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Process Development for Low-Moisture Content Wood Chips

Final Report

March 2016

Report Number 16-10

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Final Report

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NYSERDA Report 16-10 NYSERDA Contract 32981 March 2016

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Keywords

Low-moisture content wood chips; wood heat; passive drying; logging

Acknowledgments

The author wished to acknowledge the cooperation and assistance of the Northeastern Loggers' Association, VanAlstine Logging, LLC, Levi Lumber, Inc., the Town of Webb Forest, Paul J. Mitchell Logging, Lee Berry and Dr. William B. Smith.

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Summary

This project examined four methods of integrating transpiration drying into ordinary timber harvesting and wood yard operations in an attempt to produce low-moisture content (<30% MC, dry basis) wood chips. Partial drying of the wood before chipping was achieved in each case, but in none of the methods achieved the target moisture level. Each of the four approaches has some merit for partial drying prior to further processing.

1 Introduction

This project examined four methods of integrating transpiration drying into ordinary timber harvesting and wood yard operations. One method involved felling and bunching trees stems during the summer season and then allowing them to dry in place before eventually skidding and processing the stems on a landing site. A similar method involved felling, skidding, and piling tree stems and tops on a landing site for drying, followed by eventual chipping after drying had taken place. The third method involved harvesting, sorting, trucking, and piling roundwood at a maintenance yard for drying, followed by eventual chipping. The last method involved integrating the chip production from stockpiled wood at a multipurpose wood production facility. Each method and its results are described in detail in this report.

1.1 Drying Methods and Results

None of the attempted methods for transpiration drying resulted in low-moisture content chips that reached the target moisture content level of 30% or lower (dry basis). Each of the methods has some merit as an approach to produce a partially dried chip that can undergo further drying. These merits are discussed in Section 6 and Section 7.

1.2 Financial Analysis

Throughput accounting methods were used for preparing a financial analysis of each of the four methods. Throughput accounting measures net profit and return on investment for individual production situations. A customized Planning and Analysis in Timber Harvesting (PATH) spreadsheet was used to make these calculations based on the cost structure presented in each case. PATH is a Microsoft Excel spreadsheet that is freely available from the U.S. Department of Agriculture and is designed specifically for examining timber harvesting and production situations using throughput accounting.

The primary financial measurements in throughput accounting are net profit and return on investment (ROI). Profit is simply income less expenses. Return on investment is calculated by dividing the profit by the amount of the investment. In a logging operation, the investment consists of equipment and any fixed assets, such as a maintenance shop and yard. The investment for any individual harvesting project is the sum of the depreciation that occurs during production. Additionally, wood that is purchased and held for period of months (while drying) represents an investment as well and is treated that way in these analyses.

2 Method 1: Stockpile of In-Woods Material

In-woods stockpiling of wood chip feedstock was done over a four-day period, starting on July 1, 2014. Stems were felled and bunched with a tracked, swing boom, hot saw feller buncher. Bunches ranged in size from five to 20 stems, which is a typical approach for this sort of harvesting. A total of 243 bunches were created. Stems were left on site for drying until the period of October 2-18, 2014, when they were skidded to a landing site and chipped.

The timber harvesting was done in the Flatrock Mountain Demonstration Forest (1828 State Route 28, Thendara, NY 13472). This operation involved a previously planned shelterwood harvest on a 28-acre beech-sugar maple stand. The site has mild to steep slopes, with northwestern aspect. The silvicultural goal was to remove unacceptable growing stock (primarily beech) and advanced regeneration of understory beech to enhance the growth rate of the residual stand and stimulate the regeneration of a new age class of acceptable species.

Forty of the stem bunches were selected for moisture content testing. Bunches were chosen for moisture testing based on their physical location within the harvesting site to achieve a representative distribution. Moisture tests (see Box 1) of the bunched wood samples were made on July 5, 2014 through July 8, 2014. Follow up moisture tests were made on August 28, 2014 through September 3, 2014.

In-woods moisture content testing was done with a handheld Protimeter Timbermaster wood moisture meter. Moisture readings were taken from three stems in each bunch. An attempt was made to select stems from the full range of diameters present in the bunch. Measurements were made near the midpoints of the stem. A cut was made into the stems with a chainsaw or hatchet. The prongs from the moisture meter were then stuck into the stems and held in place until the meter reading stabilized, then the reading was recorded.

The Protimeter Timbermaster meter measures the moisture content of the wood on a wet basis. The wet basis measurements were converted to dry basis measurements using Equation 1.

