# Comminution of Unmerchantable Forest Residuals to Determine Power and Energy Consumption as a Function of Moisture Content and Size Reduction Range


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## Introduction

- Fossil Fuels, currently the largest used energy source, are growing increasingly scarce.
- Research into biofuels is creating sources of sustainable energy that will be used as a substitute for these depleting resources.
- In the Pacific Northwest unmerchantable forest residuals-a byproduct of logging-is being looked into as a potential source of biojet fuel. However, the process of breaking down this byproduct is extremely energy intensive.
- Thus, research needs to be made to more efficiently turn the woody biomass into an energy source.

## Objectives

- The goal of this research is to develop an equation based on Rittinger's Law, which states that the energy required for size reduction is proportional to the change in surface area of the material.
- This equation (see equation below) will be used to determine the energy that will be consumed for any given size reduction and moisture content of the woody biomass, which can then be used to predict the most optimal conditions for breaking down the forest residuals

**Eq. 1:**

$$E_{1\text{-}2} = C_{mc}\,(1/\chi_2 - 1/\chi_1)$$

X Represents the average particle size of the material and $C_{mc}$ represents Rittinger's constant, which should only account for the influence of the moisture content.

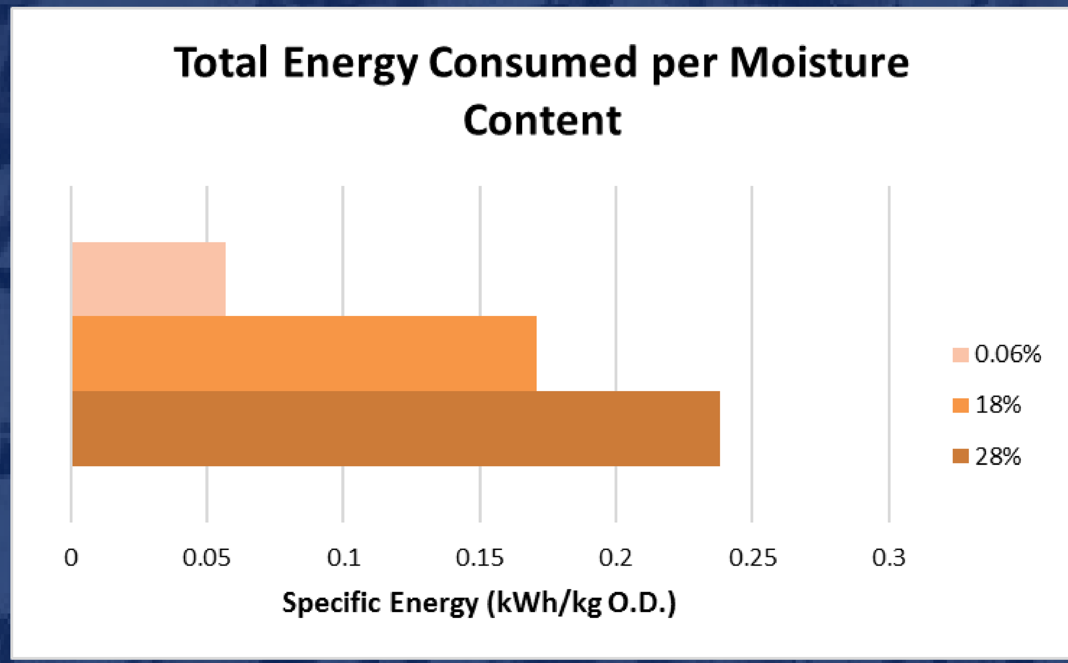


Figure 5: This graph shows the Specific Energy that is used for path 3 of each of the different moisture content being tested. (6% is missing due to difficulties with the Fluke power reader)

