Biomass Canada Cluster

Development of logistics, pretreatment and commercialization of agri-pellet

Principal Investigator: Dr. Shahab Sokhansanj
Organization: University of British Columbia

In Partnership with
Biomass Cluster holder: BioFuelNet Canada
Wood Pellet Association of Canada (WPAC)

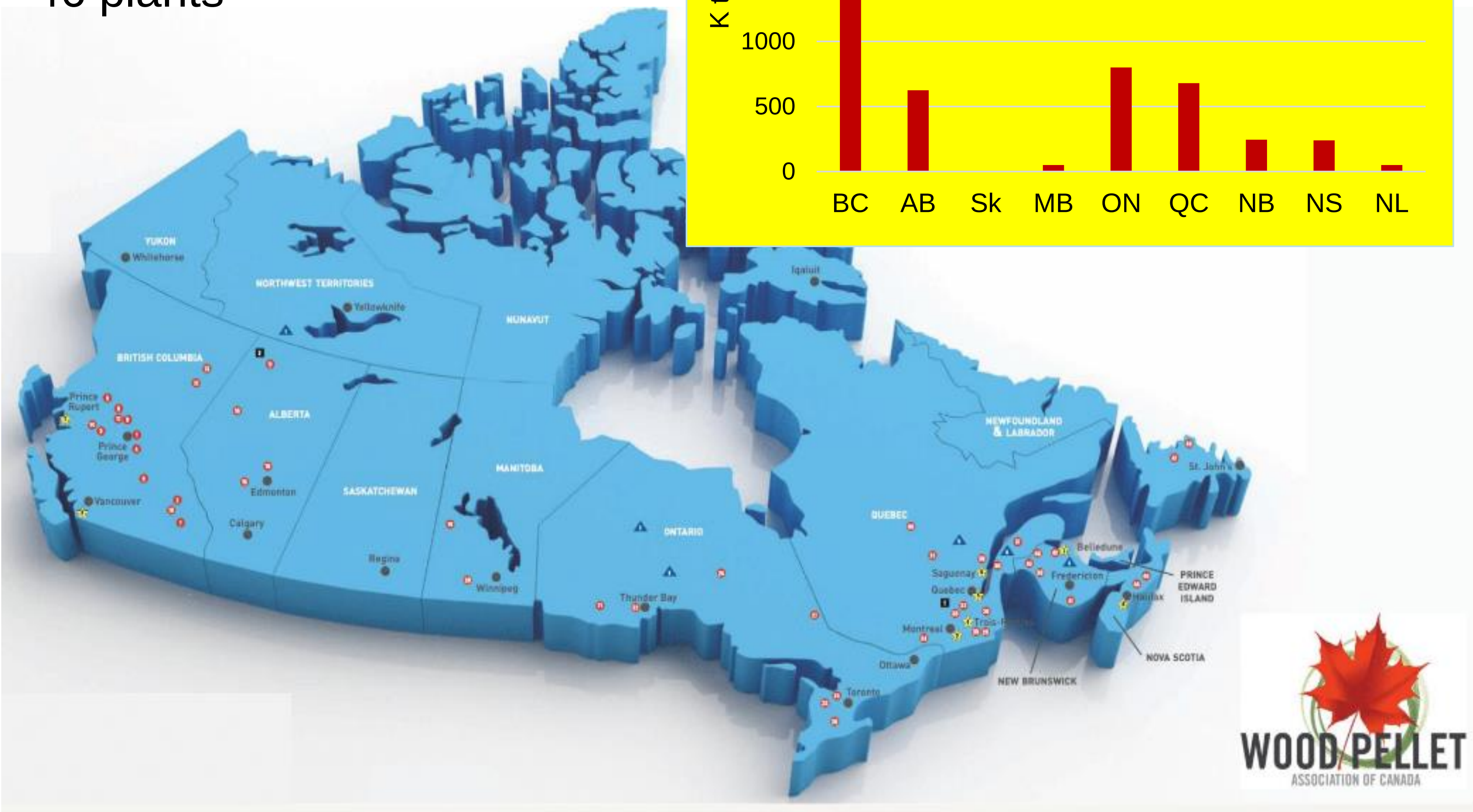
June 2, 2022
Biomass Canada Cluster Webinar Series

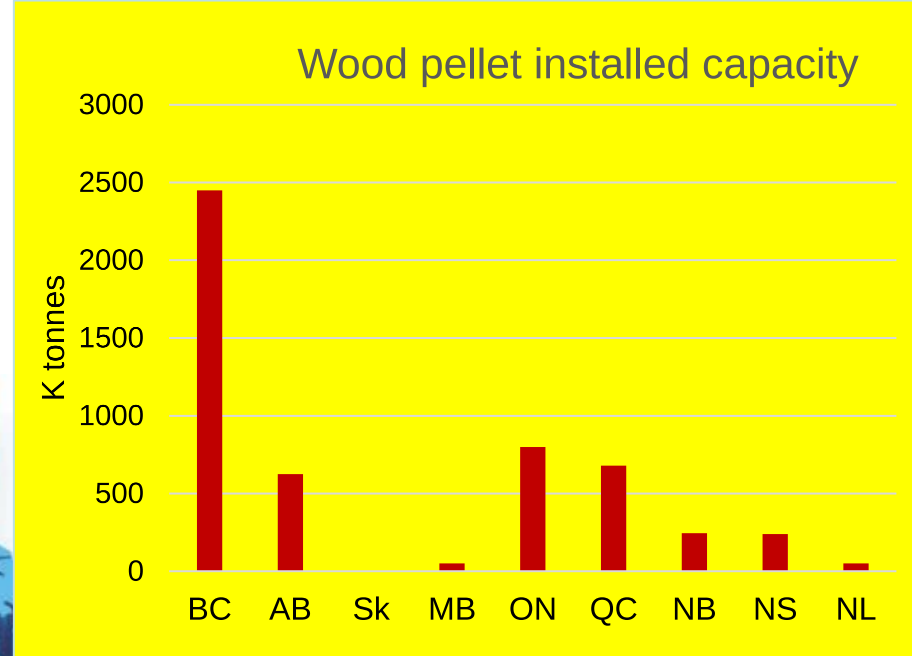
Acknowledgement

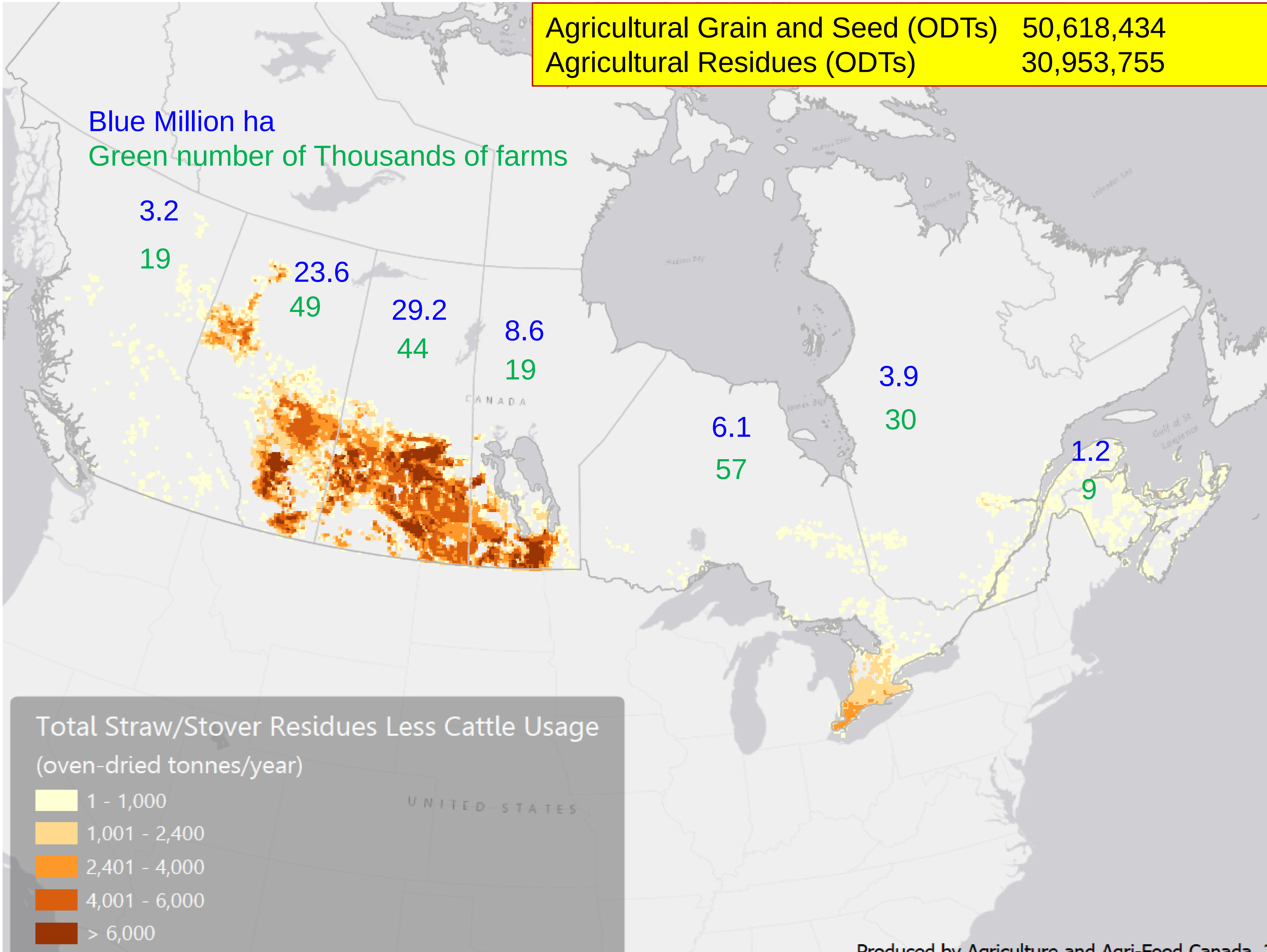
- Government of Canada under the Canadian Agricultural Partnership
- Biomass Cluster holder: BioFuelNet Canada
- Industry Partner: Wood Pellet Association of Canada
- GS Bioresource Systems

Distribution of wood pellet plants and production capacity in Canada

46 plants






Agricultural Grain and Seed (ODTs) 50,618,434
Agricultural Residues (ODTs) 30,953,755
Blue Million ha
Green number of Thousands of farms
3.2
19
23.6
49
29.2
44
8.6
19
6.1
57
3.9
30
1.2
9
CANADA
UNITED STATES
Total Straw/Stover Residues Less Cattle Usage
(oven-dried tonnes/year)
1 - 1,000
1,001 - 2,400
2,401 - 4,000
4,001 - 6,000
> 6,000
Produced by Agriculture and Agri-Food Canada,

Challenges to overcome to make ag pellets a sustained industry in Canada

- Ag pellets have a higher ash and chlorine content than wood pellets
- The natural binding in ag pellets is lower than that in softwood
- The yield of ag residue (tonnes/ha) is lower than wood reside
- The bulk density of baled biomass is much less than the density of chipped wood
- Agricultural farms are distributed around the country but most in Saskatchewan, Alberta, Ontario, and Quebec
- Distances between agricultural regions to export ports are long
- …..

