Techno-Economic Assessment of a Small-Scale, Decentralized Mobile Biochar Production Unit

Presenter: Jeff MacDonald
University: University of British Columbia

Acknowledgements

- The Government of Canada under the Sustainable Canadian Agricultural Partnership
- Biomass Canada Cluster, a BioFuelNet Canada initiative
- Supergen Bioenergy Hub (UK)
- University: University of British Columbia
- Partners: Biomass & Bioenergy Research Group (BBRG)
- Dr. Kevin Kung – Takachar Ltd.

Project Overview

2.9 million m^3 [1]

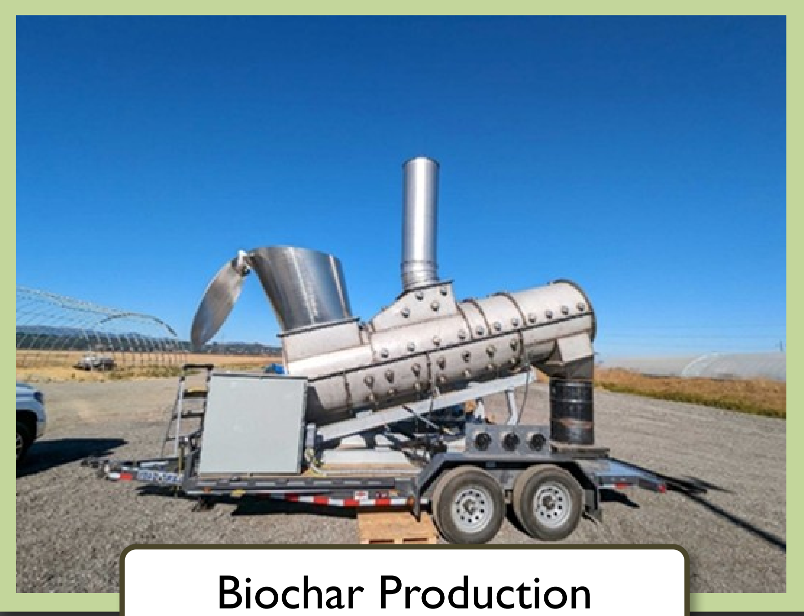
Harvest residues
- Waste
- Branches, tops, stumps, non-merchantable timber

Slash Burning

Low cost

Wildfire risk & increased emissions
- Slash burning: 2.7Mt CO_2e in 2021[2]

Better alternative needed



Biochar Production

TAKACHAR

Mobile pyrolysis auger reactor

Raw biomass in, biochar out

Biochar product:
- Increased calorific (energy) value
- Favorable properties for soil enrichment (surface area, carbon content, hygroscopicity)
- Waste utilization, sustainable resource

[1] Nance, E. (2023). *SLASH-PILE BURNING IN BRITISH COLUMBIA: MANAGEMENT CHALLENGES, EMISSIONS UNCERTAINTIES, AND ALTERNATIVE PRACTICES.*
[2] BC government Provincial Inventory report on GHG emissions (2023)

https://www.worldatlas.com/articles/what-is-slash-and-burn-agriculture.html
https://www.canadianbiomassmagazine.ca/the-burning-question-addressing-harvest-residue-management-in-b-c/

Research Objectives

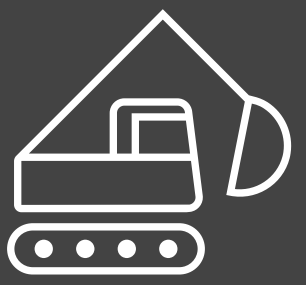
1. Determine if and under which conditions the process is economically and environmentally favorable to slash burning
2. Perform a sensitivity analysis for key factors
3. Inform BC government policy on waste biomass utilization

Build a specific case using the Takachar biochar unit, highlight obstacles, show the potential for a sustainable alternative to status quo slash burning

Approach

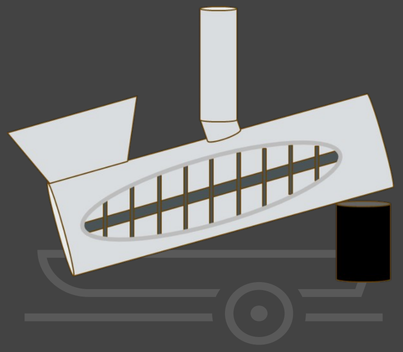
Overall Process Flow:

Slash piles



Feedstock production
- Grinding
- Shuttling
- Loading

Reactor feed



Biochar production

Transport

To storage/delivery

Utilities, fuel, maintenance, etc.

Labour

Systematic approach

Carbon accounting, equipment emissions estimates

Discounted cash flow rate of return model – 5y project

- **Production Cost**
- **Net Present Value**

Energy/ cost? Emissions?

