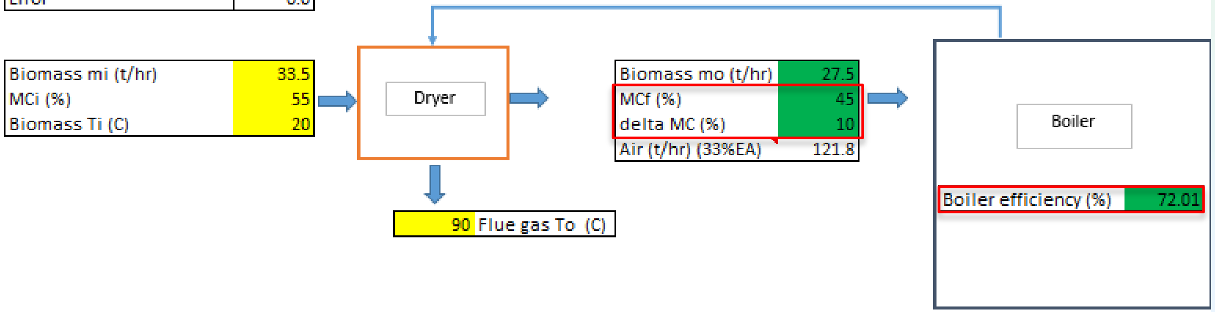
# Dryer Types Summary

| | Rotary | Belt | Flash | Fluidised-Bed |
|---|---|---|---|---|
| Heat Recovery | Difficult | Easy | Difficult | Difficult |
| Fire Hazard | Medium/High | Low | Medium | Medium |
| Sensitivity to Size | Low | Medium | High | Low |
| Air Emission | High | Low | Medium | Medium |
| Possible Steam Use | Yes | Yes | No | Yes |
| Footprint | Large | Large | Small | Small |
| Waste Heat Use | Yes | Yes | No | No |
| CAPEX | Low | Low(>rotary) | High | High |
| OPEX | Low | Low (>rotary) | High | High |

# Model Introduction: Moisture Removal Capacity of Dryers in a Steady State Condition Using Waste Heat

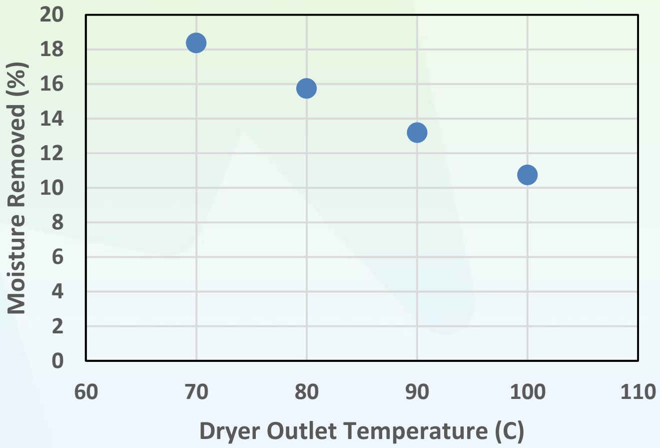
- This model iteratively calculates how much moisture could be removed by using biomass boiler flue gas
- More moisture can be removed if other heat sources such as recovery boiler flue gas is used
- It also calculates boiler efficiency based on boiler flue gas temperature and biomass final moisture content

