Itasca Community College Woody Biomass Project

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Introduction

Globally, there is an interest in utilizing forest biomass as an alternative for fossil fuels (IRENA 2014). However, challenges exist in making biomass thermal energy mainstream. In Europe, many counties have heavy adopted biomass as a source of local, renewable energy. Currently, 53% of the energy consumed in Sweden is from renewable sources and 35% of their total energy supply is derived from biofuels (Johanssen, 2015). Some areas of the United States have abundant resources for biomass, which may be a reasonable substitution for thermal energy. The Itasca Woody Biomass project goals are to demonstrate some of Sweden's successful techniques in Minnesota conditions.

The Itasca Woody Biomass Project involves three phases. First, to understand the characteristics of fuel currently generated on Northern Minnesota forests. The project evaluated several fuel parameters of chips generated in typical logging operations. Second, the project utilized Sweden's techniques, as refined the Skogforsk, for infield drying of biomass and evaluated the effects on fuel parameters. Energy derived from drying may be enhanced 20% or more, trucking costs can decrease and it has a little impact on the fuel characteristics. This phase of the project was completed by a Department of Interior grant through Fond du Lac Band of Lake Superior Chippewa. Lastly, the project has worked to identify and characterize fuel delivered for the Itasca Community College biomass heating system, installed in fall 2016.

This paper summarizes the status of work on each of these the first two phases of the project.

Fuel Parameters, Methods of Evaluation

The project identified chip size (particle size distribution), moisture content (MC_{wet}) and heat value (BTU's per pound) as the three major fuel parameters.

Standard ASTM E 11-09 screens were used to assess particle size distribution. Screen sizes are as follows: 37.5mm, 25mm, 19mm, 16mm, 12.5mm, 9.5mm, and 4.75mm, descending. Approximately 1000 gram samples were placed on a Gilson electric power shaker tower for 60 seconds and the material remaining on each screen was weighed. Material that passed through the final screen was classified as fines. All material on the largest three screens were measured along the longest axis (Blott and Pye, 2008) to determine the percentage of "overs". Chip size characteristic protocol (Merkus, 2009) is consistent with standard material testing and is displayed as cumulative percent of material retained by screen size.

Moisture content was analyzed using the ASTM E871-82 standard. The samples were dried for 24 hours at 200º F in a Quincy Lab model 40AF lab oven. Weight before and after drying was utilized to calculate moisture content on a wet weight basis (Shmulsky and Jones, 2011), where MCwet = [(wet weight)-(dry weight)]/(wet weight).

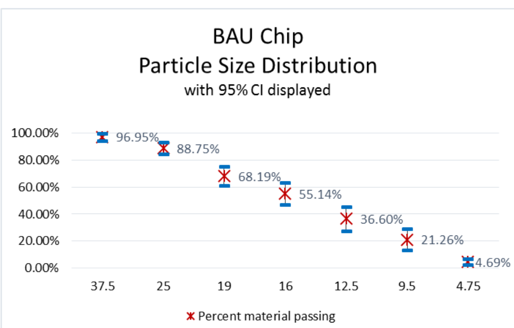
Heat values were determined using ASTM E711-87 standard. Oven dried wood was ground to powder and pelletized. The wood pellets were analyzed using a Parr 6200 Calorimeter for total available energy at zero percent moisture in BTU's per pound. The value is listed as the higher heat value (HHV). The low heat value (LHV) was then calculated (Shmulsky and Jones, 2011) by $LHV = [HHV \times (1 - MC_{wet})]$.
As the project progressed, density was identified as a fuel parameter of importance since the feed rate into a boiler is calibrated in pounds per cubic foot of delivered material. Since protocols are not well established for density calculations of biomass (Sessions, et.al. 2013), we used a 1000 ml sample and simulated a settled density by tapping the sample 10 times. The settled volume was recorded, combined with weight to provide density. Although density was not routinely measured in early aspects of the project, a subset of the materials delivered to the college's heating plant had density estimates measured.

