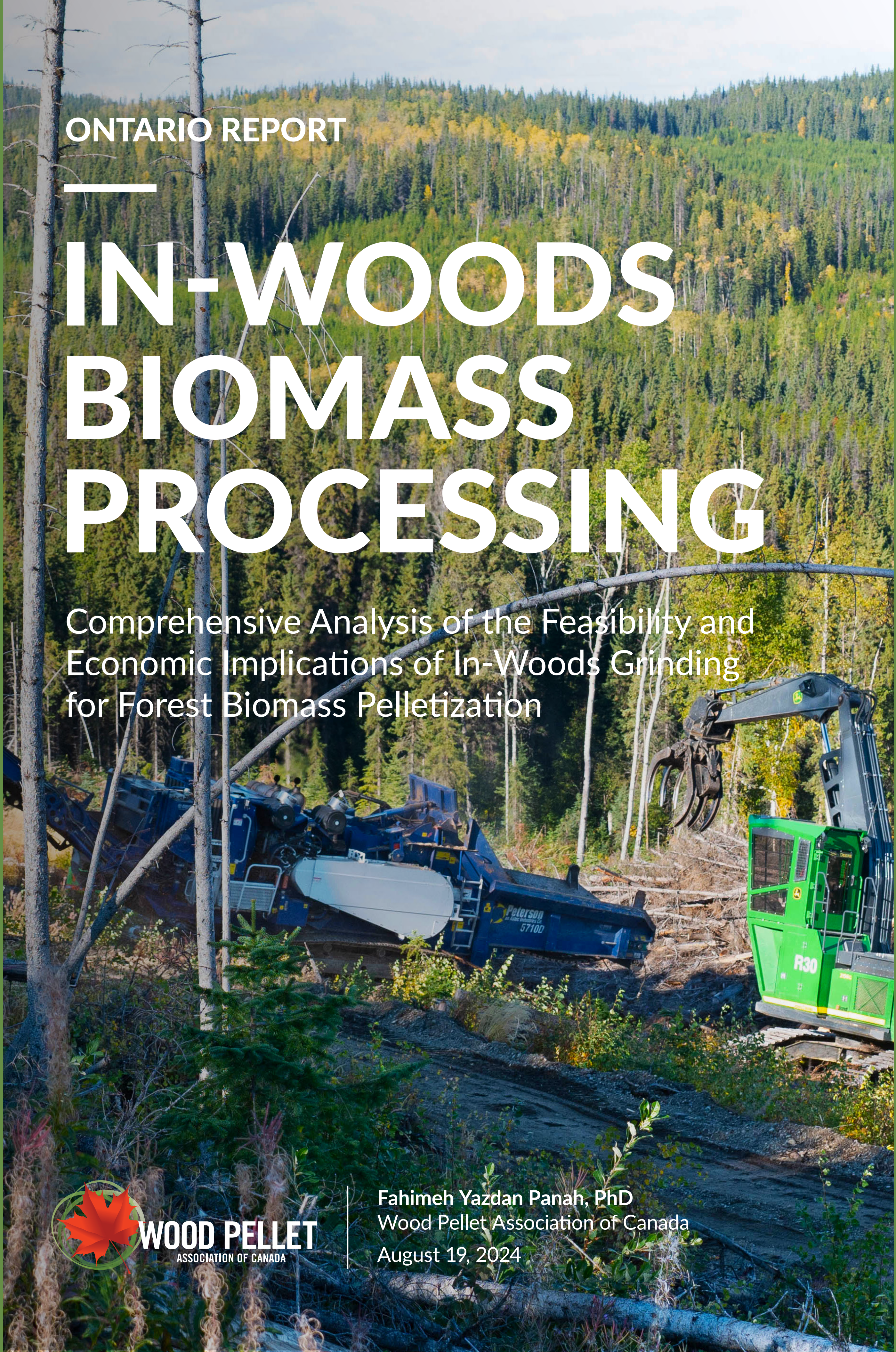
ONTARIO REPORT

IN-WOODS BIOMASS PROCESSING

Comprehensive Analysis of the Feasibility and Economic Implications of In-Woods Grinding for Forest Biomass Pelletization



WOOD PELLET ASSOCIATION OF CANADA

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EXECUTIVE SUMMARY

The Ontario wood pellet industry is moving from an exclusive dependency on sawmill residues to the utilization of forest biomass as a primary raw material. This pivotal transition is driven by a growing global demand for renewable energy sources such as pellets and the increased use of forest residues that were once left behind or burned on site after harvesting. While it offers promise, forest biomass also presents challenges such as contamination, variability in ash and moisture content, and higher processing costs, which need to be carefully managed to ensure the economic viability of wood pellet production.

In 2024, the Wood Pellet Association of Canada (WPAC), in partnership with BioPower Sustainable Energy Corporation (BioPower), conducted a comprehensive analysis of the feasibility and economic implications of using an in-woods grinder to process forest biomass so it can be used for wood pellets. BioPower, a Canadian manufacturer of commercial and residential grade wood pellets, carried out all the field tests at its operations in Northern Ontario near Atikokan, including the collection and analysis of feedstock samples, pelletization, and data collection. Its expertise and hands-on involvement helped to validate the economic and technical feasibility of using forest biomass for wood pellet production.