Goal Statement

- The overall objective of Activity 12 is to evaluate the production and use of agricultural pellets as a feedstock for low carbon bioenergy and other bio-based products.

- Production of durable agri-pellets with consistent quality at affordable price encourages the use of currently underutilized agricultural biomass in the Canadian and international bioeconomy, contributing to the GHG emission reduction and generating economic activities in the farm communities.

Project Overview

Pelletized biomass has logistical advantages over other forms of solid biomass for transport and storage (pelletized biomass fits well to the Canadian grain and wood pellets production and distribution)

- **Logistics**- Optimize agri-pellet logistics and supply chains and estimate cost, energy input, CO2 emissions for agri-pellet enterprises (Led by Dr. Mahmood Ebadian)

- **Quality**- Develop commercial grade pellets in support of commercialization of agri-pellets (Led by Dr. Hamid Rezaei)

- **Storage-** Develop best practices and standards to minimize the degradation of biomass pellets during storage, handling, and transport (Led by Dr. Fahimeh Yazdanpanah)

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Development of Logistics, Pretreatment and Commercialization of Agri-Pellet

Agri-Pellet Logistics and Supply Chains

Dr. Mahmood Ebadian

Potential Uses of Agri-Pellets

- Export markets to supplement the current global wood pellets supply for bioenergy production (heat and power)

- Bioenergy production in Canadian farm communities, e.g.,
  - Grain drying
  - Space heating in residential buildings
  - Space heating in machinery shops, poultry and swine buildings

Agri-pellet supply chains evaluation for international markets

- An inter-continental agricultural pellet supply chain was modeled, and the production cost and price of agricultural pellets were estimated and compared against the recent cost and price of wood pellets in the global marketplace

- The integrated BIMAT-IBSAL model was applied to a case study in which agricultural pellets are produced in six locations in Canada and shipped and discharged at three major ports in Western Europe

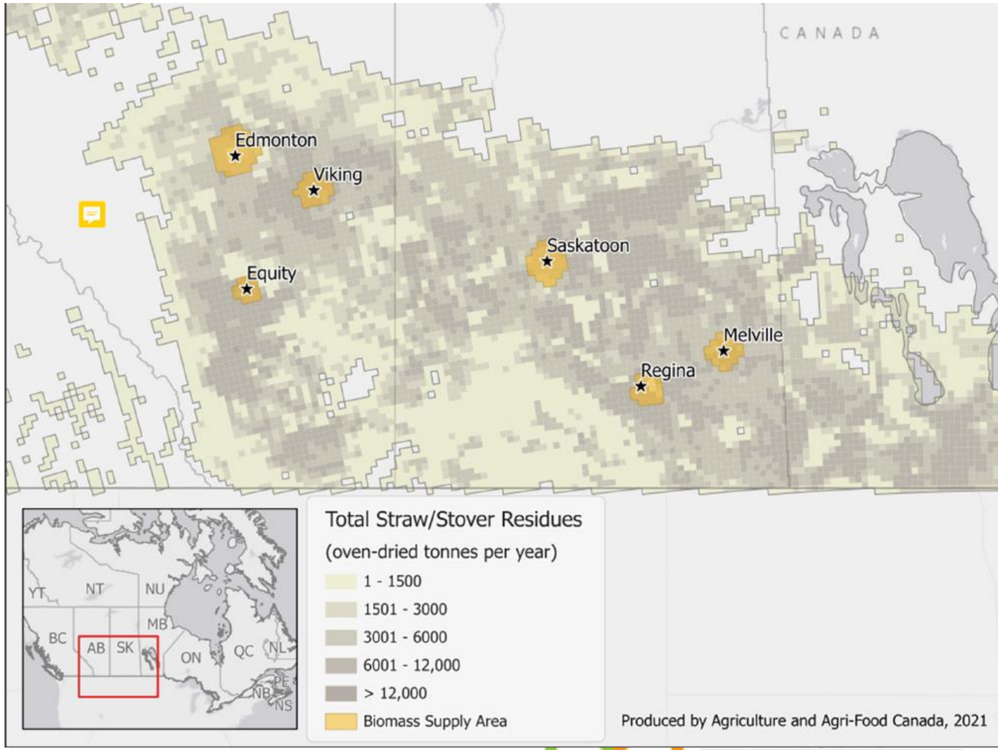

energies

MDPI

Article

Evaluating the Economic Viability of Agricultural Pellets to Supplement the Current Global Wood Pellets Supply for Bioenergy Production

Mahmood Ebadian [1,*], Shahab Sokhansanj [1], David Lee [2], Alyssa Klein [2] and Lawrence Townley-Smith [2]



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Propane vs. Biomass Burner for grain drying

The propane burner and grain dryer currently used by the farmer

Containerized Wood Chips Burner

Containerized Wood Pellets Burner

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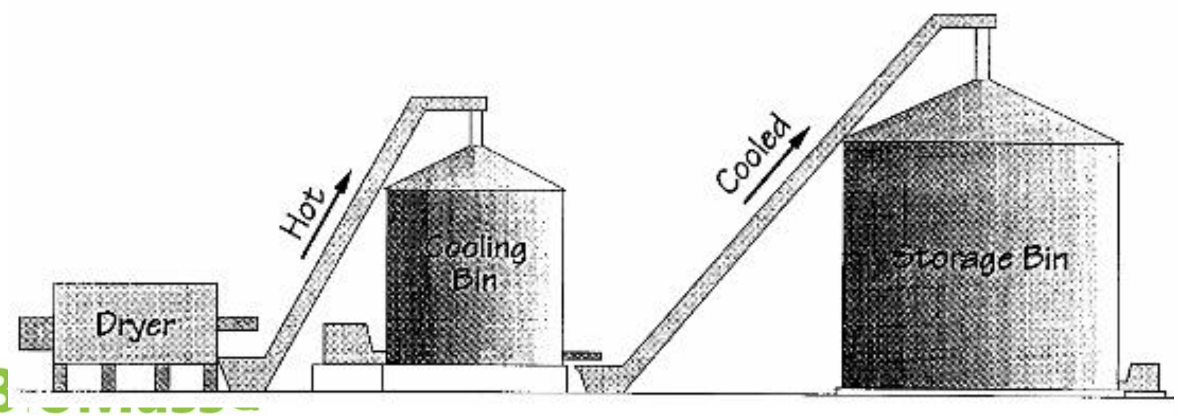
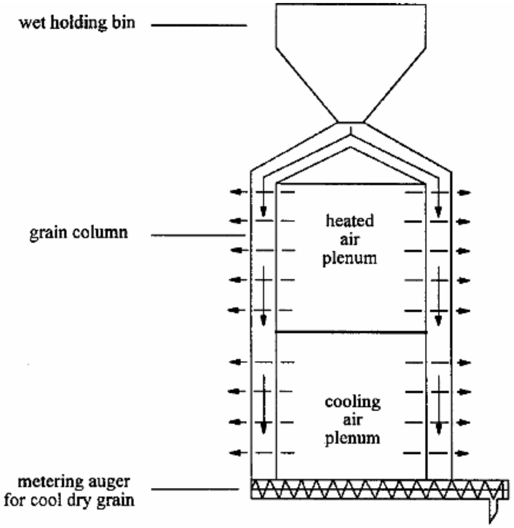
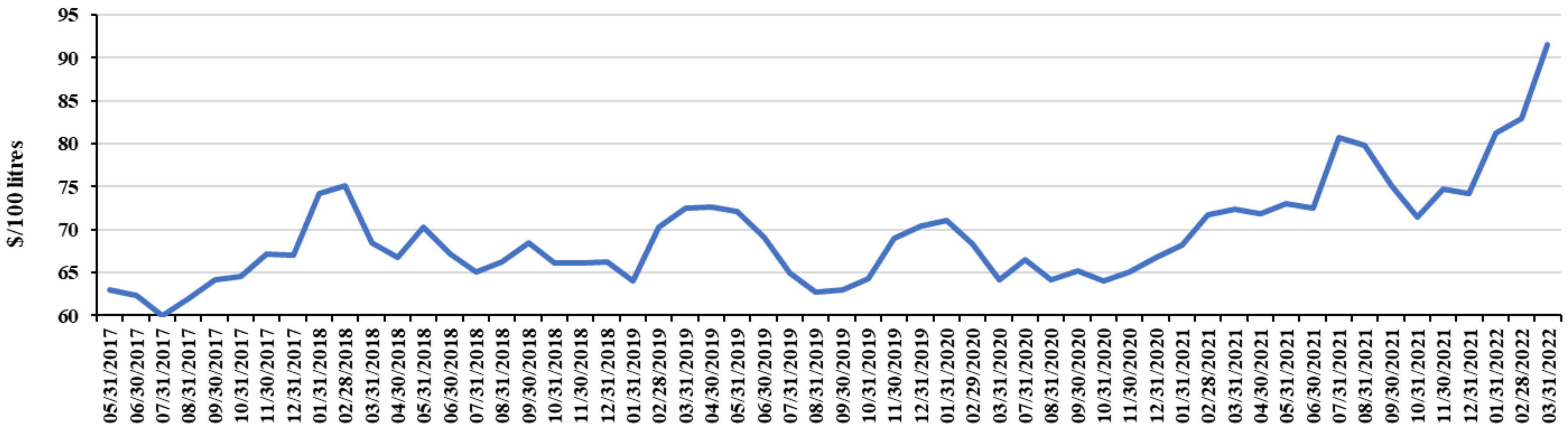
Evaluating the economic feasibility of replacing propane with biomass for grain drying- A scenario analysis

- Four scenarios:
  - Two scenarios are based on the recent increased price of fossil fuels and the possible changes in price of fossil fuels and biomass in the future
  - The other scenarios assess the impact of two policies on the drying cost including carbon pricing and a financial incentive program designed for sharing the cost of clean technology purchase and installation such as biomass burners