Equation 1 $$DMC = WMC / (100 - WMC)$$

where:

- DMC = dry basis moisture content.
- WMC = wet basis moisture content.

Box 1. Moisture Testing Disclaimer

The oven-drying method, as described in *A Practical Guide for the Determination of Moisture Content of Woody Biomass* is considered to have the highest accuracy for research purposes.

Three types of moisture measurement devices were used for various aspects of this study. None of these devices meet the oven-drying methods standards:

- The Torbal Torbal BTS120 Moisture Analyzer uses the oven-drying method, but not one sufficient to meet the Method A Standards described in the publication referenced above.
- The Protimeter Timber Master is a conductance type meter that uses the electrical conductance of the wood as an indicator of moisture content. This meter is especially convenient for use in testing moisture content of tree stems and roundwood.
- The Agratronix Wood Chip Moisture Tester is an electronic capacitance type meter. This device is especially convenient for use in testing wood chips at the production site.

Govett, Robert, Mace, Terry and Scott Bowe. 2010. *A Practical Guide for the Determination of Moisture Content of Woody Biomass.* Madison, WI: Wisconsin Department of Natural Resources. 18 p.

The mean dry-basis moisture content level of the bunched stems was 51.9% during the period of July 7, 2014 to July 9, 2014. A follow up set of measurements during the period of August 27, 2014 to September 3, 2014 revealed a mean dry-basis moisture content level of 44.3%.

The bunched stems were skidded and chipped during the period of October 2, 2014 to October 16, 2014. A total of 614.44 tons (22 loads) of wood chips were produced. The chips were noticeably drier to the touch than green chips and loaded weights were less than typical weights of green loads.

A sample of wood chips was collected for moisture testing from each load that was produced. A tarp w as placed on the ground below the chipper shoot and behind the chip trailer to collect the sample. This tarp collected chips that did not fall into the van. The wood chipper operator would periodically place his loader grapple in front of the stream of chips. This placement caused some of the chips to fall onto the trap and ensured that that collected sample included chips from multiple tree stems.

Wood chips samples were moisture tested with three separate pieces of equipment: an Agratronix wood chip moisture tester, a Protimeter Timbermaster wood moisture meter, and a Torbal BTS120 moisture analyzer. Thirty chips from each collected sample were tested with both the Agratronix wood chip moisture tester and the Protimeter Timbermaster wood moisture meter. A smaller subset (due to space constraints) from these 30 chips were placed in the Torbal BTS120 moisture analyzer for an additional test. The results of the three different moisture testing methods were then averaged.

The mean dry basis moisture content for all loads was 40.1%. Samples from six of the loads were collected under damp, rainy conditions. Samples from these loads had noticeably higher moisture contents. Excluding these six loads with potentially inflated moisture content, the mean dry basis moisture content of the remaining loads was 39.3%.

A summary of harvesting and transpiration drying conditions, along with final moisture content measurements, is shown in Table 1.

Table 1. In-wood stockpile wood chip production site, drying and moisture content summary (Method 1)

Harvest Location:	**1828 State Route 28, Thendara, NY 13472**			
28 acres	**NW Aspect Slope**			
Transpiration Drying Period		7/1/14 - 10/16/14		
Number of Days		91 to 108 days		
Start Point MC:	52.7%			
	Max	Average	Min	
Mean Temperature	81° F	64° F	45° F	
				total
Precipitation	2.06"	0.14"	0.0"	12.47"
All Loads	(22 total; 614.7tons)			
	Protimeter	Agratronix	Torbal	Average
Mean MC	39.6%	35.5%	45.2%	**40.1%**
Standard Deviation	3.2%	3.9%	12.0%	
Loads without excessive rain/moisture		(16 total, 418.1 tons)		
	Protimeter	Agratronix	Torbal	Average
Mean MC	38.3%	34.2%	45.3%	**39.3%**
Standard Deviation	1.8%	3.2%	13.7%	

2.1 Method 1 PATH Throughput Accounting Measurements

PATH spreadsheet measurements were used to make throughput accounting projections for the in-woods stockpiling harvesting procedure testing in this study (Method 1). Complete records of machine hours are central to these analyses. PATH determines hourly costs, compiles daily business overhead and includes an accounting of job specific costs. Job-specific costs in this case include the cost of moving the equipment to the job site and the opportunity cost imposed by felling the trees and waiting for several months before completing the harvest, rather than selling them right away.