The study used an in-woods Peterson 4710B grinder to grind forest biomass, assessing its efficiency in processing residual wood into pellets. The ground material was subjected to a series of tests to evaluate its quality and suitability for pelletization, including measurements of particle size, moisture content, ash content, calorific value and grind consistency. The comparison of the two scenarios indicates that in Scenario 1, where the operation uses its own equipment (Peterson 4710B grinder, loader, and truck), costs vary between $30.00 to $44.60 per tonne depending on the specific logistics and associated fees. In Scenario 2, outsourcing both grinding and delivery to a third-party supplier results in a fixed cost of $40.00 to $42.00 per tonne. This outsourcing option offers a predictable cost structure, simplifying expense management and reducing operational complexity. The results indicate that, with proper processing and cleaning, forest biomass can produce durable wood pellets that comply with ISO 17225-2 pellet standards.

The comparison of the two scenarios indicates that in Scenario 1, where the operation uses its own equipment (Peterson 4710B grinder, loader, and truck), costs vary between $41.68 to $52.46 per tonne depending on the specific logistics and associated fees. In Scenario 2, outsourcing both grinding and delivery to a third-party supplier results in a fixed cost of $44.00 to $49.00 per tonne including the associated fees. This outsourcing option offers a predictable cost structure, simplifying expense management and reducing operational complexity. The results show that owning the equipment is generally better suited for high-volume operations where the scale justifies the investment, while small-scale operations may benefit more from renting or outsourcing. Ultimately, the decision between ownership and outsourcing should consider factors like cost predictability, operational flexibility, capital investment, and risk management.

This study offers a roadmap so the wood pellet industry can add forest biomass as a feedstock in a way that ensures economic sustainability and compliance with international quality standards. It will also help to increase the use of forest resources and reduce fuel loads in the forest that can contribute to wildfires.

The report is being shared with more than 70 companies, including many WPAC members, and it is expected that the observations and recommendations will reach more than 500 key Canadian industry leaders.

The work was made possible with funding from the Government of Ontario. We acknowledge and appreciate its commitment to advancing sustainable energy solutions in the province.

BACKGROUND

The Ontario wood pellet industry is at a crossroads as it seeks to diversify its feedstock sources to include forest biomass. While it has historically relied on sawmill residues, such as sawdust and shavings, as a consistent and clean source of raw material, the increased availability of harvest residues and the shift to increase forest utilization has compelled it to explore alternative feedstocks, particularly forest biomass. This is essential for sustaining the sector and meeting the growing demand for renewable energy sources.

Forest biomass, including treetops, branches, low-quality logs, and fire-damaged timber, is abundant but presents significant challenges. Unlike sawmill residues, it is often mixed with soil, sand, and other impurities. It also exhibits a wider range of moisture and ash content, which can complicate the pelletization process and impact the quality of the final product.

The study took a comprehensive look at the feasibility of in-woods grinding for forest biomass pelletization, including:

- Examining the economic and operational feasibility of using in-woods grinding to process forest biomass into pellet feedstock.
- Identifying how best to transport the biomass to the plant and process the pellets.
- Testing the material properties of both the feedstock and the resulting pellets to ensure they achieve the highest quality and meet international standards.
- Analyzing the economic benefits to pellet plants of owning and operating grinding and trucking equipment or having the ground material delivered by a third party at a fixed cost.

IN-WOODS BIOMASS PROCESSING

The first step of the study was to secure a source of forest biomass by grinding the limbs and tops from freshly harvested white birch trees. The grinder was mobilized to a forest management block of primarily white birch in Northern Ontario near Atikokan.

Figure 1 – Forest biomass used as feedstock for pelletization

IN-WOODS GRINDING SYSTEM

A Peterson 4710B Grinder (2015), a robust and versatile piece of equipment designed to handle a wide range of forest residues, was deployed directly in the forest to process biomass on-site. It converted raw forest residues into a uniform, transportable form suitable for pelletization. This reduced the volume of material that needs to be transported, potentially lowering hauling costs.

Figure 2 – Peterson 4710B Grinder on site

Figure 3 – Forest residue grinding using Peterson 4710B

PROCESSING AT THE PLANT

We conducted several particle size trials at BioPower's plant in Atitokan, ON, overseen by the facility's general manager, and selected a target size of 3/4" or less, with more than 90% of the material meeting this required size.

The green ground material was delivered to the plant, fed into the feed bin, then passed through the BM&M Super Screen to classify the fibre before drying, ensuring a homogenous particle size. Acceptable-sized material was sent to a Baker-Rullman SD125-42 triple pass dryer. Some over-sized material was conveyed to Andritz hammer mills fitted with 3/8" screens and ground again before it went to the dryer. The 10% of the material that was greater than 3/4" was screened out for use as hog fuel in the plant's biomass furnace (45 million BTU).