My contributions

Mass balance – biomass in, solid biochar & exhaust out

Energy balance – internal energy main source of conversion

Biomass chemically complex

- Mass and energy balance, partial combustion

$$CH_xO_y(s) + \left(\frac{2 + x/2 - y}{2}\right) O_2(g) \rightarrow \frac{x}{2} H_2O(l) + CO_2(g)$$

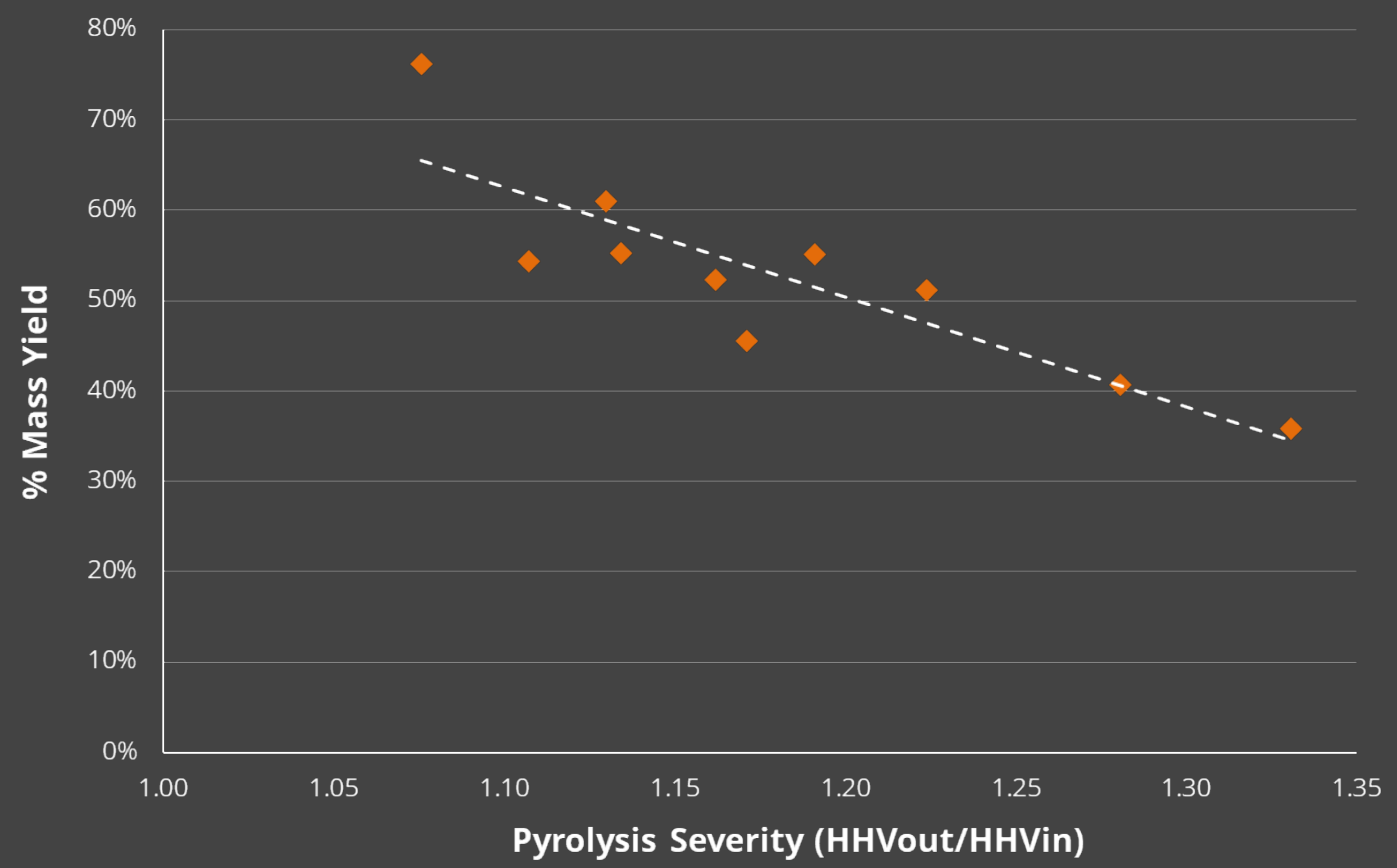


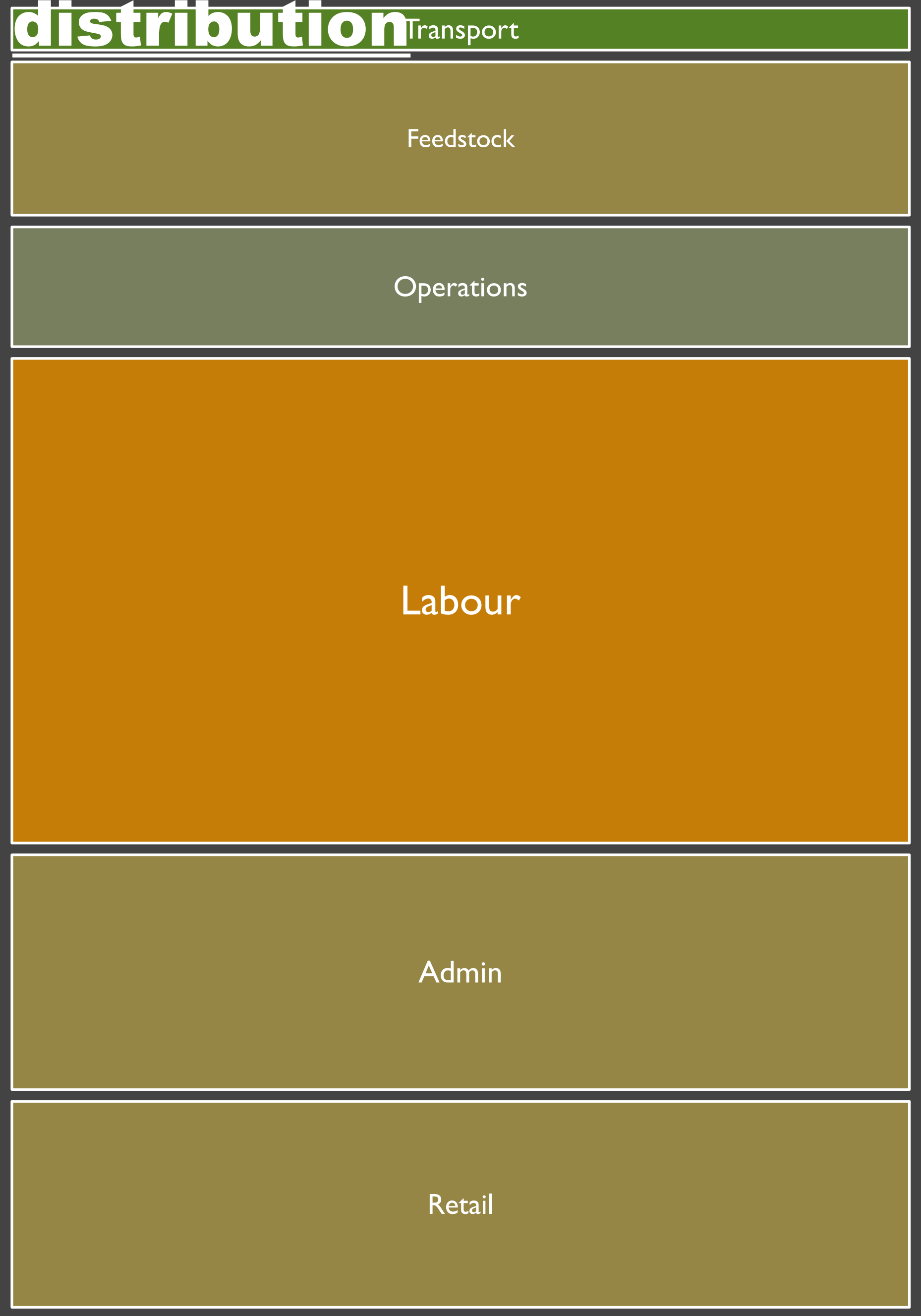
Figure 1. Relationship between torrefaction severity and product mass yield at a given moisture content.

<u>Tasks:</u>
- Simulate inputs and outputs
- Equipment, materials & production cost estimates
- Create technical basis for economic model and emissions estimates

→ Two-factor dependence of **<u>product output</u>** on **<u>feed moisture</u>** & **<u>pyrolysis severity</u>**