Using a throughput accounting approach, machine costs for wood chip production in Method 1 total $14,643. Job specific costs come to $1,153, including $153 in opportunity costs incurred by the 108-day delay while transpiration drying took place (using a 10% rate of interest). Trucking was $8 per ton and stumpage (the payment made to landowners for timber) was $4 per ton. The total estimated costs for producing and delivering 615 tons of wood chips was $26,186. The logging contractor's total investment in the project is measured as the sum of hourly depreciation for all machines. This amount comes to $2,647. A summary of the costs information is shown in Table 2.

Further analysis was done to determine the delivered wood chip prices necessary to reach certain financial benchmarks. For the producer to break even in the Method 1 production scenario, a price of $42.60 per ton is necessary. All prices above this level yield a return on investment for the business. For example, to achieve a 10% ROI, a price of $43.03 is necessary. A summary of these financial benchmarks is show in Table 3.

A Buyer's Guide to Sourcing Wood Heating Fuel in the Northeastern U. S. (2014, www.biomasscenter.org/pdfs/veic-sourcing-wood-heating-fuel-publication.pdf) reports that the price of quality woodchips commonly used for heating ranges between $45 and $65 per green ton. With this in mind, the previously calculated break-even price is at a viable market level.

Table 2. Summary of PATH throughput accounting cost measures for in-woods stockpiling wood chip production (Method 1)

Machine Costs			
Machine	PMH	$/PMH	Cost
Tracked Hot Saw Feller Buncher	44	$ 117.24	$ 5,158.56
Grapple Skidder	99	$ 57.79	$ 5,721.21
Loader with Slasher	36	$ 61.32	$ 2,207.52
Disk Chipper	18	$ 86.42	$ 1,555.56
Total Machine Costs			$ 14,642.85
Overhead	**days**	**$/day**	**Cost**
11 days on site	11	$ 274.00	$ 3,014.00
Job Specific Costs			-
Moving Equipment			$ 1,000.00
Opportunity cost of delayed harvest			
($5,158.56 @ 10% annual interest for 108 days)			$ 152.64
Trucking ($8 per ton)			$ 4,917.60
Stumpage ($4 per ton)			$ 2,458.80
Total Production & Delivery Cost			**$ 26,185.89**
Total Investment (sum of hourly depreciation)			$ 2,646.50

Table 3. PATH throughput financial measurements for in-woods stockpiling wood chip production (Method 1)

- **Financial Benchmarks for Production of 614.7 tons of Wood Chips**		
ROI Level	Price ($/ton)	Profit
Break Even	$ 42.60	$ -
2% Return on Investment	$ 42.68	$ 52.93
5% Return on Investment	$ 42.81	$ 132.33
10% Return on Investment	$ 43.03	$ 264.65
15% Return on Investment	$ 43.24	$ 396.98
20% Return on Investment	$ 43.46	$ 529.30
25% Return on Investment	$ 43.67	$ 661.63
30% Return on Investment	$ 43.89	$ 793.95
35% Return on Investment	$ 44.10	$ 926.28
40% Return on Investment	$ 44.32	$ 1,058.60
45% Return on Investment	$ 44.53	$ 1,190.93
50% Return on Investment	$ 44.75	$ 1,323.25

3 Method 2: Landing Stockpile

The landing stockpile method involved felling, skidding, sorting, and piling tree stems and tops on a log landing site for drying, with chipping occurring at a later date. A landing is the truck access site for a timber harvesting operation. Trees are typically cut up, sorted, piled, and loaded on trucks at the landing sites.

In-woods landing stockpiles were created at two different sites. This made it possible to test a greater number of variations, including site conditions, seasons (leaf-on; leaf-off) and drying times. Site 1 was winter season wood (leaf-off) on a north-facing landing site on the Bisby Road in the Town of Webb, NY. Site 2 was summer season wood (leaf-on) on a south-facing landing site on the Cemetery Road in the Town of Forestport, NY. Details for each site are reported separately as follows.

3.1 Site 1

Trees for the Site 1 (Bisby Rd.) stockpile were felled and skidded in December 2013. The wood was piled on an accessible landing site. This stockpile was purchased on December 18, 2013 from the logging contractor who harvested it.

All of the individual stems in the stockpile were measured, noting their species and butt end diameter. This information, along with average stem length (determined by the pile size) was used to estimate the cubic foot volume of the stems, by species. Cubic foot volume estimates were used to determine the species composition of the pile. The species composition reflected the silvicultural removal goals of the landowner where the harvest took place. The stockpile was primarily beech (70%), with sugar maple (13%), red maple (8%), yellow birch (7%) and red spruce (2%) also present.