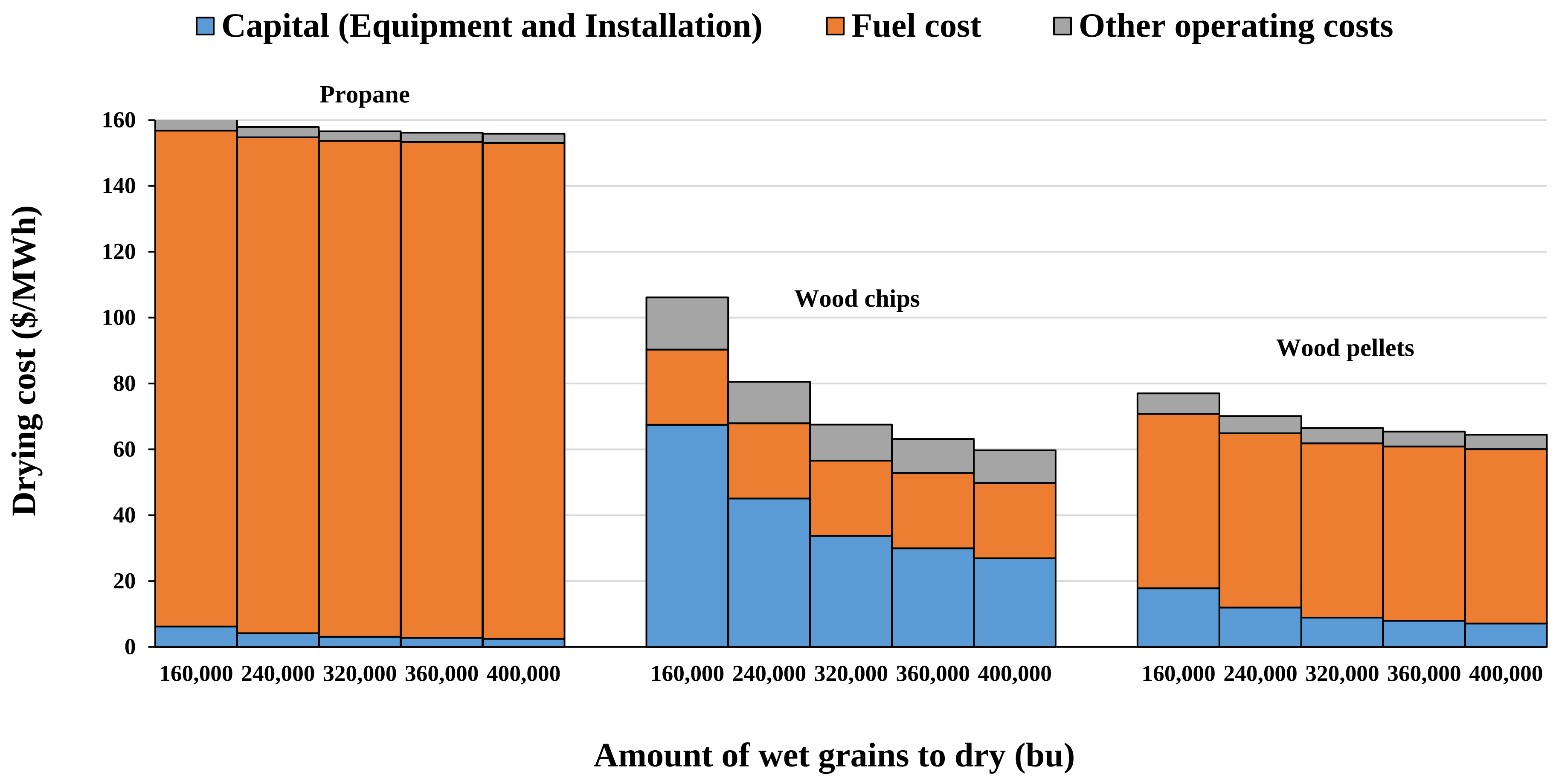


Market Price of Propane (2017-2022) and the impact of federal carbon pricing

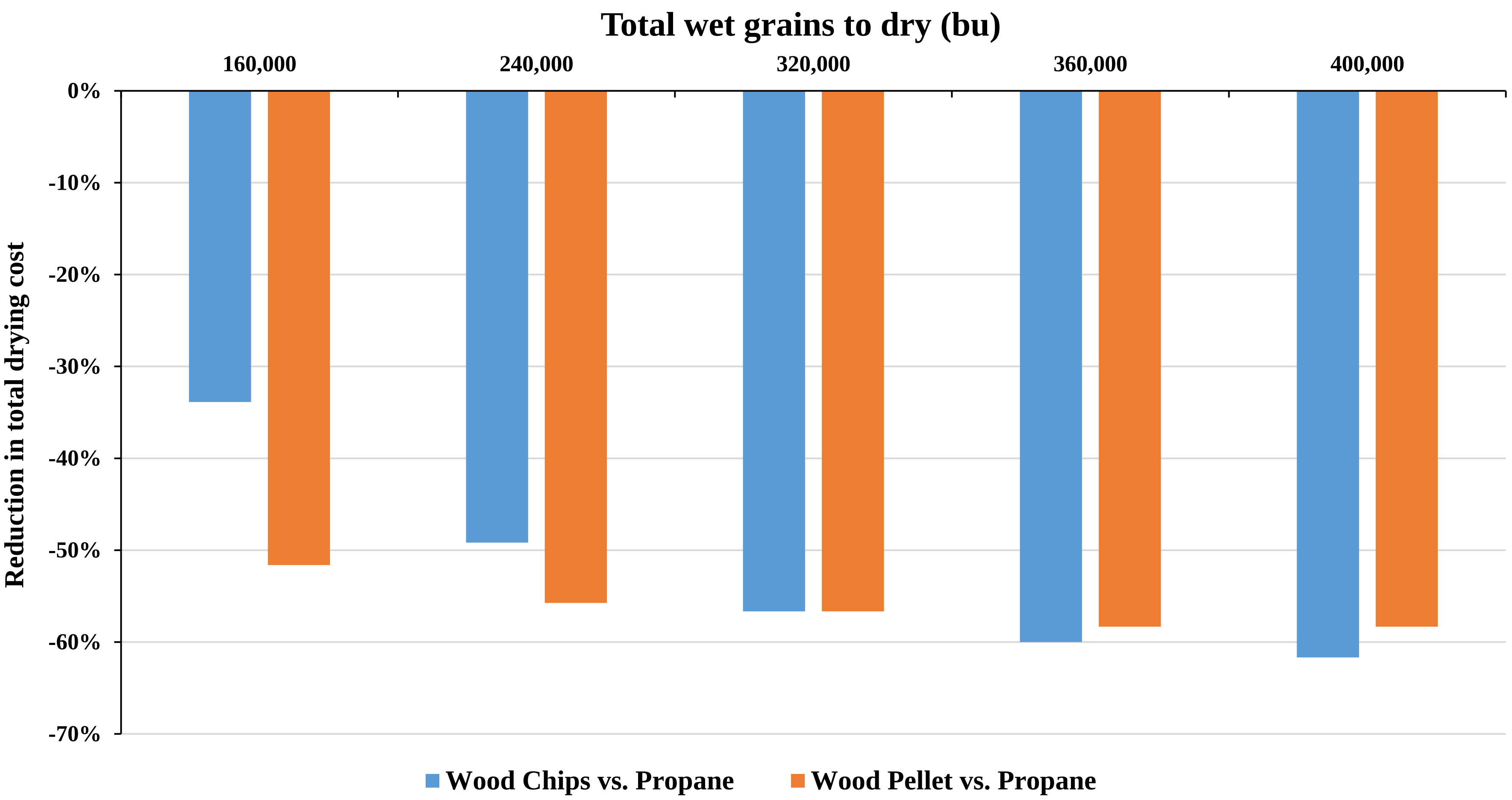


Year	Carbon Pricing (tCO2eq)	Propane Price ($/L)
Pre-2019	$0	$0.90
2019	$20	$0.93
2020	$30	$0.95
2021	$40	$0.96
2022	$50	$0.98
2023	$65	$1.00
2024	$80	$1.02
2025	$95	$1.05
2026	$110	$1.07
2027	$125	$1.09
2028	$140	$1.12
2029	$155	$1.14
2030	$170	$1.16

Drying cost ($/MWh) using propane, wood chips and wood pellets burners for drying various amount of wet grains



Reduction in drying cost (%) using wood chips and wood pellets burners compared to the propane unit



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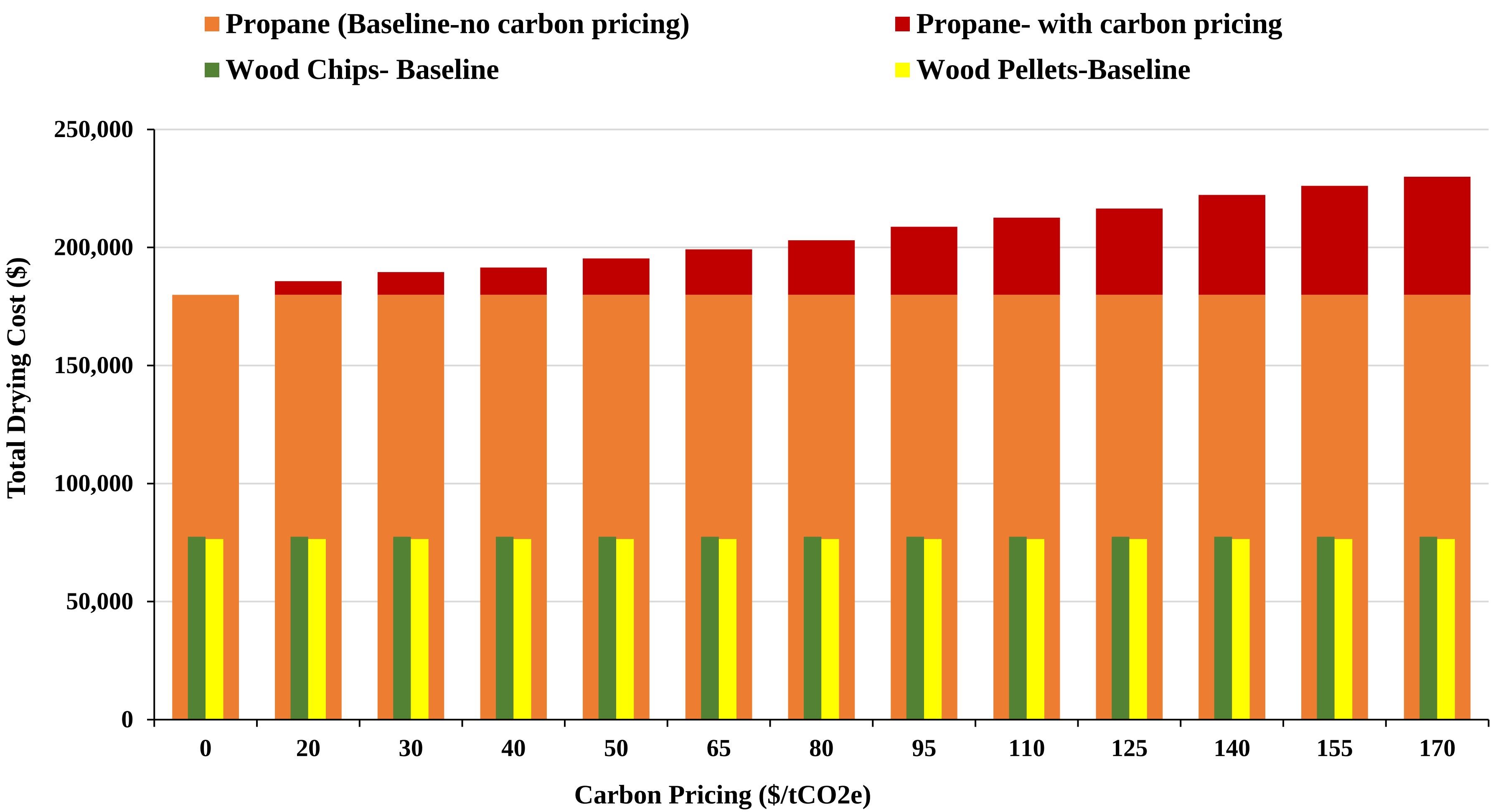
Impact of federal carbon pricing on grain drying cost