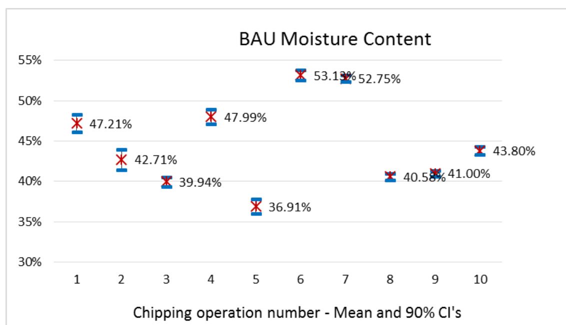
Phase 1: The "Business as Usual Chip":

From November 11 through December 11, 2014, producers of wood chips were contacted for interest in supplying wood chips for the Itasca Community College (ICC) boiler. A standard chip needed to be characterized, so that boiler manufacturers could design feed and combustion systems. Logging operations which currently supply large industrial consumers of biomass for energy were surveyed. The chips generated constitute the business as usual (BAU) chips found in the region. The consumers of these chips have designed feed systems and combustion processes around these chips. New thermal energy plants need to be able to utilize them, as logging operations will likely not alter their production methods for medium sized consumers.

	Harvest Type	Date	Operation Details	Species	Chipper HP & size	Samples
1	CTL	11/11/2014	Tops and limbs forwarded to chipper	Aspen, balsam, birch, maple and balm	John Deere, 300hp, 2 knife, ¾ chip slot	6
2	Tree Length	11/14.2014	Tops, limbs and non-merchantable bole wood from active landing	Aspen, birch, ash and pine	Mobark, 500hp, 3 knife, 5/8 inch chip slot	9
3	CTL	11/20/2014	Long tops skidded and piled on the landing for 3 to 4 weeks	Oak	Mobark, 600hp, 4 knife, ¾ inch chip slot	9
4	CTL	11/22/2014	Tops and limbs forwarded to chipper	Aspen and birch	John Deere, 300hp, 2 knife, ¾ chip slot	9
5	CTL	11/26/2014	Long tops skidded and piled on the landing for 3 weeks	Aspen, birch and maple	Mobark, 600hp, 4 knife, ¾ inch chip slot	9
6	CTL	11/26/2014	Tops and limbs forwarded to chipper	Birch	John Deere, 300hp, 2 knife, ¾ chip slot	9
7	CTL	12/5/2014	Long tops skidded and piled on the landing for 3 weeks	Oak	Mobark, 600hp, 4 knife, ¾ inch chip slot	9
8	Whole tree	12/9/2014	Tree length piles, skidded directly to chipper	Oak, maple, aspen and birch	Mobark chipper (600 hp, 4 knife, 7/8" chip slot	9
9	CTL	12/10/2014	Long tops skidded to landing and chipped	Birch, aspen and maple	Mobark, 500hp, 3 knife, 5/8 inch chip slot	9
10	Whole tree	12/11/2014	Tree length piles, skidded directly to chipper	Oak	Mobark chipper (600 hp, 4 knife, 7/8" chip slot	9

Below, is the result of 87 samples taken on 10 different logging sites and represent a range of chipper configurations.





Fuel quality is measured by several parameters. Perhaps the most important and often evaluated is heat value. Measured in BTU's, this parameter affects all users, regardless of plant size. Wood is a relatively dense fuel source and has a similar heat content as some western coals. However, in the forest, the BAU chips contain an average of 44.6% moisture. The water in wood has a dramatic effect on the heat value. Practices which dry wood prior to combustion greatly improve or enrich that heat value. A drop of moisture from 44.6% to 24.6% yields almost twice the heat energy available.