The fibre was dried to a moisture content of 9% and again passed through a BM&M Super Screen for final classification. At this stage, over-sized material was directed to Andritz hammer mills with 5/16" screens, and the rest went into pelletizer surge bins.

The grinding process was tailored to achieve a consistent 3/4" particle size, optimizing the material for pellet production. A mixture of white birch and conifer sawdust was used to maximize throughput in the Andritz 26 LM pelletizers. Once the optimal particle size was determined, full operations began using five trucks with triaxle possum belly trailers to deliver maximum load sizes to the pellet plant. This process ensured that material was efficiently processed and stored, with the contractor absorbing the delivery cost as part of the rate paid for each metric tonne. The focus on consistent particle sizing is critical to maintain pellet quality while managing operational costs effectively.

OPERATIONAL CONSIDERATIONS

The operational factors we considered during the grinding process included the moisture content of the biomass, which can vary significantly depending on the season and storage conditions. Moisture content directly impacts the efficiency of the grinding process, the weight of the material during transport, and the quality of the final pellets. To mitigate these challenges, we closely monitored moisture levels, and implemented strategies to maintain optimal conditions for processing and pelletization.

BIOMASS TRANSPORTATION AND PELLETIZATION

BioPower made some alterations to the truck tipping and dumping operation in order to utilize the trailers. As designed, the system conveyed the material directly from the truck tipper/dumper into the plant. The alterations meant the ground material could bypass the conveyance system and be deposited into a bunker where it could be stored in a stockpile in the yard for later use.

Figure 4 – Receiving material at the BioPower pellet plant

Figure 5 – Ground material in process at BioPower plant

After the optimum particle size distribution was found, three Andritz 26 LM pelletizers were used to pelletize the white birch/conifer sawdust mixture. Initial operations found that an acceptable quality pellet could be produced at a rate of upwards of four metric tonnes an hour per machine. Moisture content and feed rates were adjusted over time to determine how this would affect pellet quality.

Figure 6 – Pellets produced at BioPower plant

The study found that decreasing the moisture content to 4.5% to 5% increased the quality of the pellets produced. We also found that using this material reduced screen and die life by about 5% to 10% in the winter and spring cut grind, with a considerably higher loss in the spring/summer grind.

FEEDSTOCK AND WOOD PELLET TESTING

Each load of ground forest residue delivered to the pellet plant was tested internally for moisture content and ash content before it entered the production system. The moisture content averaged 42% and the ash content averaged 0.75%. Both were deemed acceptable.

Material property testing was done through a third-party lab on a regular basis. Samples were also collected before pelletizer and after pelletizer for thorough testing by the University of British Columbia's Biomass and Bioenergy Research Group. Three pre-pelletizers and three types of wood pellets were tested for moisture content (ISO 18134-2:2024), ash content (ISO 18122:2022), calorific value (ISO 18125:2017), bulk density (ISO 17828:2015), mechanical durability (ISO 17831-1:2015), and particle size distribution (ANSI/ASAE Standard S319.4) according to ISO and ASABE standards.

Three mixes were tested:

1. 50% white birch and 50% conifer sawdust;
2. 40% spring and summer birch and 60% conifer sawdust; and
3. 50% spring and summer birch and 50% conifer sawdust.

BioPower's initial testing indicated 40% spring and summer birch and 60% conifer sawdust was preferred due to increased quality, lower ash content and less equipment wear.

Figure 7– Pre-pelletizer feedstocks from left to right: 50% white birch and 50% conifer sawdust; 40% spring and summer birch and 60% conifer sawdust; and 50% spring and summer birch and 50% conifer sawdust.

Figure 8 – Wood pellets made from pre-pelletizer feedstocks from left to right: 50% white birch and 50% conifer sawdust; 40% spring and summer birch and 60% conifer sawdust; and 50% spring and summer birch and 50% conifer sawdust.

In spring and summer grind operations, there can be an increase in silica and ash content because full trees are being skidded in wet and muddy conditions. We were forced to halt grinding operations twice when heavy rain led to excessively muddy skidding trails.

Figure 7 shows the three different pre-pelletizer samples prior to testing. Figure 8 shows the pellets made from the tested forest residue mixes.

TABLE 1: PRE-PELLETIZER FEEDSTOCKS ANALYSIS

SAMPLE	PRE-PELLETIZER 1 50% white birch and 50% conifer sawdust	PRE-PELLETIZER 2 40% spring and summer birch and 60% conifer sawdust	PRE-PELLETIZER 3 50% spring and summer birch and 50% conifer sawdust
Moisture content (wt %)	7.38	11.26	12.66
Ash (wt %)	0.72	2.68	2.60
HHV (MJ/kg)	20.8	20.1	19.8
Bulk density (kg/m3)	174	188	189
Particle size distribution	See Figure 9	See Figure 10	See Figure 11