Agri-pellet supply chains evaluation for domestic markets- Grain Drying

Summary of Main Findings

- Under all scenarios, biomass burners are more economic options than propane burners for grain drying
- In the baseline scenario (no carbon pricing/financial support), a cost reduction in a range of 34-62% can be achieved by using a wood chips burner instead of a propane burner. This reduction is estimated to be 52-58% for wood pellet burners versus the propane burner.
- Every $10/tCO2e increase in the carbon pricing adds about 1.7% to the total drying cost for propane burner. This further increases the cost saving by switching from propane to biomass as no carbon pricing is applied to biomass as a renewable energy source.

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Development of Logistics, Pretreatment and Commercialization of Agri-Pellet

Collecting Agri-Pellet Production Data

Dr. Hamid Rezaei

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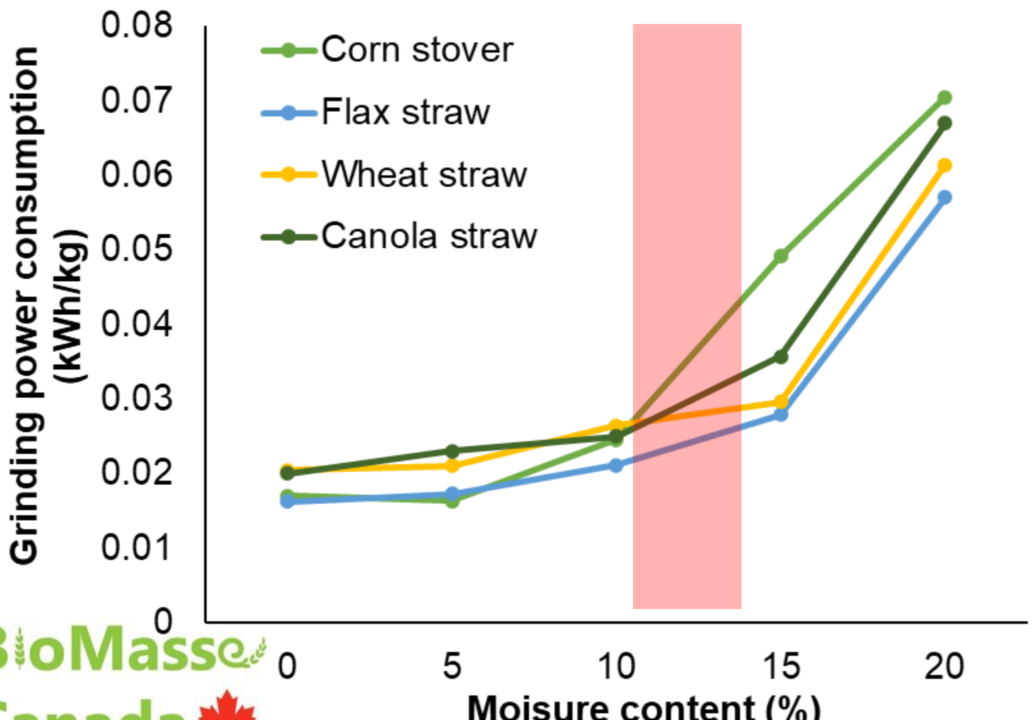
Commercialization Barriers

Our research is oriented around the following challenges of agricultural residues to be used as a commercial bioenergy feedstock:

1) ***Variability*** in physical properties
2) Ag-residues are ***difficult to grind***, and ground biomass has poor flowability.
3) Excessive Chlorine, K, in some cases silica, and ***ash*** content (biogenic and environmental)
4) Lack of ***lignin*** as a binder to make durable pellets without additives
5) Little ***experience*** on commercial handling of ag-material for pelletization, and most of operations are farm based

Size Reduction – Effect of Moisture

- Collected four species of corn stover, wheat straw, switchgrass and flax straw from various regions of Canada.
- Ground them in a hammer mill and observed their grindability at moisture contents of 0% to 20%.
- Moistening from 0% to 20% does not change the size distribution meaningfully. But increases the grinding energy consumption.



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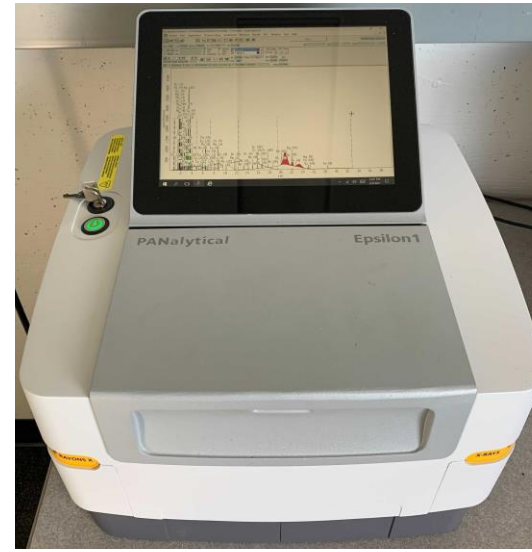
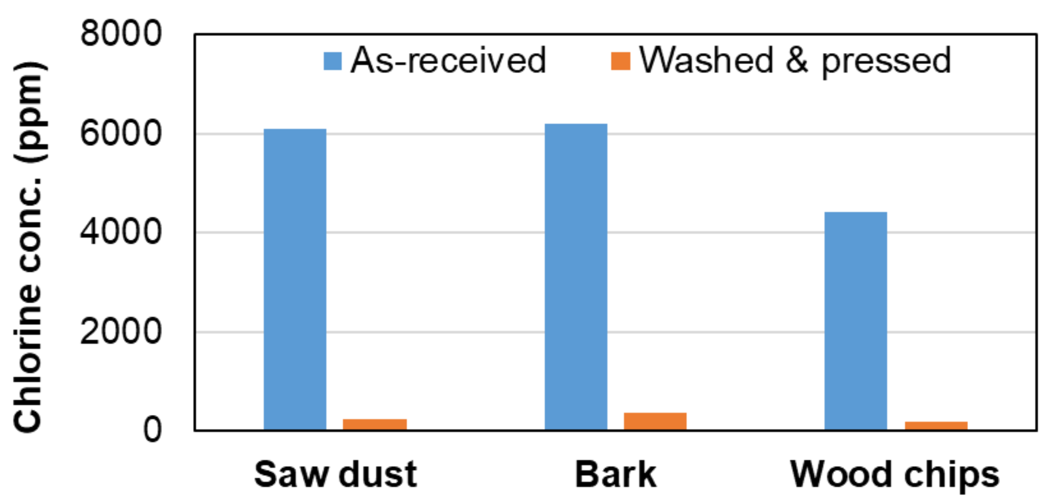
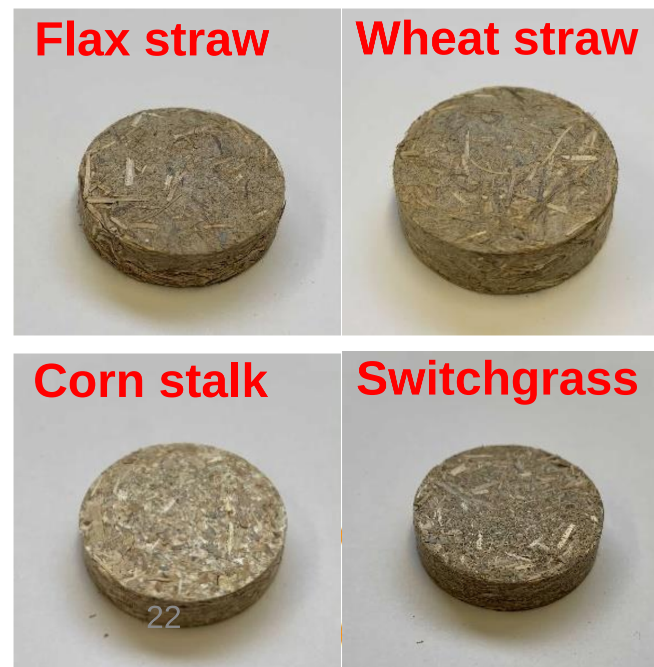
Mineral Content

- Mineral content is critical to show the biomass potential for power generation applications.
- Measurements on high-chlorine content woody biomass proved the efficiency of washing and pressing in biomass demineralization.
- We developed a standard operating procedure at this stage and used it for ag-samples.