Phase 2: Evaluation of European Models for Fuel Treatment:

To evaluate the ability to enrich fuel value through in-woods drying, the project used a methodology identified by Skogforsk, the Swedish forest research agency. This project brought researcher Tomas Johansson, of Skogforsk to Minnesota to train the Fond du Lac loggers, foresters and the analysis team in the in-woods drying process. The Skogforsk methodology identifies strategic planning of biomass retrieval, piling and protection of the piles from re-wetting. The methodology was applied to three sites, over a three-year timeframe. The first site, a cut-to-length hardwood thinning operation, involved the removal of the merchantable bole wood, then forwarding of tops and limbs to a landing. The second operation utilized a whole tree final harvest in a predominantly red pine stand, where the non-merchantable tops and limbs were piled for chipping. The third site involved a tree length harvest of an aspen-birch forest. Non-merchantable tops where piled at the landing site.

Dry-down Site Summary

Site	Logging system	Pile Created	Pile Chipped	Species	ECS Site Class
Hardwood Lake Road	Hardwood thin: C-T-L	1/31/14	2/17/15	Birch (50%), maple (30%) aspen (20%)	MHn35
Berthiaume Road	Pine clearcut: whole tree	12/22/14	7/29/15	Red pine (95%), balsam fir (5%)	FDn43
CFC-Sawyer Road	Aspen-birch clearcut: tree length	1/24/15	5/13/16	Aspen (90%), birch (10%), maple and balsam fir (minor)	FDn33

For all operations, the biomass "residue" was strategically piled to facilitate retrieval and drying. Aspects of strategic piling include proximity to site infrastructure (roads and landings), access to prevailing winds (open to the northwest), and careful placement of the residue with butts towards roads to facilitate handling and efficiency in feeding a chipper. Some of the piles were covered using a biodegradable blanket, which is designed to reduce re-wetting. This practice is wide spread in Sweden, but has not been adopted in the United States. The project served to evaluate the effectiveness of this practice in Minnesota climatic conditions.

Constructing piles at Hardwood Lake Road during a thinning operation. CTL harvester and forwarder are pictured.

Pile of conifer tops at Berthiaume Road. The blanket is a degradable and is intended to reduce re-wetting from rain and snow.

Piles in the process of being chipped at the CFC-Sawyer Road. Shown are covered and uncovered piles. Biodegradable blanket is chipped with the biomass.

The dry down project sites were sampled either immediately or within a few days of piling to establish a starting or green moisture content. The piles were then sampled at approximately 3 to 4 month intervals to determine dry down that occurs during each of the seasons. Since piles were established during the winter, the piles were sampled at the time of initial piling, in early spring (3 months), and again in late summer (6 months), and lastly prior to chipping. At the initial and interim sampling dates, wood for analysis was extracted using chain saw methodology. Chainsaw or sawdust samples were also collected at the time of chipping and served as a check to evaluate similarity of the saw samples to the chip results.

Sample extraction.

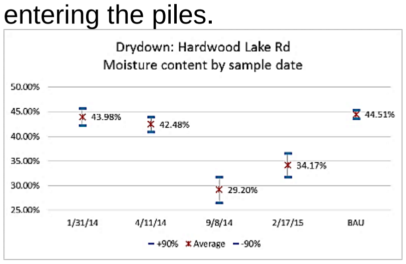
Left: Chainsaw samples were extracted from within the piles at four locations, the butt end, the tops, and each side of the pile. The chainsaw was drawn down into the stem to obtain a cross section. Saw dust was collected from the chain saw using a collector developed by Itasca Community College Engineering student, Bridger Hopkins.

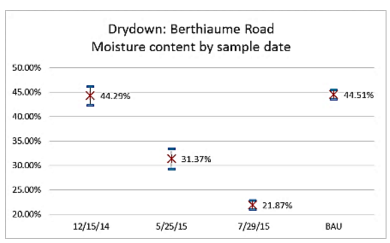
Right: Collecting samples from the chip stream. Samples were collected at periodic intervals during the chipping of a pile. The materials were collected over a total of 5 to 6 minutes, so each sample represents a wide range of materials.