TABLE 2: WOOD PELLETS ANALYSIS

SAMPLE	WOOD PELLET 1	WOOD PELLET 2	WOOD PELLET 3	INDUSTRIAL PELLET REQUIREMENT (I1)	INDUSTRIAL PELLET REQUIREMENT (I2)	INDUSTRIAL PELLET REQUIREMENT (I3)
Moisture content (wt%)	5.84	7.43	6.61	M10 ≤ 10	M10 ≤ 10	M10 ≤ 10
Ash (wt %)	0.77	0.97	1.35	A1.0 ≤ 1,0	A1.5 ≤ 1,5	A3.0 ≤ 3,0
HHV (MJ/kg)	21	20.7	20.4	Q ≥ 16,5	Q ≥ 16,5	Q ≥ 16,5
Bulk density (kg/m3)	655	656	658	BD ≥ 600	BD ≥ 600	BD ≥ 600
Single pellet density (g/cm3)	1.15	1.21	1.20	N/A	N/A	N/A
Durability (Tumbler)	99.6	99.8	99.8	97,5 ≤ DU ≤ 99,0	97,0 ≤ DU ≤ 99,0	96,5 ≤ DU ≤ 99,0
Fine content	0.4	0.2	0.2	F ≤ 4,0	F ≤ 5,0	F ≤ 6,0

* 50% white birch and 50% conifer sawdust | ** 40% spring and summer birch and 60% conifer sawdust | *** 50% spring and summer birch and 50% conifer sawdust

The particle size distribution (PSD) of wood pellets significantly impacts their durability. A more uniform PSD promotes better bonding and if it is too varied this can create weak points within the pellet. The mix of very large and small particles might not bond as well, leading to fractures and breakdown.

The moisture content also interacts with PSD, affecting the durability. Fine particles absorb and retain moisture differently compared with coarse particles, and this can impact the pellet's structural integrity during drying and storage.

> A well-graded PSD improves the efficiency of the pellet mill, as the material flows more smoothly and compresses more evenly, and this results in pellets with higher durability.

Overall, the PSD of the raw material used in pellet production is crucial for determining the durability of the final product. Optimal pellet durability is generally achieved with a balanced PSD that includes a mix of fine and coarse particles, allowing for effective compaction, bonding, and moisture management. Adjusting the PSD during processing can help produce pellets that are more resilient and durable, reducing losses during storage and transportation.

Comparison of the three different types of pre-pelletizer mix reveals that the share of particles >3.15 is much higher for pre-pelletizer 1 which can be detrimental to the quality and durability of the pellets.

Figures 9, 10, and 11 illustrate the PSD of three pre-pelletizer feedstocks. Comparing these figures helps to assess the impact of different biomass compositions on the quality and efficiency of pellet production. It also reveals that the share of particles greater than 3.15 is much higher for pre-pelletizer 1, which could be one of the reasons for slightly lower wood pellet durability. Reducing the proportion of over-sized particles can improve the efficiency of the pelletization process and result in higher quality pellets.

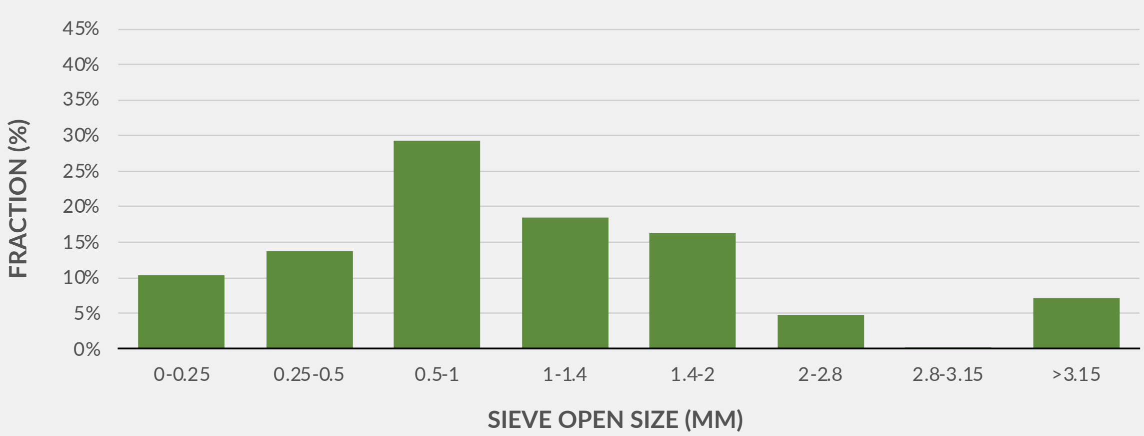

Figure 9 – PSD of pre-pelletizer 1 feedstock (50% white birch and 50% conifer sawdust)