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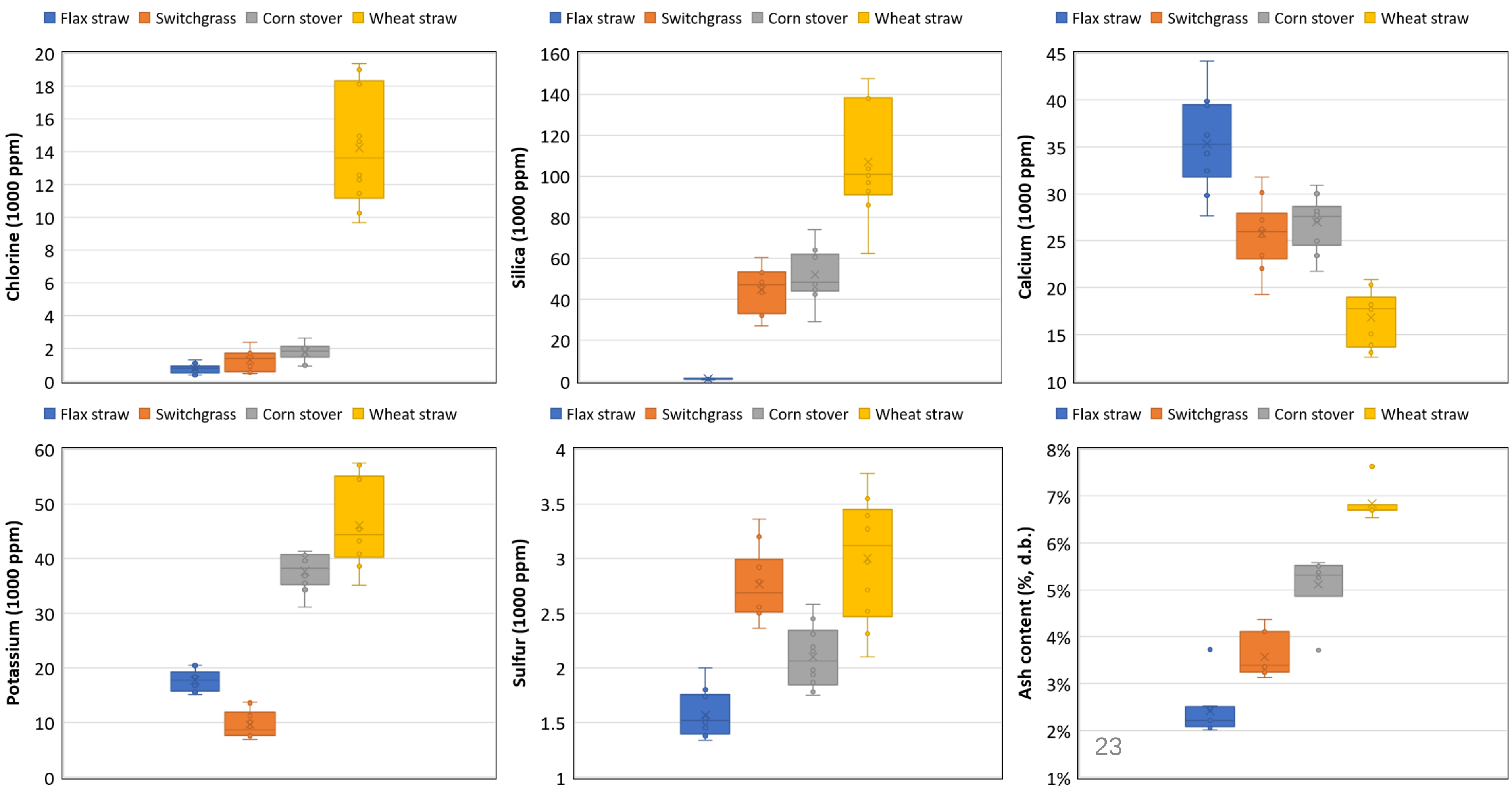
Elemental Composition

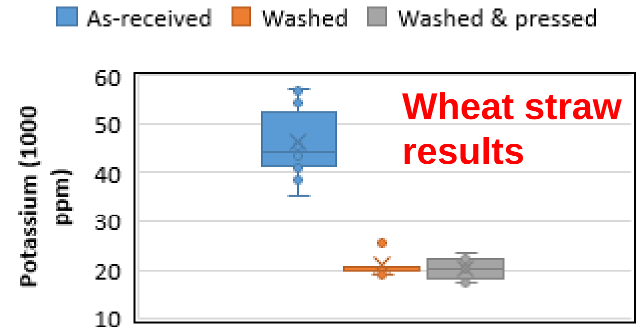
- All ag-residue samples need **demineralization** process to meet the standard requirements.
- Wheat straw has higher chlorine and ash than other tested samples.

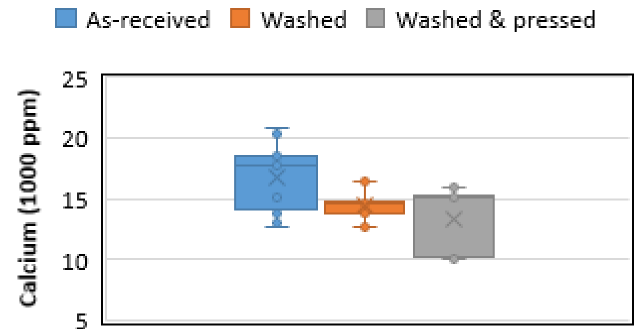


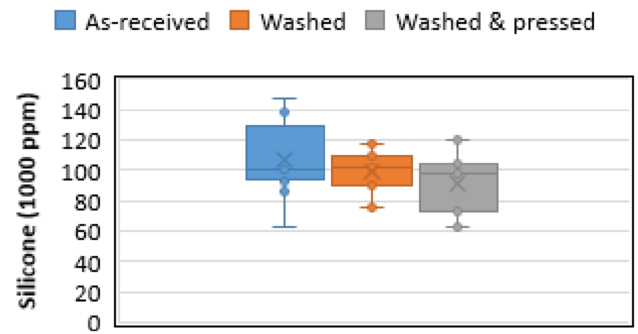
Washing & Pressing

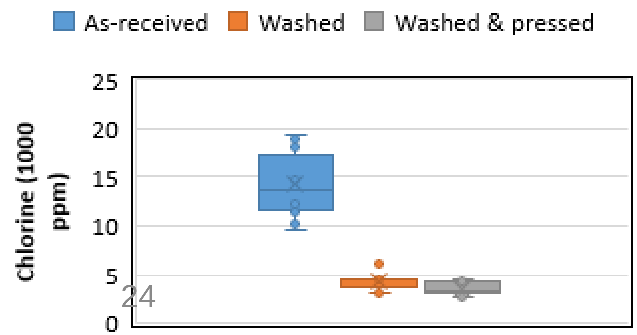
- We washed the samples for 5 minutes and then pressed it using a hydraulic press.
- Washing reduced the chlorine and potassium but the reduction in silicone and calcium was not significant.

	Elements	As-received	Washed	Washed & pressed	%Removal from as-received
Flax straw	Cl (ppm)	427.1	177.8	89.0	79%
	Si (ppm)	1753.1	1568.9	2063.8	10%
	K (ppm)	17021.9	8578.7	9956.7	41%
	Ca (ppm)	35521.3	30954.2	32178.1	9%
	Ash (%, d.b.)	**2.5**	**1.9**	**1.9**	**25%**
Wheat straw	Cl (ppm)	14403.75	3610.7	2980.7	79%
	Si (ppm)	91818.7	103855.0	98648.4	7%
	K (ppm)	46434.35	19944.3	18759.6	59%
	Ca (ppm)	15957.7	14772.1	15048.0	5%
	Ash (%, d.b.)	**6.9**	**5.8**	**5.7**	**18%**