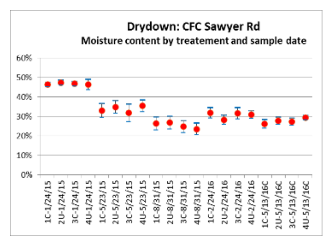
Samples were also drawn at the time of chipping. Materials extracted from the chip stream over an extended time, up to 5 or 6 minutes. This provided for a thorough picture of a large portion of the pile. Two sample collections were made for each biomass pile. These chips were analyzed for moisture, heat and particle size distribution.

Results of In Field Drying:

Moisture Content: Overall, the initial moisture content was consistent with that found in the BAU project sites, at approximately 45% MC_{wet}. In spring, moisture content appears to fall relatively rapidly, with sample dates in April showing little change, but those in May display a 10% or larger drop. This tends to indicate that moisture losses occur relatively soon after thaw. By fall (approximately 6 months) moisture content dropped dramatically losing from 15 to 29%, depending on the site and materials. When samples were extracted during the winter following piling (approximately 1 year after piling), the trend indicates there may have been a small amount of re-wetting of the material, however the results are not significant across all piles. If the re-wetting has in fact occurred, it is presumably due to fall rains and snow re-entering the piles.







At Hardwood Lake, data for the BAU moisture content is displayed (right side) to serve as reference. The BAU material has similar MC values to initial the initial piled material. By fall (9/8) MC on the field dried material had dropped by 15%, and in February (2/17) MC was 10% less than initial piling.

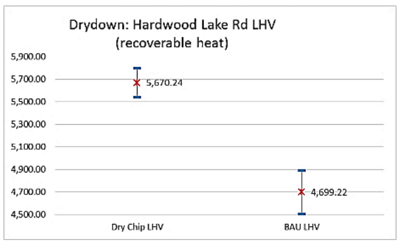
For the Berthiaume site, again, BAU is displayed (at right of graph) to serve as reference. Dramatic losses at Berthiaume over the 7.5 months was 22.42%, presumably due to the pile make-up. A high percentage of conifer in these piles likely contributed to the large moisture losses.

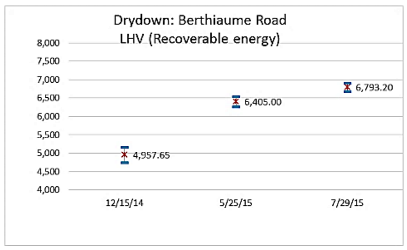
The study evaluated the impact of covering the biomass piles during the drying period at the CFC site. The covering did not significantly change the seasonal drying. Moisture losses displayed graphically here show the seasonal re-wetting during winter months. No significant difference was found for the covered verse uncovered piles

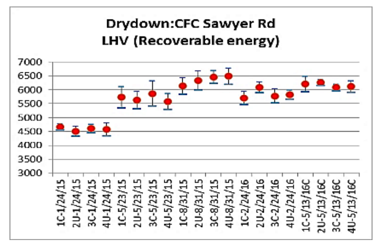
Sample date means for the CFC-Sawyer road are displayed at the right. Note that materials reach the lowest MC levels prior to fall rains and snow. Covering of the piles does not significantly reduce the re-wetting, so is likely not worth the costs to implement this in Minnesota conditions

	CFC-Sawyer Rd MC Range by Date
1/14/15	47.29%-46.32%
5/23/15	32.42%-27.40%
8/31/15	20.55%-23.45%
2/24/16	29.13%-25.94%
5/13/16	26.21%-29.38%

<u>Heat Value:</u> Comparing dry-down materials to the initial piling and the BAU materials demonstrates there is significant energy enhancement. Energy, measured in BTU's/lb. increased between 20% to 45% depending on the materials and the timing of the pile removal. The conifer materials and chipping during later summer/early fall tend to yield the greatest benefits.







Comparison of final chipped materials at Hardwood Lake Rd to BAU chips. A significant increase, from 4,699 BTU's/lb for BAU material verses 5,670 BTU's lb for dry-down, resulted in over 20% more energy per pound.