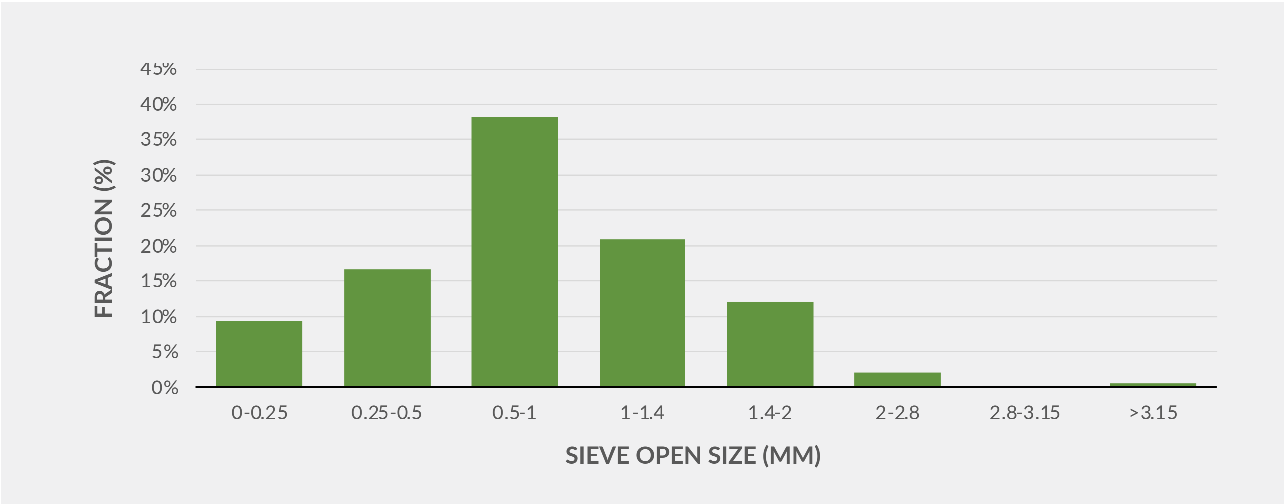

Figure 10 – PSD of pre-pelletizer 2 feedstock (40% spring and summer birch and 60% conifer sawdust)

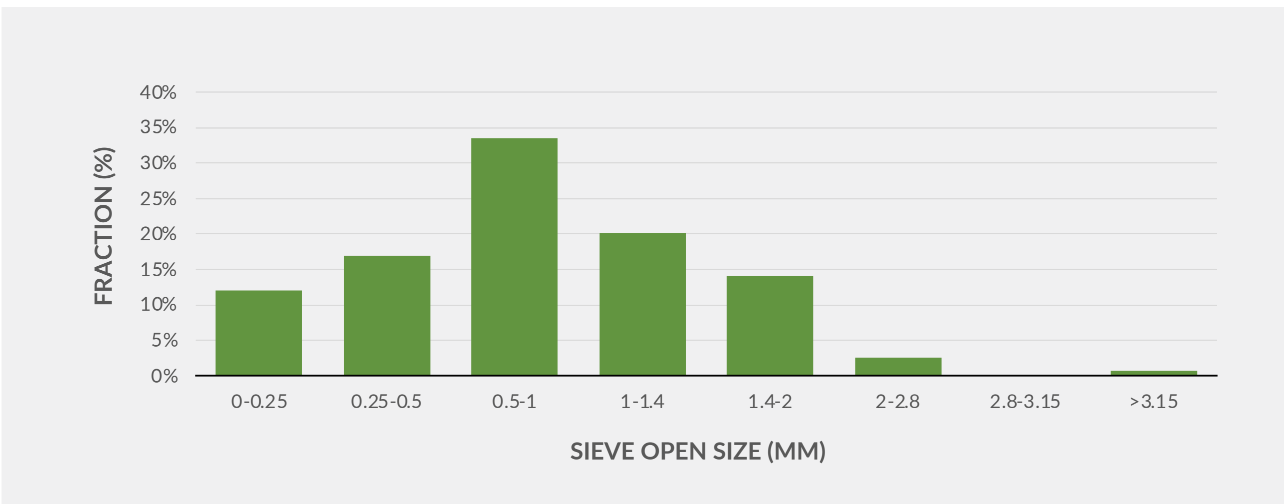

Figure 11 –PSD of pre-pelletizer 3 feedstock (50% spring and summer white birch and 50% conifer sawdust)

ECONOMIC ANALYSIS OF BIOMASS GRINDER

SCENARIO 1: OWNERSHIP AND OPERATION

Costs Overview:

The pellet plant owns and operates the grinding and trucking equipment, and it is assumed that the feedstock is obtained at no cost. The analysis considers the full spectrum of costs, including capital investment in the grinder and trucks, as well as ongoing expenses such as fuel, labour, maintenance, insurance, and depreciation.

Cost Effectiveness and Efficiency:

Owning the equipment offers greater control over operations and the potential for cost savings, particularly if the equipment is used efficiently and at scale. However, there are financial risks such as fluctuations in fuel prices, unexpected maintenance issues, and variations in biomass availability. The ability to tailor operations to specific project needs provides flexibility, but also requires careful management to mitigate risks.

Long-Term Considerations:

While initial costs are high, they may be offset over time by reduced per-unit costs, especially if the equipment is used consistently and at high capacity. The plant maintains full control over the supply chain, reducing reliance on external suppliers and potentially mitigating disruptions.