Measurements of the starting moisture content of the stockpile were made on January 12, 2014, using a Protimeter Timbermaster Wood Moisture Meter. Outside temperatures were too low to make accurate readings on site. Pieces of wood were cut from stems with a chainsaw and brought indoors for thawing before moisture readings were made. A total of 30 samples of wood were collected from the stockpile, in proportion to the species distribution present.

The average starting point dry-basis moisture content of the stockpile was 61.5%. Follow-up moisture measurements were made to track drying progress on three occasions. The dry-basis moisture content of the stockpile was 58% of June 17, 2014; 52% on August 30, 2014; and 43% on October 23, 2014.

A sample of wood chips was collected for moisture testing from the load that was produced. As in Method 1, samples were collected by placing a tarp on the ground below the chipper shoot and behind the chip trailer. This tarp collected chips that didn't fall into the van. The wood chipper operator would periodically place his loader grapple in front of the stream of chips. This placement caused some of the chips to fall onto the trap and ensured that that collected sample included chips from multiple tree stems.

Wood chips samples were moisture tested with three separate pieces of equipment: an Agratronix wood chip moisture tester, a Protimeter Timbermaster wood moisture meter, and a Torbal BTS120 moisture analyzer. Ninety wood chips were taken from the collected sample and were tested with both the Agratronix wood chip moisture tester and the Protimeter Timbermaster wood moisture meter. A smaller subset (due to space constraints) from these 90 chips were placed in the Torbal BTS120 moisture analyzer for an additional test. The results from each moisture testing method were then averaged.

The mean dry basis moisture content for these wood chips was 43.1%. A summary of harvesting and transpiration drying conditions, along with final moisture content measurements, is shown in Table 4.

Table 4. In-woods tree stem stockpile drying information and wood chip moisture for landing Site 1

Stockpile Location: roadfront landing	**Little Moose Mountain, Bisby Road, Old Forge, NY 13420 N Aspect Slope**			
Transpiration Drying Period		4/15/2014 - 10/24/14		
Number of Days		192 days		
Start Point MC:	61.5%			
	Max	Average	Min	
Mean Temperature	80° F	61° F	26° F	
				total
Precipitation	2.06"	0.14"	0.00"	27.93"
Wood Chip Moisture Measurements				
	Protimeter	Agratronix	Torbal	Average
Mean MC	43.8%	44.0%	41.5%	**43.1%**

3.2 Site 2

Trees for the Site 2 (Cemetery Rd.) stockpile were felled and skidded in June 2013. The wood was piled on an accessible landing site. This stockpile was purchased from the logging contractor who harvested it on July 2, 2014.

All of the individual stems in the stockpile were measured, noting their species and butt end diameters. The species composition reflected the silvicultural removal goals of the landowner where the harvest took place. The stockpile was primarily red maple (39%) and beech (34%), with lesser amounts of Eastern hemlock (10%), sugar maple (7%), yellow birch (5%), black cherry (5%) and balsam fir (<1%).

Measurements of the starting moisture content of the stockpile were made on July 2, 2014, using a Protimeter Timbermaster Wood Moisture Meter. A total of 33 samples measurements were collected from the stockpile, in proportion to the species distribution present.

The average starting point dry-basis moisture content of the stockpile was 63.1%. Many of the stems still had green leaves intact, so a significant amount of initial transpiration drying was anticipated. Follow up moisture measurements were made two weeks later on July 17, 2014. The dry-basis moisture content of the pile was 49.1% on that date. Subsequent moisture testing on August 28, 2014 and November 3, 2014 revealed moisture contents of 47.3% and 35.8%, respectively.

Three loads of wood chips were produced from this stockpile on November 2, 2014 (2 loads) and November 3, 2014 (1 load). Samples of wood chips were collected from each load. Samples were collected by placing a tarp on the ground below the chipper shoot and behind the chip trailer. This tarp collected chips that didn’t fall into the van. The wood chipper operator would periodically place his loader grapple in front of the stream of chips. This caused some of the chips to fall onto the trap and ensured that that collected sample included chips from multiple tree stems.

Wood chips samples were moisture tested with three separate pieces of equipment: an Agratronix wood chip moisture tester, a Protimeter Timbermaster wood moisture meter, and a Torbal BTS120 moisture analyzer. Thirty wood chips were taken from each collected sample and were tested with both the Agratronix wood chip moisture tester and the Protimeter Timbermaster wood moisture meter. A smaller subset (due to space constraints) from these chips were placed in the Torbal BTS120 moisture analyzer for an additional test. The results from each moisture testing method were then averaged.