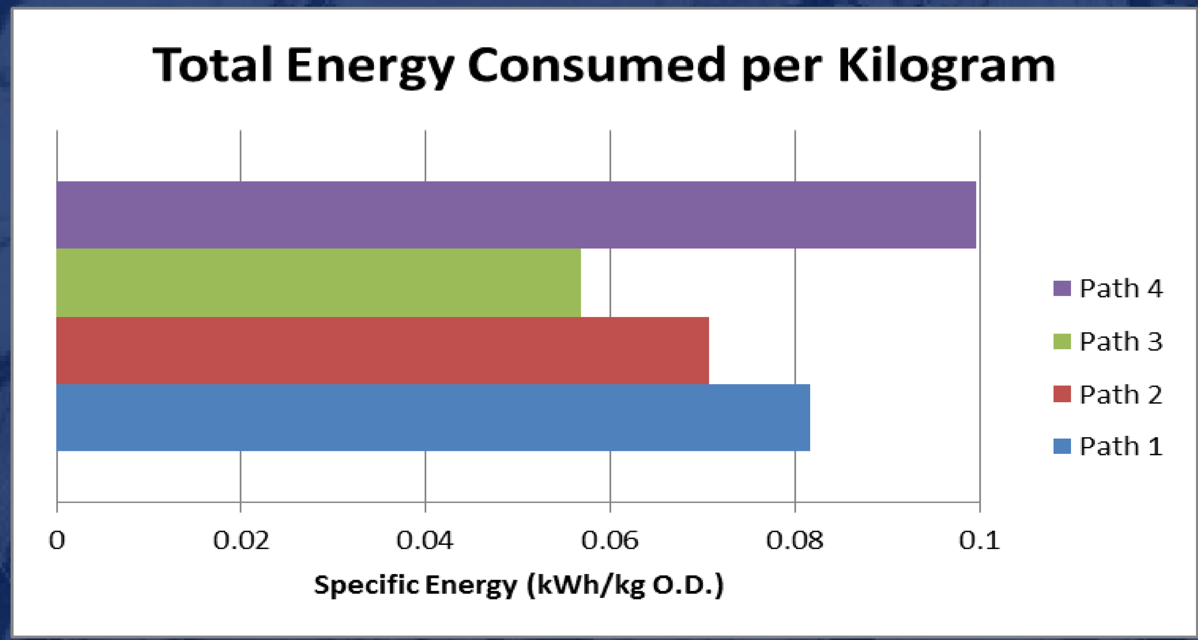


Figure 6: This bar graph is a representation of the Specific Energy for each Path shown in Figure 3.

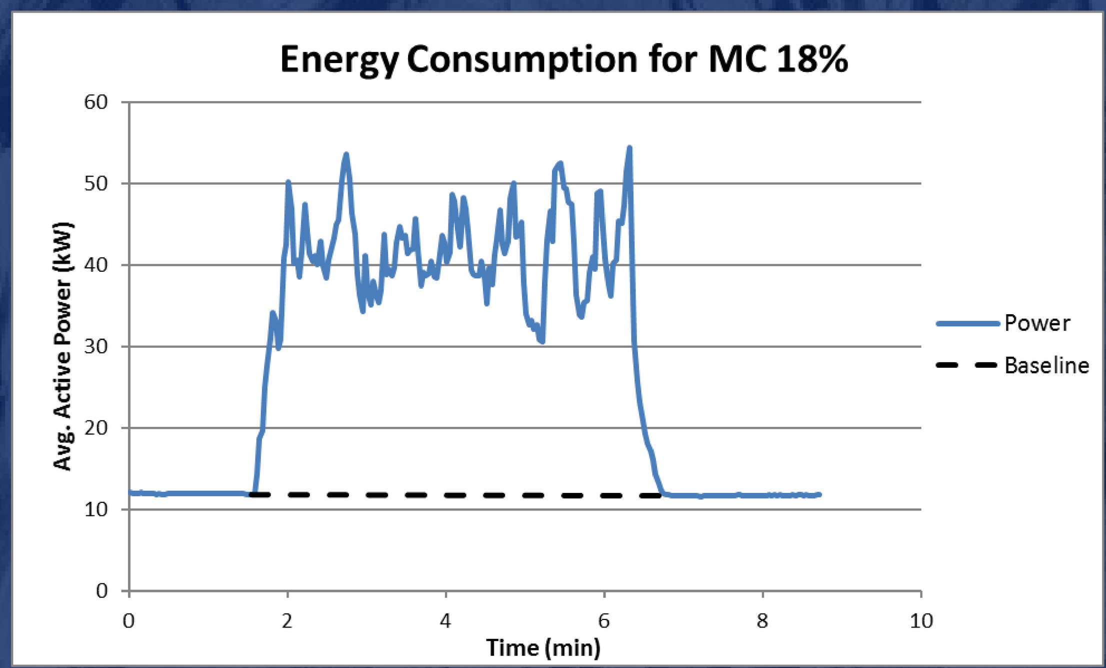


Figure 3: This graph represents an Energy output for the moisture content of 18% going through a screen size five with is 5/64 in.