SCENARIO 2: OUTSOURCING MATERIAL DELIVERY

Costs Overview:

The plant relies on a third-party supplier to grind the biomass and deliver it at a fixed cost, eliminating the need for capital investment in grinding and trucking equipment. This simplifies the supply chain, provides financial predictability and reduces exposure to fluctuations in operational costs.

Cost-Effectiveness and Efficiency:

Outsourcing may be more cost-effective where the availability of biomass is inconsistent or where the scale of operations does not justify the purchase of specialized equipment. The pellet plant can focus on core production activities while leveraging the expertise of third-party suppliers who often have economies of scale and specialized expertise that can result in lower overall costs.

Long-Term Considerations:

While outsourcing reduces financial risk and operational complexity, it introduces dependency on external suppliers. Any disruptions in the supply chain, such as delays in delivery or quality issues with the ground material, could impact pellet production. Ensuring the reliability and quality of outsourced material is crucial to the success of this approach. Additionally, while the fixed-cost structure offers predictability, it may also limit the plant's ability to benefit from potential cost savings associated with owning and operating the equipment.

COMPARATIVE ANALYSIS AND RECOMMENDATIONS

Cost-Benefit Comparison

Tables 3 and 4 show the detailed cost comparison between the two scenarios. All assumptions made to calculate equipment rate and conduct a cost-benefit comparison are listed in Appendices A and B.

TABLE 3: GRINDING OPERATION CALCULATIONS (GRINDER AND LOADER RATES)

FIXED COSTS	
Purchase price ($)*	515,000
Annual depreciation ($/hr)	54.93
Annual interest ($/hr)	23.35
Annual insurance and taxes ($/hr)	11.61
Annual productive machine hours (h)	1,500
Hourly fixed machine cost ($/hr)	**89.95**
VARIABLE COSTS ($/hr)	
Labour	33.75
Repair and maintenance	16.48
Fuel cost	214.36
Lubricants cost	75.02
Loader cost**	102.89
Supportive equipment	14.80
Hourly variable costs	**457.30**
RISK, 10% ($/hr)	54.72
Total cost ($/hr)	**601.97**

*Grinder cost, depreciation and all associated costs are calculated based on the operation done by BioPower and data collected during the operation.
**Loader costs used in the calculations are borrowed from the same operation with Peterson 4710B (Zamora et al. 2013, Anderson et al. 2012).

TABLE 4: TRUCK RATE CALCULATIONS

FIXED COSTS	Standard 7.62 m	Standard 13.7 m	Triaxle possum belly 14.63 m
Purchase price tractor–trailer ($)*	100,000	180,000	300,000
Annual depreciation ($/hr)	4.64	8.24	14.70
Annual interest ($/hr)	3.23	5.81	9.74
Annual insurance and taxes ($/hr)	3.23	5.81	9.74
Annual productive machine hours (h)	2,000	2,000	2,000
Hourly fixed cost ($/hr)	11.10	19.86	34.17
VARIABLE COSTS ($/hr)			
Labour	23.18	23.18	27.61
Tire cost	6.41	6.41	9.50
Repair and maintenance	3.25	5.77	11.76
Fuel and lubricants	19.30	19.30	26.55
Overhead cost	6.70	6.70	6.70
Hourly variable cost	58.84	61.36	82.13
RISK, 10% ($/hr)	6.99	8.12	11.63
Total cost ($/hr)	76.94	89.35	127.93

**Trucking costs, depreciation and other associated costs calculations are borrowed from the same operation with Peterson 4710B (Zamora et al. 2013, Anderson et al. 2012)

Griding cost per tonne, assuming an output rate of 65 tonnes per hour, will be $9.26 per tonne. For a standard 7.6 m, 13.7 m and 14.6 m tractor trailer the cost of transportation is $36.20, $29.70 and $28.42 per tonne respectively. Detailed information can be found in Appendix A. Depending on the forest and species there would be an additional $4.00 to $7.00 per tonne in management fees, road fees, renewal fees and Crown dues. Table 5 lists the cost of grinding and delivery to the plant for Scenario 1. The total processing cost of such forest residue, depending on which truck/trailer is used, would be between $41.68 to $52.46 per tonne.

TABLE 5: GRINDING AND DELIVERY COST CALCULATIONS IN SCENARIO 1

COST ($/tonne)	
Standard 7.62 m	$36.20
Standard 13.7 m	$29.70
Triaxle possum belly 14.63 m	$28.42
Grinding operation (Peterson 4710B grinder and loader)	$9.26
Fees (management fees, road fees and Crown dues)	$4.00-$7.00

TABLE 6: COST OF FOREST RESIDUE PELLETIZATION IN SCENARIO 1 AND 2

COST ($/tonne)	
SCENARIO 1 - OWNERSHIP AND OPERATION	
Peterson 4710B grinder and loader, Standard 7.62 m Trailer and Truck and other fees	$49.46 to $52.46
Peterson 4710B grinder and loader, Standard 13.7 m Trailer and Truck and other fees	$42.96 to $45.96
Peterson 4710B grinder and loader, Triaxle possum belly 14.63 m Trailer and Truck and other fees	$41.68 to $44.68
SCENARIO 2 - OUTSOURCING MATERIAL DELIVERY	
Third-party supplier to grind the biomass and deliver it at a fixed cost plus fees	$44.00 to $49.00

The table presents the cost of forest residue pelletization under the two different operational scenarios investigated: Scenario 1 – Ownership and Operation and Scenario 2 – Outsourcing Material Delivery. Each scenario outlines a range of costs per tonne of forest residue processing, depending on the specific logistics and operational strategies employed.