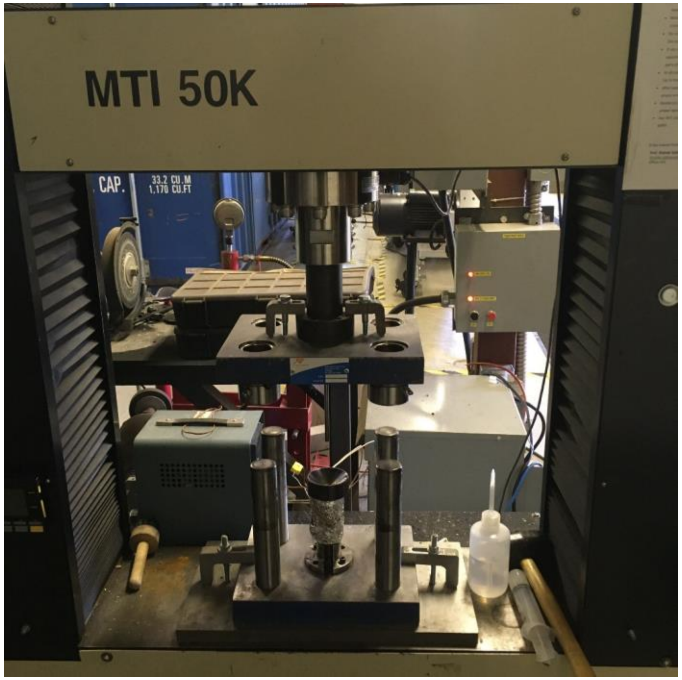


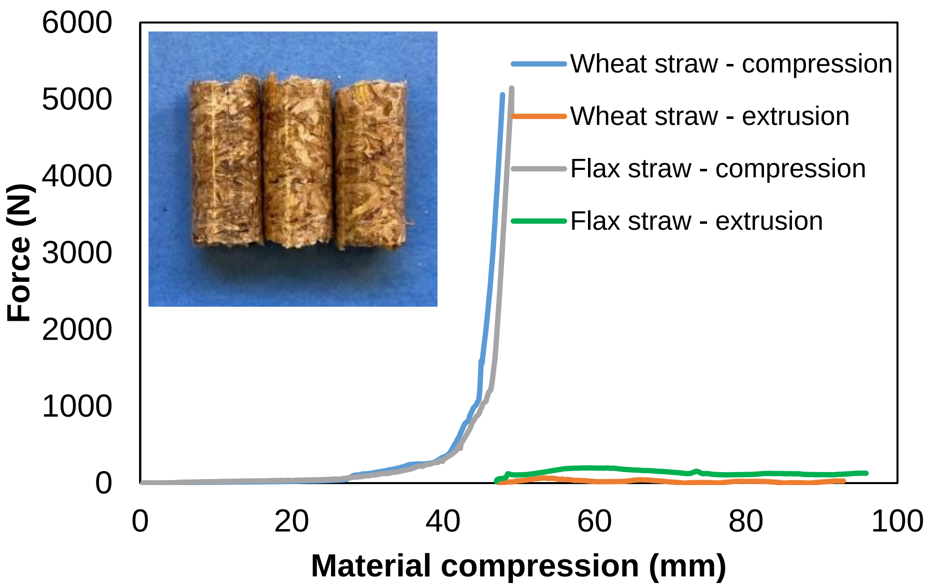


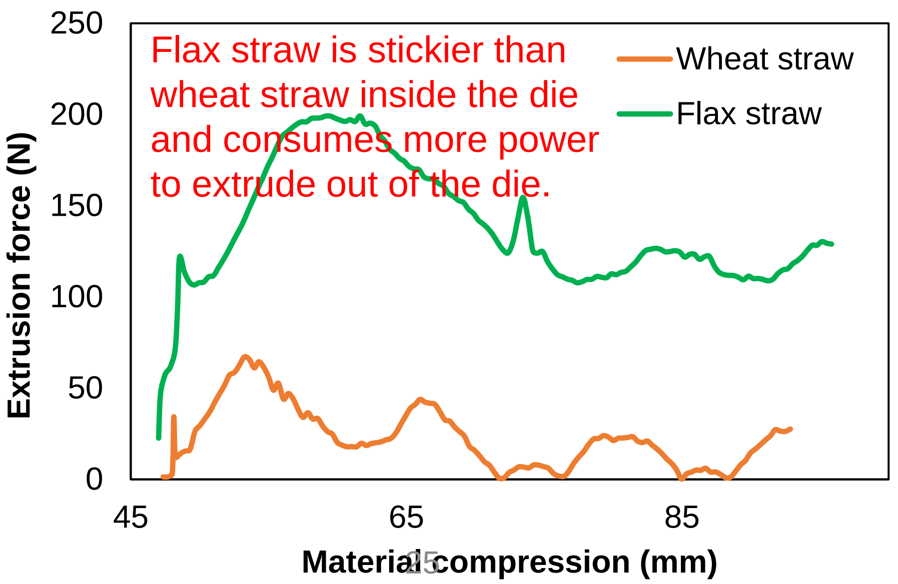


Single Pellet Testing

- We used a fully-controlled MTI unit to measure required power to form a single pellet.
- Extrusion force analysis is crucial to study the effect of lignin addition on compression behavior of material.

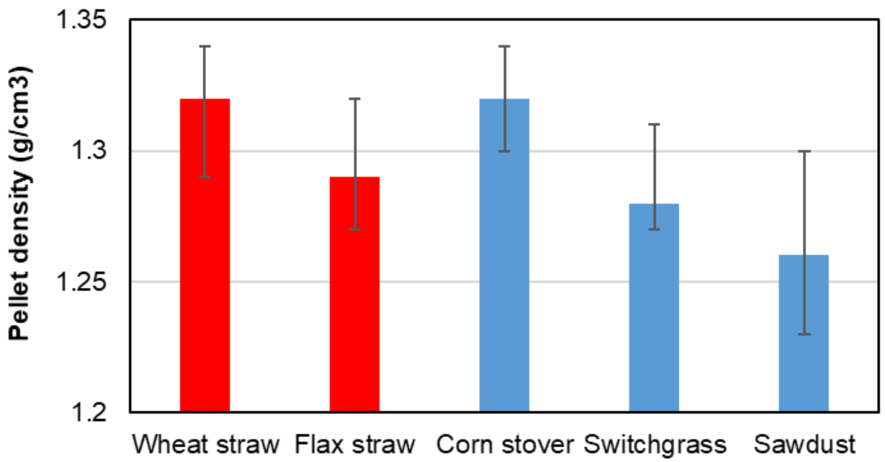


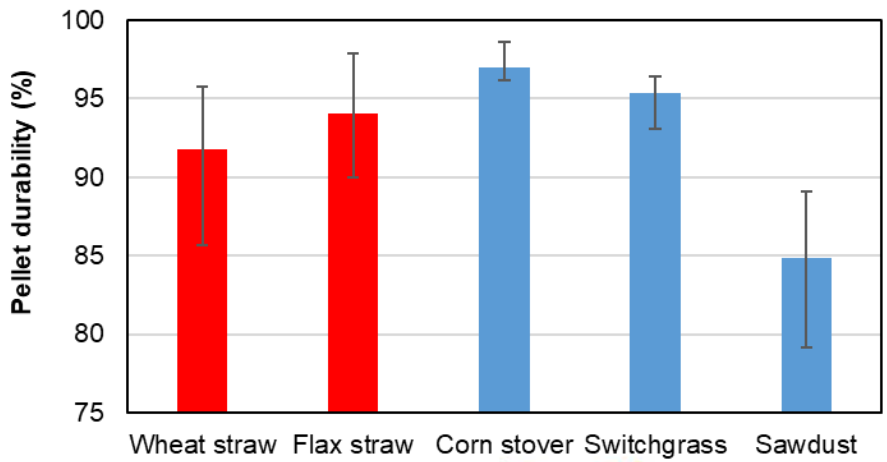




Pellet Properties

- Density of all pellets meet the ISO standard of **1.25 g/cm³**.
- Durability of all pellets are higher than 92%. It does not meet the ISO standard (**>97.5%** for grade A; **>96%** for grade B)
- Pellets made by industrial pellet mills are expected to be more durable than single pelletizer.
- Also, tumbler durability tester (referred in ISO) measures higher durability values than single pellet durability tester.





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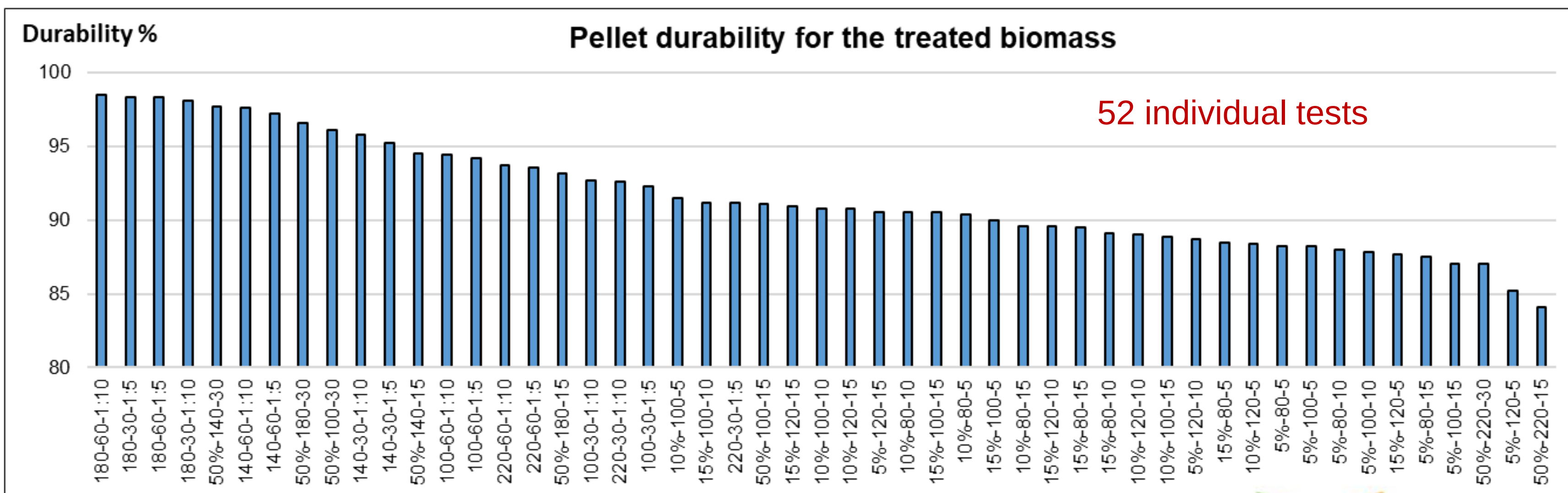
In search of biomass treatment to meet the durability specifications

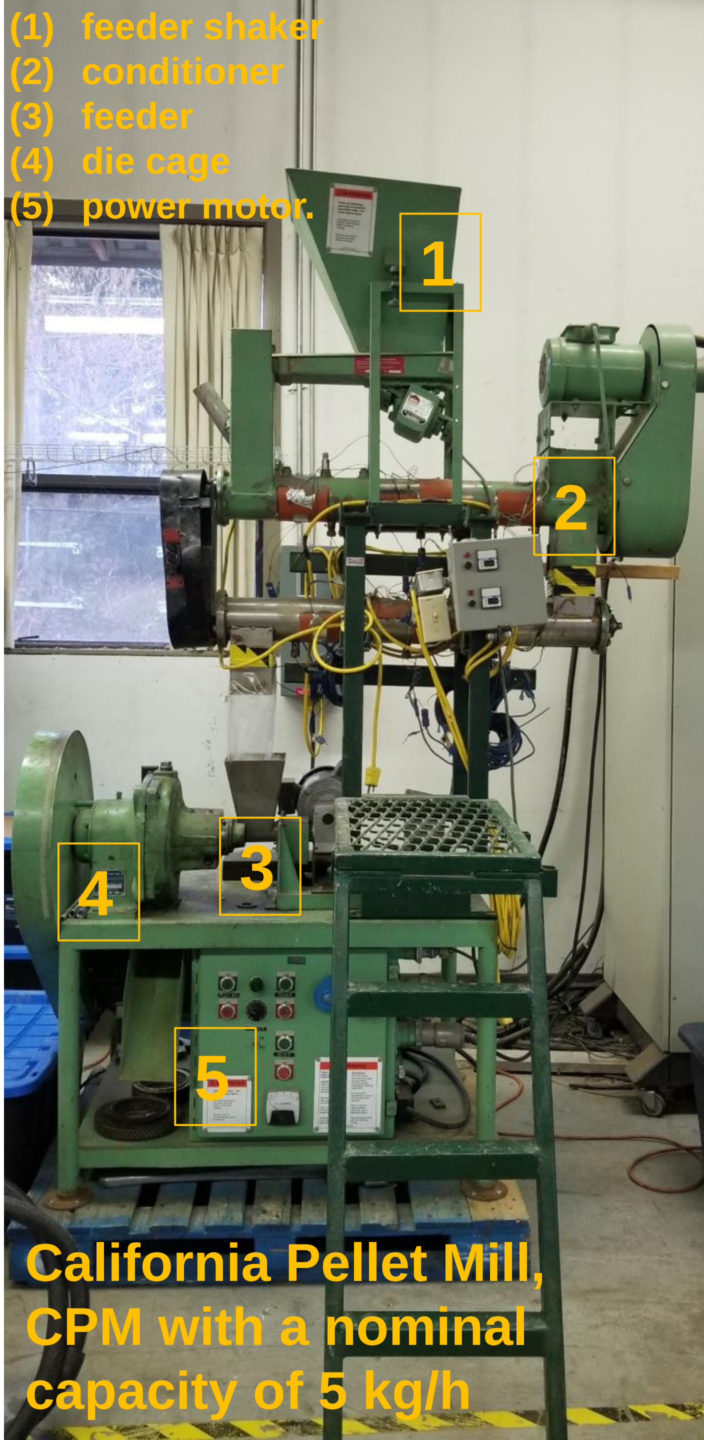
Exp.	Description of experiment	Variables
1	Dry biomass exposed to continuous steam	Biomass: wood chip, wheat straw, timothy hay, canola Temperature: 135 °C Time: 90 min
2	Biomass with certain moisture exposed to dry heat (low temperature)	Moisture content: 5, 10, 15% Temperature: 80, 100, 120 °C Residence time: 5, 10, 15 min
3	Biomass with 50% moisture exposed to dry heat (high temperature)	Moisture content: **50%** Temperature: 100, **140**, 180, 220 °C Residence time: **15** and 30 min
4	Dry biomass treated in water (hydrochar)	Biomass-to-water ratio of 1:5 and **1:10** Temperature: 100, 140, **180**, 220 °C Residence time: 30 and **60 min**

The optimum treatment temperature depends on the way the material has been treated.