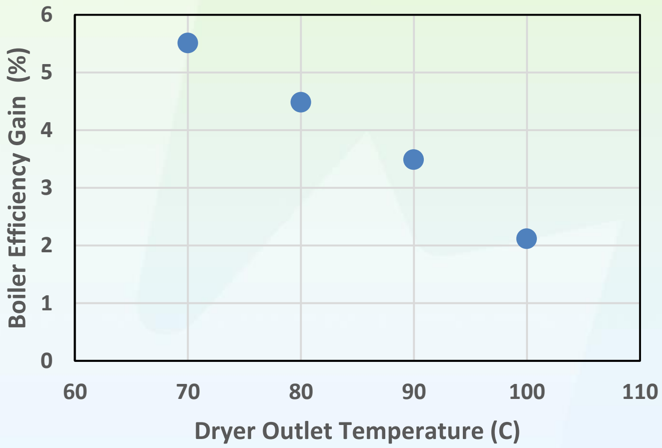
| Heat Sources | | |
|---|---|---|
| Biomass Boiler | Boiler flue gas To (C) | 200 |
| | Boiler flue gas flow (t/hr) | 149.3 |
| Recovery Boiler | Boiler flue gas To (C) | 170 |
| | Recovery boiler flue gas flow (t/hr) | 783.9 |
| | Fraction flue gas flow sent to dryer (%) | 0% |
| | Black liquor dry solid flow (t/hr) | 130 |
| Ambient Air | Temperarture (C) | 20 |
| | Flow (t/hr) | 0 |
| Overall | Temperarture (C) | 200 |
| | Flow (t/hr) | 149.3 |
| Error | 0.0 | |



# Moisture Removal Capacity - Effect of Dryer Outlet Temperature

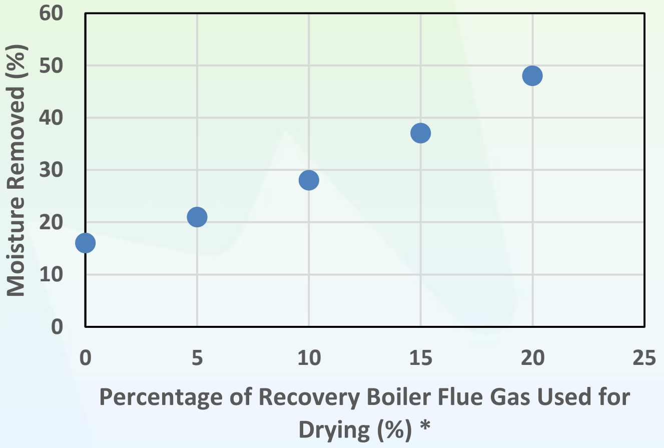
- More moisture can be removed by biomass boiler flue gas for lower dryer outlet temperatures

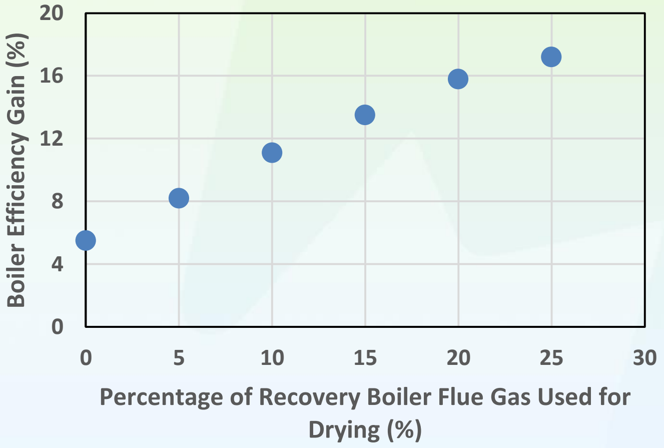


# Moisture Removal Capacity - Effect of Additional Heat Sources

- More moisture can be removed by adding recovery boiler flue gas as another heat source