In Scenario 1 (ownership and Operation), the primary cost drivers include the Peterson 4710B grinder, a loader, and a truck, along with associated fees. As seen in the table, the cost ranges between $41.68 to $52.46 depending on the type of truck used as well as the associated fees.

In Scenario 2 (outsourcing material delivery), the operation is outsourced to a third-party supplier who handles both the grinding and delivery of the biomass at a fixed cost of $44.00 to $49.00 per tonne including the associated fees. Outsourcing provides a clear, predetermined cost structure, making it easier to predict expenses. lease add this paragraph to the executive summary. In Scenario 2, material is delivered at a fixed cost of $44.00 to $49.00 per tonne including the associated fees. This offers a predictable expense with potentially lower financial risk. However, Scenario 1 may provide cost advantages if the company can operate efficiently and at scale, potentially lowering per-unit costs over time. The decision between these scenarios hinges on factors such as capital availability, operational efficiency, risk tolerance, and long-term financial planning.

A detailed cost-benefit comparison between the two scenarios reveals that while ownership and operation of the equipment involve higher upfront costs and greater operational risks, they also offer the potential for long-term savings and increased control over the supply chain. In contrast, outsourcing simplifies operations and reduces financial risk, but may result in higher overall costs and greater dependency on external suppliers.

Ownership becomes more cost-effective when utilization rates are high and operational efficiency is maximized. Conversely, outsourcing is more advantageous in situations where biomass availability is uncertain or where the plant prefers to minimize capital expenditures and operational complexity.

STRATEGIC RECOMMENDATIONS

Based on the analysis, the following strategic recommendations are made:

- **FOR LARGE-SCALE OPERATIONS:**
  Ownership and operation of grinding and trucking equipment are recommended for large-scale operations with consistent biomass availability and the capacity to maximize equipment utilization. This approach offers the potential for long-term cost savings and greater control over the supply chain.
- **FOR SMALL-TO-MEDIUM-SCALE OPERATIONS:**
  Outsourcing is recommended for small to medium-scale operations or in situations where biomass availability is uncertain. This approach minimizes financial risk and operational complexity, allowing the plant to focus on core production activities while benefiting from the expertise and economies of scale offered by third-party suppliers.
- **HYBRID APPROACH:**
  A hybrid approach may also be considered, where the plant owns a portion of the equipment for critical operations while outsourcing additional capacity as needed. This strategy provides flexibility and reduces dependency on external suppliers while allowing the plant to scale operations based on demand.

CONCLUSIONS

The study's thorough testing and analysis of forest residue material for pelletization in Ontario shows that such material can be utilized to produce high-quality pellets that comply with ISO standards.

The biomass exhibited higher levels of moisture and ash content compared with sawmill residues. However, with appropriate drying and processing techniques (such as mixing different feedstocks), these levels were brought within the acceptable range for pellet production, minimizing the risk of operational issues like slagging and fouling in boilers. The finished pellets were tested against ISO 17225-2 standards, confirming that the pellets made with the proposed blends meet either I1 or I2 industrial pellet ISO specifications for durability, energy content, and ash content.

The addition of forest biomass as a primary feedstock for Ontario's wood pellet industry presents both challenges and opportunities. While forest biomass is more complex to process than sawmill residues, it offers a sustainable and abundant source of raw material for pellet production. There are added environmental benefits in reducing fuel loads in the forest that can contribute to wildfires and improving air quality by not burning slash.

Examining the economic feasibility of using in-woods grinding to process forest biomass into pellet feedstock was done through two scenarios of (1) Ownership and Operation and (2) Outsourcing material delivery. In Scenario 1, the primary cost factors include the Peterson 4710B grinder, a loader, and a truck, with associated fees resulting in costs ranging from $41.68 to $52.46 per tonne, depending on the specific trailer/truck used and other operational variables. In Scenario 2, outsourcing to a third-party supplier for both grinding and delivery sets a fixed cost of $44.00 to $49.00 per tonne including the associated fees.

The decision to invest in in-woods grinding equipment versus outsourcing ground material delivery depends on the specific operational and financial circumstances of each pellet plant. There are higher initial costs and increased operational risks in owning and operating the equipment, but it provides significant potential for long-term savings and enhanced control over the supply chain.