The mean dry basis moisture content for all three loads of wood chips was 37.4%. The first load was the driest, at 33.5%. The second and third loads had higher moisture contents (38.9% and 39.9%, respectively). Much of the first load may have come from stems on the upper portion of the pile. These stems had greater exposure to air and sunlight, which may explain why the first load was somewhat drier than the others.

A summary of harvesting and transpiration drying conditions, along with final moisture content measurements, is shown in Table 5.

Table 5. In-woods tree stem stockpile drying information and wood chip moisture for landing Site 2

Stockpile Location: roadfront landing	**Cemetery Road, Forestport, NY 13338 S Aspect Slope**			
Transpiration Drying Period		7/2/14 - 11/2/14		
Number of Days		124 days		
	Max	Average	Min	
Mean Temperature	80° F	62° F	36° F	
				total
Precipitation	2.06"	0.14"	0.0"	17.41"
Start Point MC:	63.1%			
Wood Chip Moisture Measurements				
	Protimeter	Agratronix	Torbal	Average
Mean MC	34.7%	38.2%	39.4%	**37.4%**

3.3 Method 2 PATH Throughput Accounting Measurements

PATH was used to make a financial analysis of the landing stockpile method of drying wood for later chipping into low-moisture content heating fuel (Method 2). The two sites used in this test formed the basis for a hypothetical business model of this approach.

An assumption was made that a minimum of four loads of wood chips (approximately 152 tons) would be needed to warrant moving the chipping equipment to the site for a single day of production. The cost of purchasing wood on the landing was set at $20 per ton. This amount allows for payment of stumpage to the landowner, felling, skidding, and piling of the wood.

Production of wood chips would require moving two pieces of equipment to the stockpile site: a knuckle-boom log loader and a disk chipper. The cost of moving the equipment was estimated at $1,000.

Hourly operating costs for each machine were calculated in PATH. The cost of the loader is $108.56 per hour, and the cost of the chipper is $154.83. These costs include the cost of a single operator who would run both machines (the chipper is simply running; the loader has an operator who uses it to feed the chipper). Production of four loads would require 4 hours of loader operation and 3 hours of chipper operation.

A single day of business overhead ($275) was attributed to this production. Trucking of wood chips up to 30 miles was assumed to cost $8 per ton. The opportunity cost of purchasing the wood and letting it dry for four months was calculated using the wood value ($1,824) and 10% annual interest, applied for 120 days.

The total investment in this undertaking is the cost of purchasing and holding the wood, plus the hourly depreciation of the equipment that was used. This cost came to $1,999.75

The foregoing cost estimates were purposely generous, but within observed ranges for such costs. Some of the components of the work could possibly be accomplished at a lower cost (for example, moving costs, equipment costs and daily overhead). All costs are summarized in Table 6.

Assumed profit levels ranged from breaking even to a 100% return on investment (ROI). This information was then used to calculate the delivered prices for the wood chips necessary to achieve target ROIs. A summary of these benchmark prices is shown in Table 7.

Table 6. Summary of cost information associated with throughput analysis of single-day low moisture content wood chip production from landing stockpiles (Method 2)

Machine Costs	**Production of 152 tons (4 loads) wood chips**		
Machine	PMH	$/PMH	Cost
Knuckle-Boom Loader	4	$ 108.56	$ 434.23
Disk Chipper	3	$ 154.83	$ 464.49
			$ -
			$ -
Total Machine Costs			$ 898.73
Overhead	**days**	**$/day**	**Cost**
1 day on site	1	$ 275.00	$ 275.00
Job Specific Costs			
Moving Equipment			$ 1,000.00
Opportunity cost of delayed harvest			
($1,824 @ 10% annual interest for 120 days)			$ 593.97
Trucking ($8 per ton)			$ 1,216.00
Stumpage, Felling, Skidding ($12 per ton)			$ 1,824.00
Total Production & Delivery Cost			**$ 5,807.70**
Total Investment (sum of hourly depreciation & purchased wood)			$ 1,999.75

Table 7. Price per ton benchmarks necessary to achieve target ROI levels for single-day production of low moisture content wood chips from landing stockpiles (Method 2)