Continuous Pelletization

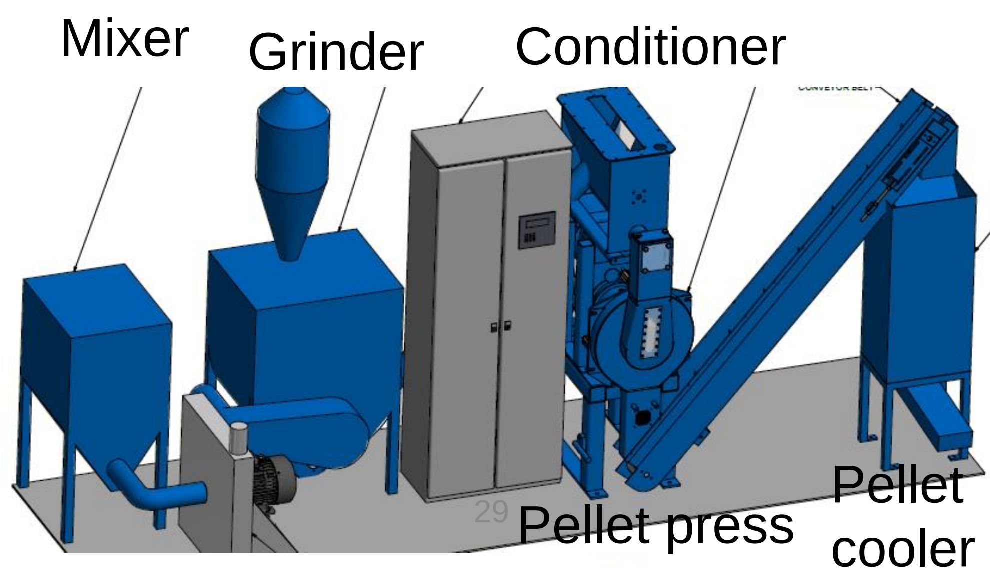
- We study the influence of particle size, moisture content and feeding performance on pelletization process.
- Grinder screen of 1/8” and 10%-12% are the minimum condition for forming pellets.
- Material flowability has been a major barrier in pelletization in CPM machine.
- We will test the effect of steam conditioning and adding binder to improve the process.



Pilot Scale Pelletization

- The pilot pellet mill (SPC, 150 kg/h) is moved to Alberta, FourPeaks farm.
- We did partial CSA certification process at university, and it is completed by our partner.
- We will collaborate with our industrial partner to produce durable pellets and collect production data to revise the supply chain model developed in task 3 of this activity.

Mobile pellet plant in the container



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Lessons Learned from Agri-biomass Characterization

- Lower moisture content reduces the grinding energy consumption. We suggest an initial cutting and shredding the ag-residue instead of hammering it.
- Washing and pressing reduces 80% of the chlorine and 50% of the potassium, but the reduction in silicone and calcium is not significant.
- Other demineralization technologies should be further studied to push the pellet quality closer to ISO standards.
- Flow and uniform feeding of ground ag-biomass is a major challenge in continuous CPM pelletization that was originally used for woody biomass.
- Steam conditioning and adding binder might be the solution of making durable ag-pellets that we will experiment in the future.

Safe Storage and Handling of Commercial Biomass Pellets

Fahimeh Yazdan Panah

Pellet quality throughout the supply chain and compliance (standard development)

Director of Research and Technical Development, Wood Pellet Association of Canada

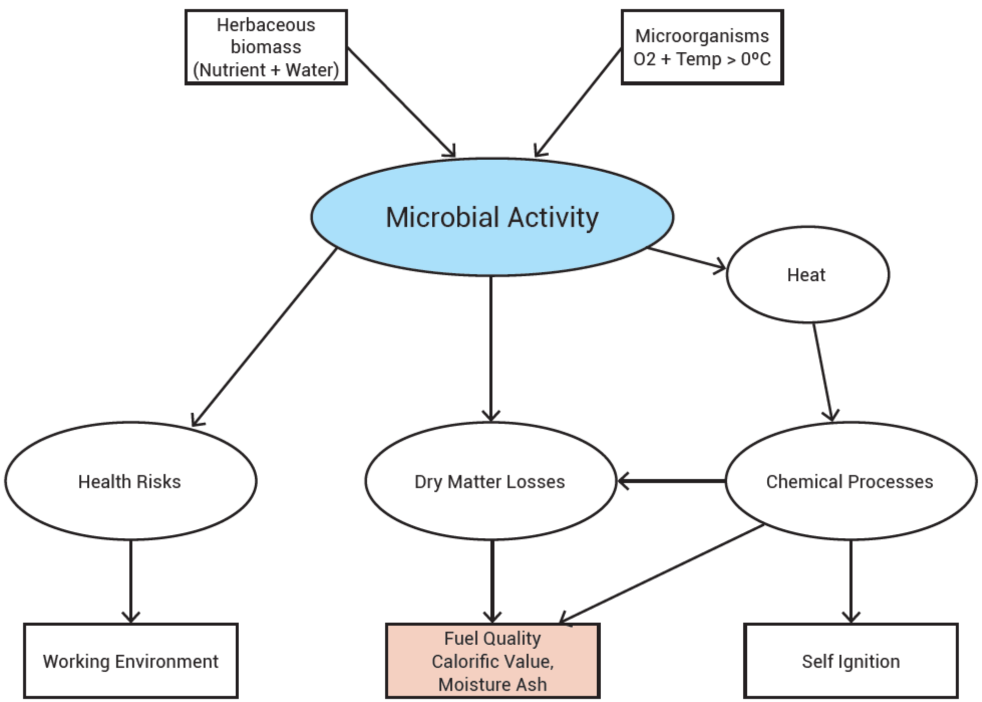
Research Associate, University of British Columbia

Approach & Technical Progress

- Storage is a critical factor in commercial ag pellet production and use as the seasons are short
- Self-heating, off-gassing and oxygen depletion are determinants for Safe storage of biomass pellets
- Determine parameters that contribute to self heating during storage and to understand the contribution of heat release due to different processes such as auto oxidation, moisture addition as well as temperature and humidity changes
- This task is done through experimental work while a modeling on self heating is also done and reported in Task 1 (presented by Dr. Hamid Rezaei)
- Develop methods to measure agricultural pellet properties and their compliance with the international standards (ISO TC 238)

Herbaceous Biomass Deterioration

The sequence of operations for handling of baled herbaceous biomass from the farm to the storage site



Processes involved in deterioration of herbaceous biomass during storage

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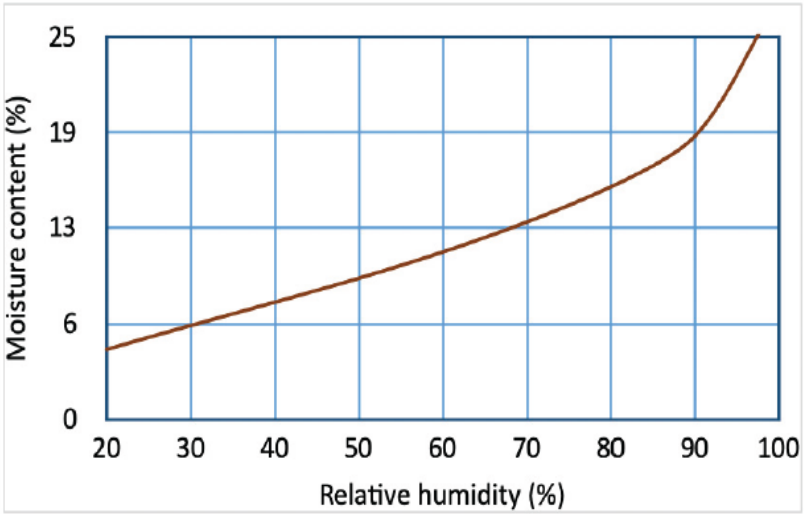
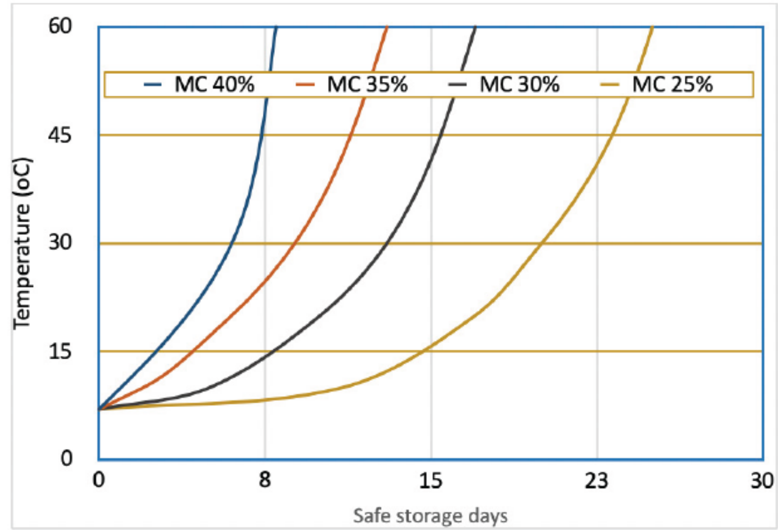
Herbaceous Biomass Deterioration



Relationship between the relative humidity of the air and moisture content of herbaceous biomass



Moisture content and temperature of herbaceous biomass have a large influence on safe storage duration

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Heat Release During Storage (Reactivity)

- We used the calorimetry method to measure the amount of heat released from biomass during storage.
- Thermal Activity Monitor (TAM) and Rh perfusion capability of the system was used.
- We developed the procedure for reactivity measurement in 2020-21.
- In 2021-2022, we continued using the developed procedure for testing all agricultural samples received.
- Evaluated the effect of oxygen availability, storage temperature and humidity level change and exposure time, wetting and age of sample during short term and long-term storage (self-heating contributors).