> Ownership is most cost-effective when the equipment is utilized at high rates and operational efficiency is optimized. Conversely, outsourcing is preferable when biomass availability is uncertain or when there is a desire to minimize capital expenditures and operational complexity.

Identifying and mitigating risks such as fluctuations in raw material prices, changes in energy policies, technological obsolescence, and market competition are vital for ensuring the long-term viability of the wood pellet production using in-woods grinding.

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APPENDIX A:

COST BREAKDOWN FOR PETERSON 4710B GRINDER IN SCENARIO 1

Purchase price (P)	$515,000
Machine horsepower rating (hp)	700 hp
Machine life (n)	5 years
Salvage value, percent of purchase price (rv%)	20%
Utilization rate (ut%)	75%
Repair and maintenance, percent of depreciation (rm%)	30%
Interest rate (in%)	10%
Insurance and tax rate (it%)	5%
Fuel consumption rate (fcr)	0.048 gal/hp-hr
Fuel cost (fcg)	$6.38 per gal
Lube and oil, percent of fuel cost (lo%)	0.35%
Operator wage and benefit rate (WB)	$25.30/hr
Scheduled machine hours (SMH)	2000 hrs/yr
Salvage value (S) = (P*rv%)	$103,000
Annual depreciation (AD) = ((P-S)/n)	$82,400.00
Average yearly investment (AYI) = ((((P-S)*(n+1))/(2*n))+S)	$350,200.00
Productive machine hours (PMH) = (SMH*ut%)	1500 hrs/yr
OWNERSHIP COSTS Interest cost (IN) = (in%*AYI)	$35,020.00 yr
Insurance and tax cost (IT) = (it%*AYI)	$17,510.00 yr
Yearly ownership cost (YF$) = (AD+IN+IT)	$134,930.00 yr
Ownership cost per SMH (F$SMH) = (YF$/SMH)	$67.46/hr
Ownership cost per PMH (F$PMH) = (YF$/PMH)	**$89.95/hr**
OPERATING COSTS Fuel cost (F) = (hp*fcr*fcg)	$214.36/hr
Lube cost (L) = (F*lo%)	$75.02/hr
Repair and Maintenance cost (RM) = (AD*rm%/PMH)	$16.48/hr
Loader cost (LC)	$102.89/hr
Supportive equipment (SE)	$14.80/hr
Operator labour and benefit cost (WB/ut%)	$33.75/hr
Operating cost per PMH (V$PMH) = (F+L+RM+LC+SE +(WB/ut%))	**$457.3/hr**
Operating cost per SMH (V$SMH) = (V$PMH*ut%)	$342.97/hr
PROFIT AND RISK, 10% ($/hr) (per Practical Machine Hour)	**$54.72**
TOTAL COST PER PRACTICAL MACHINE HOUR (T$PMH) = (F$PMH + V$PMH)	**$601.97/hr**

APPENDIX B:

Data was collected on initial investment costs such as purchasing the grinder. Data was also collected on operational costs such as fuel required to power the grinder, maintenance expenses, labour costs, and raw material procurement costs. Some of these data are collected through a Peterson 4710B grinder specification sheet.

Since Scenario 1 assumes owning the grinder and trucks, machine rates are calculated for both. Here is a list of assumptions made/data used in Scenario 1:

- Grinder output: 65 tonnes per hour
- Trucking distance from forest to the plant: 240km one way
- Average truck weight: 36 tonnes
- Average speed: 60km/h

$$\text{Cost per tonne for the grinder} = \frac{\text{(Cost per hour)}}{\text{(Tonne processed per hour)}}$$

$$\text{Cost per tonne for the Peterson 4710B grinder} = \frac{\$601.94}{65} = \$9.26/\text{tonne}$$

To calculate the cost of trucking in dollars per metric tonne using the truck rate in dollars per hour, along with the distance and weight of the material moved, time required for the trip is calculated.

Total time needed for a round trip, including loading, unloading, and travel time.

$$\text{Total time (hours)} = \left(\frac{\text{Distance (km)}}{\text{Average speed } (\frac{km}{h})} \times 2\right) + \text{Loading/Unloading time}$$

$$\text{Total time (hours)} = \left(\frac{240 \text{ (km)}}{60 \ (\frac{km}{h})} \times 2\right) = 8 \text{ hours}$$

$$\text{Total cost for the trip (dollars)} = \text{Total time (hours)} \times \text{Truck rate} \left(\frac{\$}{\text{hour}}\right)$$

$$\text{Total cost for the trip (dollars)} = 8 \text{ hours} \times 127.93 \left(\frac{\$}{\text{hour}}\right) = \$1{,}023.44/\text{hour}$$

$$\text{Cost per tonne for trucking} \left(\frac{\$}{\text{tonne}}\right) = \frac{\text{Total cost (\$)}}{\text{Weigh of material (tonnes)}}$$

$$\text{Cost per tonne for trucking} \left(\frac{\$}{\text{tonne}}\right) = \frac{1{,}023.44 \text{ (\$)}}{36 \text{ (tonnes)}} = \$28.42/\text{tonne}$$

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