Results and Accomplishments

Production cost distribution



Labour – highest cost category

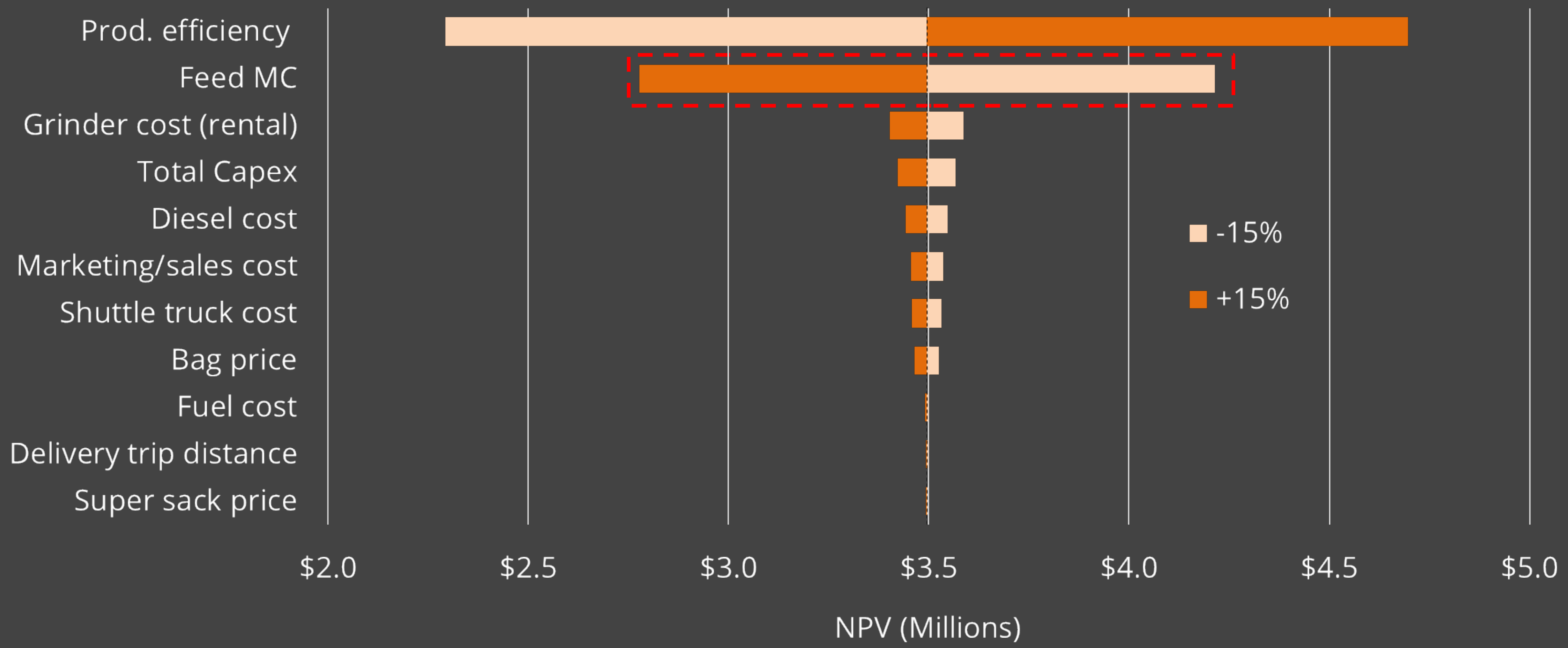


Figure 2. Tornado chart showing response of NPV to 15% + and - change in input variables

Most sensitive factors - production efficiency, **moisture content**

Considerations for moisture content effects:

- Effect on drying, reactor operation
- Weather effects (below freezing)
- Grinding energy requirements
- Mass yield – high dependence

→ Refine model, find & test relationships

Challenges

Production cost still high – solutions for pre-drying, production efficiency

Simulating biochar product – tradeoff between carbonization and yield

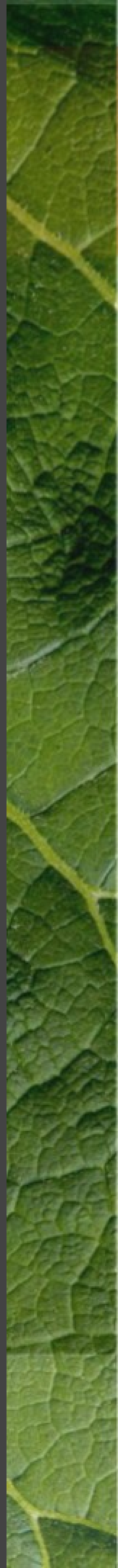
Estimating NPV given volatility of carbon market and biochar market

Table 1. Benchmark production cost of biochar in other contexts

Study	Production cost $\$Mg^{-1}$ biochar
Nematian et al. (2021)[3]	1004
Sahoo et al. (2019)[6]	1440
Present study	**1869**

Required for carbon credits:
H/C_{org} ratio < 0.7 (hydrogen to organic carbon)

From simulation:
For H/C_{org} of 0.7, mass yield < 20%
- Low likelihood of profitability



[3] Nematian, M., Keske, C., & Ng'ombe, J. N. (2021). A techno-economic analysis of biochar production and the bioeconomy for orchard biomass. *Waste Management*, *135*, 467–477. https://doi.org/10.1016/j.wasman.2021.09.014
[6] Sahoo, K., Bilek, E., Bergman, R., & Mani, S. (2019). Techno-economic analysis of producing solid biofuels and biochar from forest residues using portable systems. Applied Energy, 235, 578–590. https://doi.org/10.1016/j.apenergy.2018.10.076

Next steps

- Field results → validate (or invalidate) predictions for mass yield & moisture content effects
- Address issues with current model
  - Unreasonably high I_{torr} required to meet carbon credit requirements
- Dryer adaptation, waste heat recycle
- Further model interrogation
  - Multiple reactors in parallel?