Using the same BAU chip comparison (4,699 BTU's/lb), the dry material at the Berthiaume site achieved higher fuel enrichment due to dry down (6,793 BTU's/lb). The improvement was a 45% increase in energy. The high percentage of conifer is a presumed contributor to the larger increase.

At the final chipping, the increase in energy was between 29% and 34%.

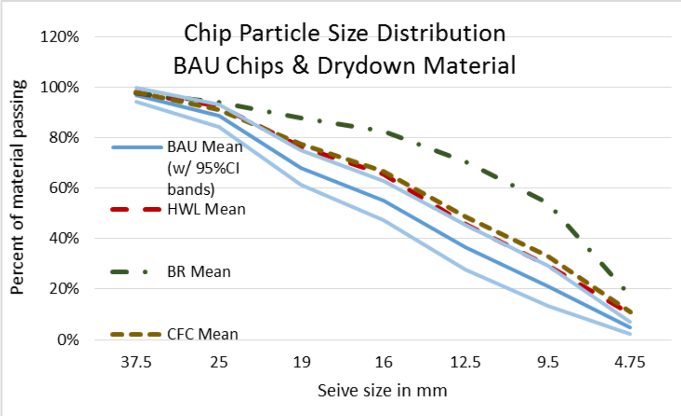
	CFC-Sawyer Rd LHV Range by Date
1/14/15	4,510-4,666 BTU/lb
5/23/15	5,579-5,866 BTU/lb
8/31/15	6,140-6,489 BTU/lb
2/24/16	5,704-6,093 BTU/lb
5/13/16	6,081-6,286 BTU/lb

At the CFC-Sawyer road, the impact of covering the piles was examined. There was not significant impact from the covered verses the uncovered piles, indicating that the covering is likely not an important investment in Minnesota climate.

Data at the left displays the average across the piles for each sample date. Regardless of pile and covering treatment, the dry fuel contains more energy per pound, even after 16 months in the field.

With a large window, it is likely that numerous opportunities arise for retrieval.

<u>Particle Size Distribution</u>: Above data provides evidence that infield storage enhances fuel value. Anecdotal evidence from logging firms indicated that dry fuel results in a change in fuel processing. Loggers noted that as wood dries out, the density increases, resulting in a harder material being drawn through a chip processor. The project sought to examine whether this had a significant impact on the particle size distribution of the chips produced.



When comparing the BAU chips (blue above with 95% CI's), it is apparent there is a slight shift to finer materials.

Discussion

This project demonstrates that strategic piling of woody biomass in the field allows for a drier, more energy rich fuel. For all project sites, the initial chip moisture was similar to that of BAU chip. Using in-woods drying, it is possible to achieve substantial energy benefits. Periodically collecting and testing the chips showed an averaged loss in moisture from 45.12% to 23.87% depending on the season of final processing and type of material piled. Over all, fall chipping yielded the largest benefits. Covering of the chip piles with the bio-blanket resulted in little or no additional benefit, so it is not worth the cost in Minnesota conditions. Allowing wood to dry on site to achieve lower MC increases the heat value by nearly 1500 BTU's per pound, providing more recoverable energy.

Since fuel-handling systems are designed around a specific fuel configuration, the project evaluated the effect on particle size distribution resulting from chipping dry-down materials. The results indicate a slight increase in medium to fine material for the hardwood sites and a substantially larger portion of fines for the conifer tops. Since most of the BAU sites contained very little conifer, we cannot confirm cause and effect for the conifer material. For hardwood, the increase was in the 19mm to 9.5mm chips, and little additional fines (less than 4.75mm). For feed system sensitive to fines, the confer material may cause handling issues.

A dry down operation changes biomass chips by lowering the density and in return, gives us the opportunity to haul more energy per pound. When the fuel weighs less, controversy arises with cost because shipment is paid by weight. An alternative payment would include an allowance for energy content (BTU) of the fuel. When adjusted for moisture content, a loaded semi-van containing dry-down material can haul up to 34% percent more energy than a BAU product.

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