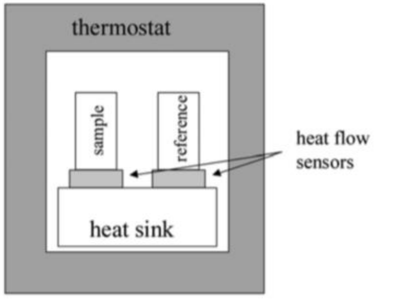

Figure 1 - Schematic drawing of an isothermal calorimeter

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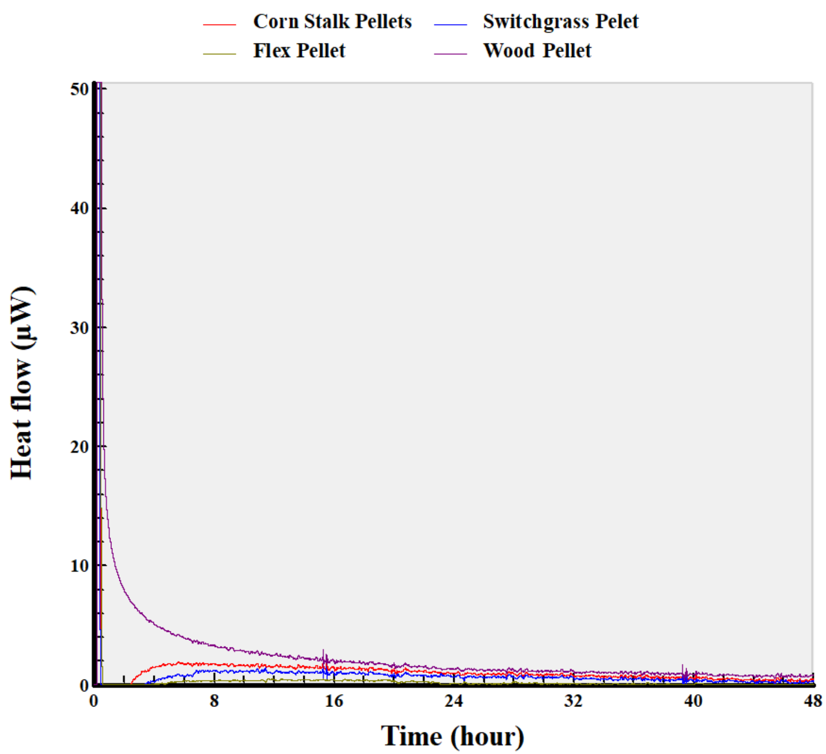
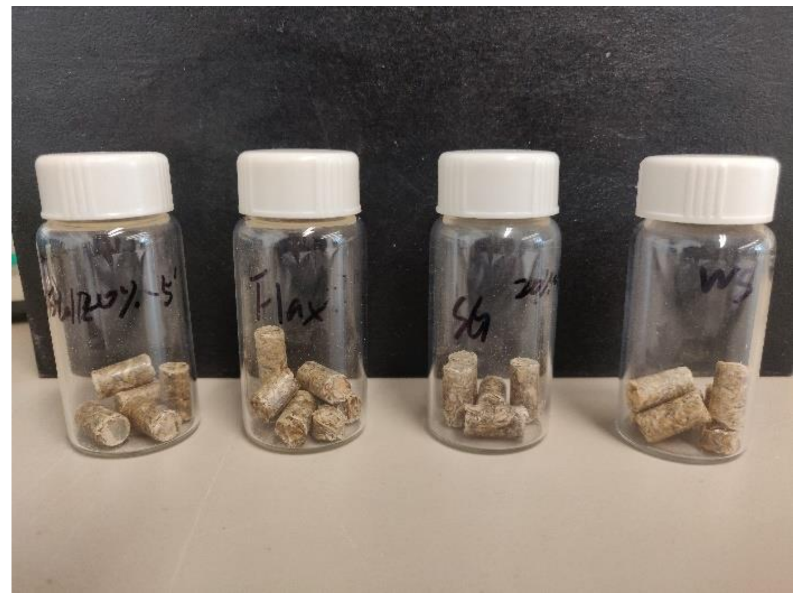
Heat of Oxidation



Released heat from switchgrass pellet, corn stalk pellet , flax straw pellets as well as wood pellets stored at 40° C during 48 hrs of storage



Agricultural Pellets made using MTI machine

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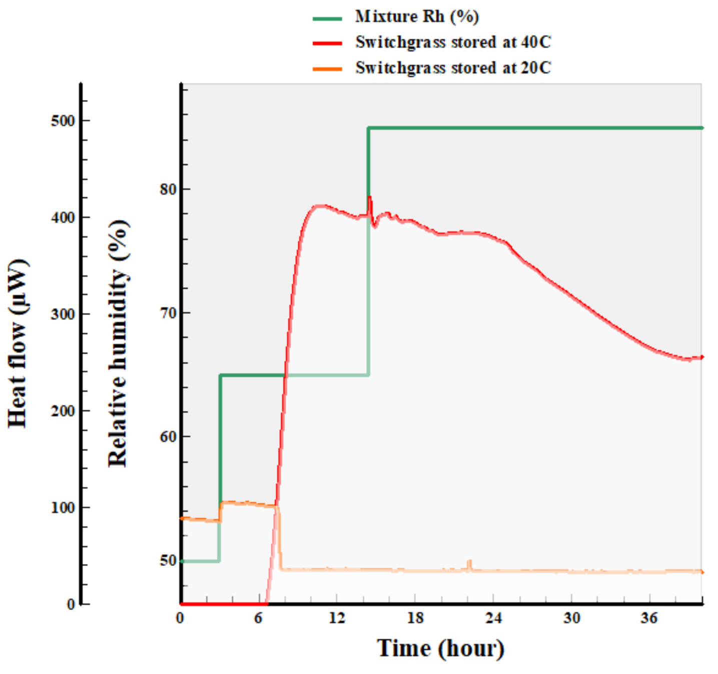
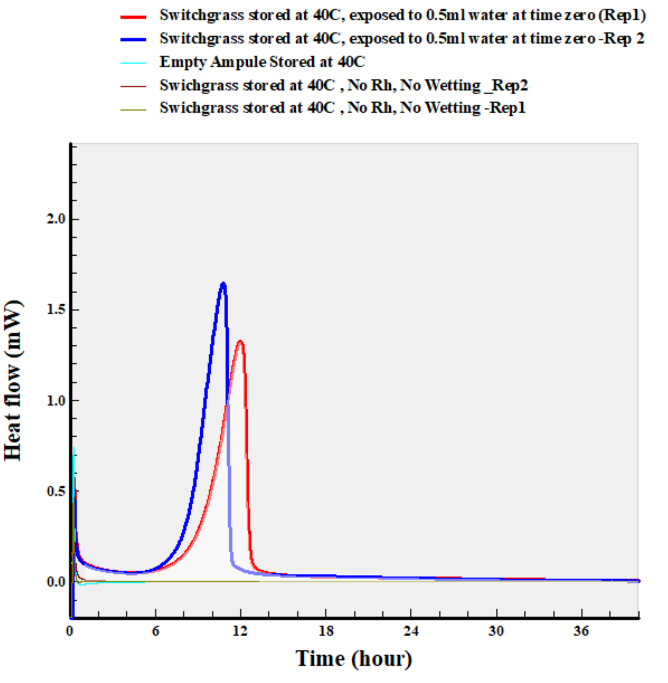
Heat Release- water vapor adsorption and water uptake





Q= **16.25 J/g** (Switchgrass stored at 20C and exposed to Rh of 50 to 85%)
Q= **96.47 J/g** (Switchgrass stored at 40C and exposed to Rh of 50 to 85%)

Q= **38.3 J/g** when switchgrass was stored at 40C and exposed to **0.5ml water**
Q= 0 J/g when switchgrass was stored at 40C, no Rh, no wetting

Reactivity Results

- The results so far have consistently shown agricultural pellets reactivity (heat of oxidation) is far less than wood pellets (Ag pellets are made using single pelletizer). This will be repeated using pellets made by SPC unit (demonstration unit).
- From the parameters tested so far, wetting and humidity have shown to have the greatest impact on agricultural pellet reactivity.
- Dry matter loss, deterioration of fuel quality like loss of calorific value and heat accumulation may ultimately lead to spontaneous ignition.
- Moist ground biomass tends to contain high concentrations of bacterial particles and fungal spores creating an undesirable storage environment.
- Biomass bales should be placed on dry, level ground close to and along the transport road. The ground should be free of stumps, stones, and large residues.

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Relevance

- Understanding of the technical and economic aspects of agri-pellets production and use for applications such as grain drying is critical to help farmers accelerate the transition from fossil fuels to locally produced biomass resources.
- The developed IBSAL simulation model in this project allows farmers to compare and contrast the fossil fuels they are using for operations such as grain drying versus the use of biomass
- Ash and mineral reduction improves the combustion properties of biomass
- Hydrothermal pretreatment of biomass makes the pellets durable

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Critical Success Factors

- Identify the processes that need to be improved in the production of agri-pellets to make them comparable with commercial wood pellets from a quality standpoint

- Understand the economics of agri-pellet production and use in comparison with other available feedstocks such as wood pellets

- Understand the storage and handling behavior of agri-pellets in the commercial settings in order to fit them into the existing grain and wood pellets supply chains.

Work to be completed by March 2023

- Produce ag-pellet in pilot scale on the farm and understand/compare the product quality with the lab scale palletization (in collaboration with activity 13)
- Compare and contrast the properties of agri-pellets vs. wood chips and wood pellets for grain drying
- Conduct techno economic analysis of washing and hydrothermal treatments
- Evaluate effect of other contributors to self-heating including ag pellet porosity and pore size and volume

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Thank you!

Q&A

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