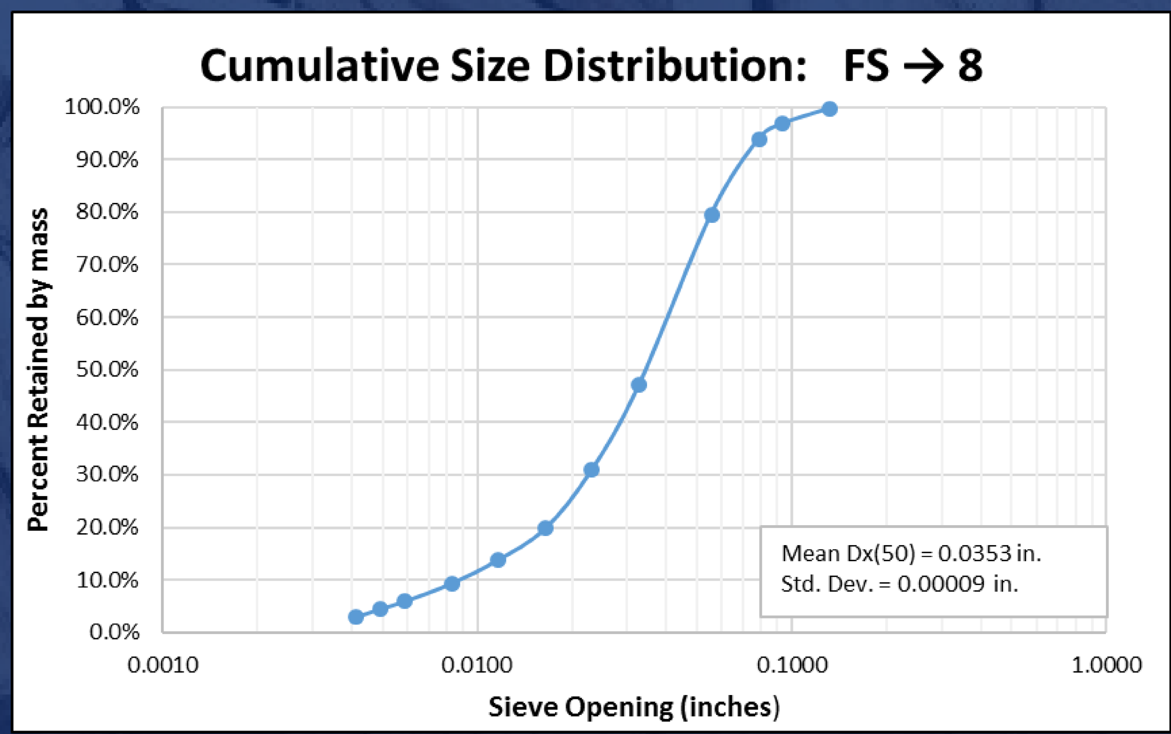


Figure 4: This graph is a representation of the average particle size distribution of the feedstock at 12% moisture content going through a screen size of ¼ in