* Dryer exhaust T of 90 ◦C

# Case Study

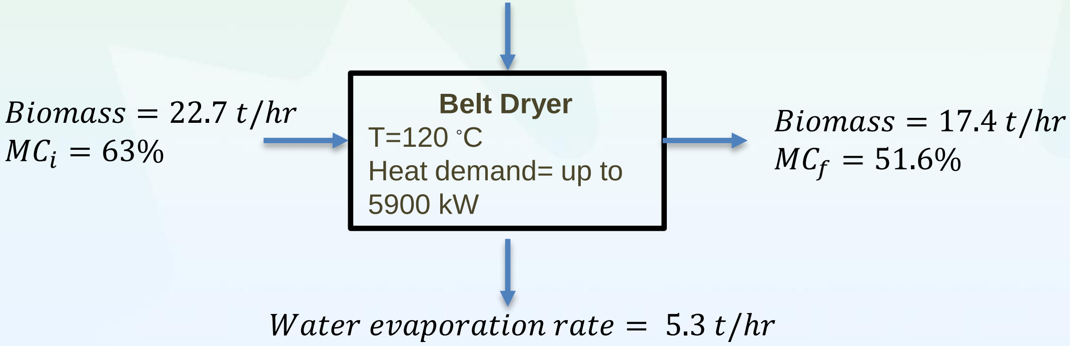
- A prefeasibility study was conducted to evaluate adding a biomass dryer to a high-pressure biomass boiler
- Biomass input to the boiler consists of a mixture of 55% wet wood waste, 15% wet pressed sludge and 30% wet purchased biomass
- Boiler limited in the air side (FD and ID fans)
- Specific case with excess steam. In general, boiler flue gas would be a better choice for heat source

| Biomass Boiler Steam Generation | | |
|---|---|---|
| | **Designed** | **Currently** |
| Flow rate (lb/hr) | 190,000 | 150,000 |
| Steam Temperature (°F) | 850 | 850 |
| Steam Pressure (psig) | 800 | 800 |

# Case Study – Technical Data

- An indirect belt dryer to dry a mixture of hogged wood waste and pressed sludge was proposed
- Dryer available heat sources: 10 t/hr LP steam at 270 kPa and 160 °C (excess from Turbine)
  20 t/hr dirty steam condensate at 100 °C
  180 t/hr paper machine white water at 65 °C
- The evaluated case:

  4 t/hr LP steam; 20 t/hr hot water; 90 t/hr white water




| Economics | |
|---|---|
| Capacity improvement | 10 klb/hr HP steam and 0.8 MW power |
| Capital cost | $5.5M |
| Payback | 10 years |

# Biomass Dryer Projection in Canada

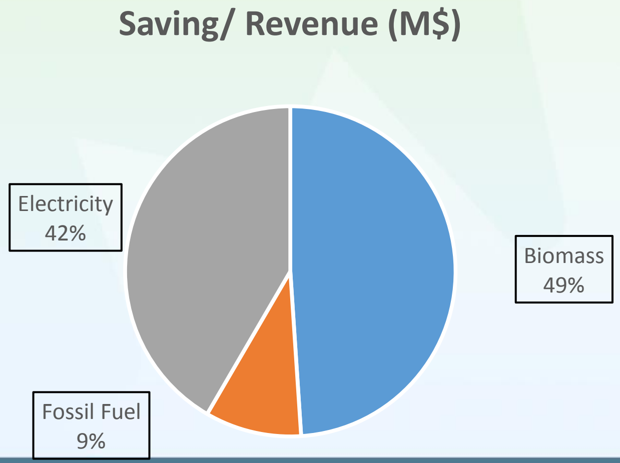
- The impacts of installing biomass dryers were evaluated in nearly 50 pulp and paper mills across Canada that burn biomass to produce steam
- Mills were categorized and evaluated based on their cogeneration system and power generation contracts:
  - Mills with condensing turbine
    - Since there is capacity to generate more electricity either more steam could be generated or fuel (biomass/ fossil fuel) could be saved
  - Mills with back pressure turbine or no cogeneration
    - No capacity to generate more electricity so, without venting steam, fuel (biomass/ fossil fuel) could be saved

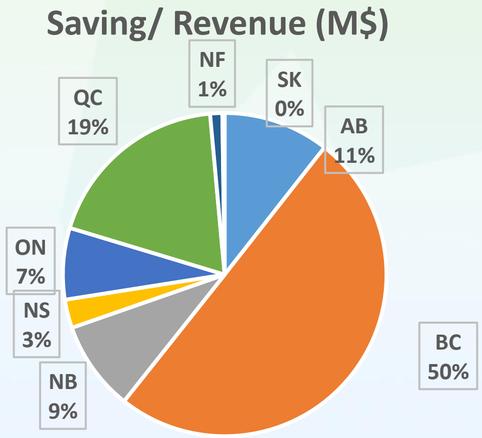
# Biomass Dryer Projection in Canada - Main Assumptions