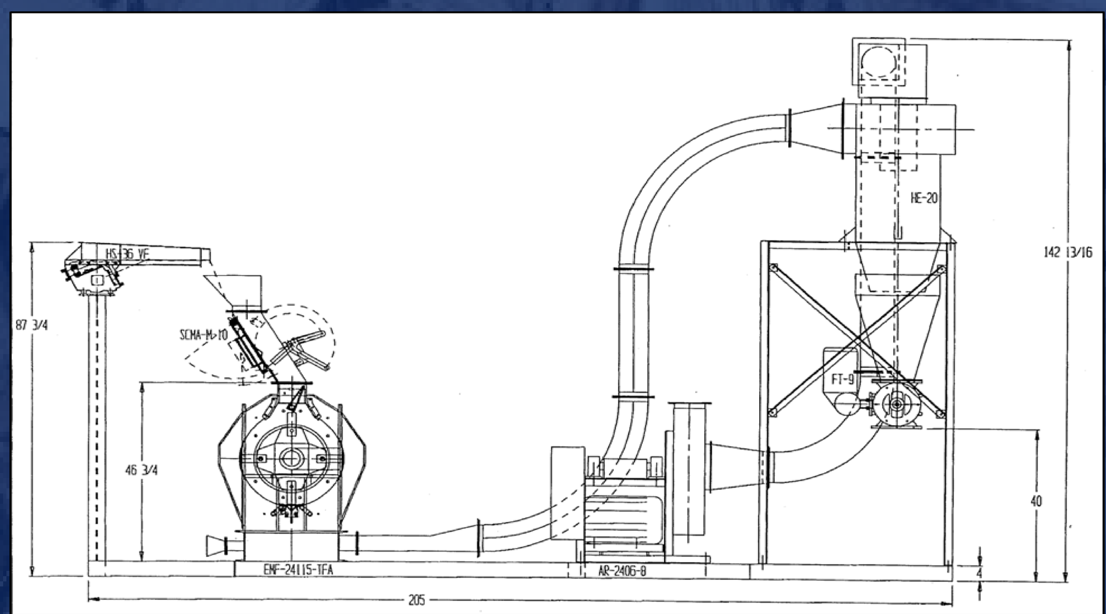

Figure 1: This figure (source: Bliss Industries, Inc., Washington State University, edited) represents tha Hammermill that was used in the particle size reduction of the Forest Residuals.

| Screen # | Screen Size | Path 1 | Path 2 | Path 3 | Path 4 | Path 5 | Path 6 |
|---|---|---|---|---|---|---|---|
| 8 | 1/4" | | | | | | |
| | | FS → 8 | | | | | |
| 6 | 1/8" | | | | | | |
| | | | FS → 6 | | | | |
| 5 | 5/64" | | | | | | |
| | | FS.8 → 5 | | FS → 5 | | | |
| 4 | 0.046" | | | | | | |
| | | FS.8.5 → 4 | FS.6 → 4 | | FS → 4 | | |
| 3 | 0.033" | | | | | | |
| | | | FS.6.4 → 3 | FS.5 → 3 | | FS → 3 | |
| 2 | 0.027" | | | | | | |
| | | FS.8.5.4 →2 | | | FS.4 → 2 | | FS → 2 |

Figure 2: This figure shows how we ran through the material through the Hammermill for each moisture content. FS sands for feedstcok and the number represents the screen used. (Ex. Path 1 had four different screen sizes that were used and the first screen was screen #8 which was a ¼" screen.)

## Preliminary Results

- Optimal Path
  - Based on the data that has been collected and analyzed from the completion of paths 1-4 for the moisture content of 6, 12, 18, and 28 percent we predict that the optimal particle reduction range will be through Path 3 and the optimal moisture content will be 6%. (See Figures 5 & 6)
  - Based on the same data the path that would consume the most energy would be Path 4.
- Equation
  - The four completed paths for each of the given moisture content contribute data that will aid in the successful creation of equation 1.

## Project Future

- Path 5 and Path 6 will be completed for the moisture content of 12 and 28
- The data that has been collected for Path 5 and 6 for the moisture contents of 6 and 18% will be analyzed.
- For each of the moisture contents the feedstock will be ran through the Hammermill for each of the Paths and the energy consumed will be measured.
- After each screen size, for each of the moisture contents, a sieve analysis will be done to determine average particle size.
- The resulting data will be analyzed to create equation 1 and the final equation and results will be written and sent for publication.


## Acknowledgements

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## Methods

- Overview
  - To reach this objective the energy consumed by running the material through a small scale industrial Hammermill (see Figure 1 above) using 4 different levels of moisture content (6, 12, 18, and 28 percent) is being measured.
  - At each moisture content the material is being ran through multiple screen sizes to get varying particle size reductions (see Figure 2 above)
- Data Collection
  - The material was conditioned for 6, 12, 18, and 28 percent moisture content using a G-series elite conditioning chamber.
  - 50 lbs. of material was used for each of the Paths shown in figure 2.
  - A rotap testing sieve shaker was used to determine the average particle size after each size reduction.
  - A rotap testing sieve shaker was also used to determine the starting average particle size of the whole feedstock before being run through the Hammermill.
  - A fluke power reader was used to measure the energy consumed for each path and screen size.