- A fixed price was assumed for purchased biomass for all mills ($30/t wet biomass)
- Green electricity selling price was assumed fixed for the mills in each province ($35-110/MWh)
- Dryer capital cost was estimated based on a variable cost correlating with water evaporation rate and a fixed cost taken from quotes provided by dryer manufacturers
- It was assumed that thermal energy is converted to electricity with 27% efficiency
- Biomass boiler efficiency was assumed 68% and 74% burning 55% and 45% wet biomass respectively; and 82% burning natural gas (HHV base)
- Drying using boiler waste heat only

# Biomass Dryer Projection in Canada - Savings

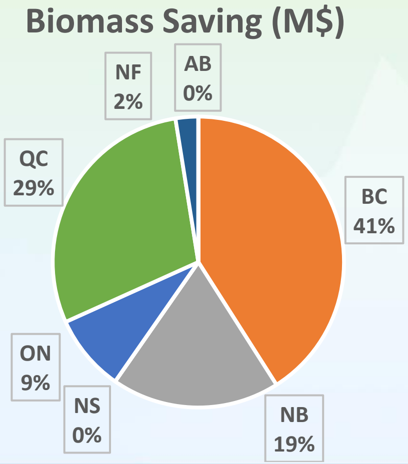
- An annual saving and additional revenue of $110M was estimated if theoretically all biomass feedstock could be dried from 55% to 45% moisture content in 50 P&P mills in Canada
- The cost to install dryers in all studied P&P mills was estimated to be $476M
- Installing a dryer will be most profitable for British Columbia, as BC is the province that has the largest number of mills with condensing turbine in Canada (subject to contract renewal)

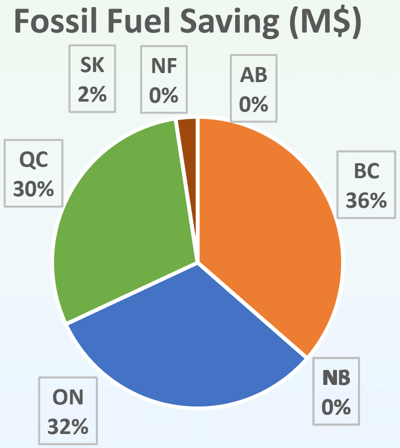


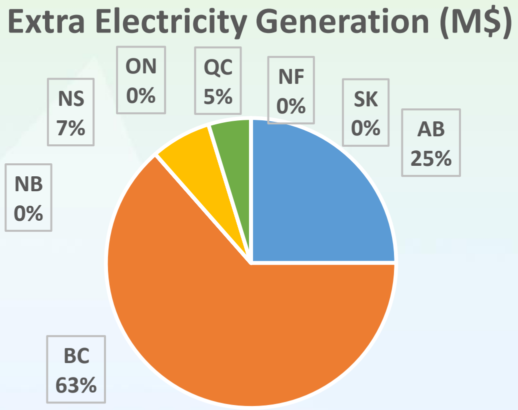



# Biomass Dryer Projection in Canada - Savings By Province

- BC as the biggest consumer of biomass could annually save over $21M worth of biomass
- 3,443 TJ fossil fuel worth $10M could be annually saved, which corresponds to a saving of 193 kt$CO_{2eq}$
- 671 GWh of extra electricity could be annually generated, mainly in BC



# Conclusions

- Biomass drying using waste heat is a promising approach to improve the quality of biomass, increase biomass boiler efficiency, decrease fossil fuel consumption and eventually decrease $CO_{2eq}$ emissions
- A dryer model was developed using heat and mass balance equations governing the drying process
- The model showed that the moisture content of biomass feedstock could be lowered by almost 10% using the biomass boiler flue gas in the dryer
- It was projected that pulp and paper mills across Canada could annually save 2 Mt of biomass, 3400 TJ of fossil fuel and generate 2400 TJ of additional green power by reducing biomass feedstock moisture content from 55% to 45%
- An average simple payback time of 5 years was estimated for dryer installations in Canada

# Thank you!

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