Financial Benchmarks for Production of 152 tons of Wood Chips

ROI Level	Price ($/ton)	Profit
Break Even	$ 38.21	-
10% Return on Investment	$ 39.52	$ 199.98
15% Return on Investment	$ 40.18	$ 299.96
20% Return on Investment	$ 40.84	$ 399.95
25% Return on Investment	$ 41.50	$ 499.94
30% Return on Investment	$ 42.16	$ 599.93
35% Return on Investment	$ 42.81	$ 699.91
40% Return on Investment	$ 43.47	$ 799.90
45% Return on Investment	$ 44.13	$ 899.89
50% Return on Investment	$ 44.79	$ 999.88
100% Return on Investment	$ 51.36	$ 1,999.75

4 Method 3: Roundwood Stockpile at Maintenance Shop

The third method studied involved harvesting trees, sorting out roundwood portions of stems, and then trucking them to a logger’s maintenance shop for drying and subsequent chipping. The roundwood stockpile was created over a three-week period from mid-February to early March 2014. Four tandem loads of roundwood were delivered to a logger’s maintenance shop and yard on Limekiln Road in the Town of Inlet, NY.

All of the individual stems in the stockpile were measured, noting their species and small and butt end diameters. The stockpile was primarily beech (63%), with red maple (22%), hemlock (10%), yellow birch (4%) and sugar maple (1%) also present.

Measurements of the starting moisture content of the stockpile were made on March 5, 2014, using an Agratronix Wood Chip Moisture Tester. Outside temperatures were too low to make accurate readings on site. Sawdust was created and collected by plunge cutting into the stems with a chainsaw and catching the sawdust on a tarp. These sawdust samples were brought indoors for thawing before moisture readings were made. A total of 60 sawdust samples were collected from the stockpile, in proportion to the species distribution present.

The average starting point dry-basis moisture content of the stockpile was 79.4%. Follow-up moisture measurements were made to track drying progress on three occasions. The dry-basis moisture content of the stockpile was 65.1% on June 10, 2014; 53.8% on August 29, 2014; and 36.2% on November 3, 2015.

The roundwood stockpile was chipped on January 2, 2015. A sample of wood chips was collected for moisture testing from the loads of wood chips that were produced. Samples were collected by placing a tarp on the ground below the chipper shoot and behind the chip trailer. This tarp collected chips that didn’t fall into the van. The wood chipper operator would periodically place his loader grapple in front of the stream of chips. This placement caused some of the chips to fall onto the tarp and ensured that that collected sample included chips from multiple tree stems.

Wood chips samples were moisture tested with three separate pieces of equipment: an Agratronix wood chip moisture tester, a Protimeter Timbermaster wood moisture meter and a Torbal BTS120 moisture analyzer. Sixty wood chips were taken from the collected sample and were tested with both the Agratronix wood chip moisture tester and the Protimeter Timbermaster wood moisture meter. A smaller subset (due to space constraints) from these 60 chips were placed in the Torbal BTS120 moisture analyzer for an additional test. The results from each moisture testing method were then averaged to arrive at a mean dry basis wood moisture content.

The mean dry basis moisture content for these wood chips was 36.7%. A summary of harvesting and transpiration drying conditions, along with final moisture content measurements, is shown in Table 8.

Table 8. Roundwood stockpile drying information and wood chip moisture

Stockpile Location: yard landing	**92 Limekiln Lake Rd, Inlet, NY 13360 SE Aspect Slope**			
Transpiration Drying Period		4/15/14 - 10/31/14		
Number of Days		200 days		
	Max	Average	Min	
Mean Temperature	60° F	62° F	26° F	
				total
Precipitation	2.06"	0.14"	0.0"	28.4"
Start Point MC:	81.5%			
Wood Chip Moisture Measurements				
	Protimeter	Agratronix	Torbal	Average
Mean MC	38.6%	32.8%	38.7%	**36.7%**

4.1 Method 3 PATH Throughput Accounting Measurements

Stockpile drying of roundwood for chips to supply a market demand would almost certainly be done at a larger scale than was done in this project trial. Nevertheless, the production steps followed in this project are instructive in providing the background necessary for a larger analysis. This section will use throughput accounting to make projections for both the project steps and steps necessary to do this sort of drying of roundwood at a larger scale.

Accounting for production from logging must take three key components into account: machine hours, overhead, and job specific costs. These three costs for the work that was done in stockpiling roundwood and producing chips (Method 3) are summarized in Table 9.

Table 9. Summary of costs associated with stockpiling roundwood and subsequent production of low-moisture content wood chips (Method 3)

Machine	PMH required	$/PMH	Cost
tracked feller buncher	1	$ 125.50	$ 125.50
grapple skidder	2.5	$ 87.68	$ 219.20
loader with slasher	2.5	$ 71.48	$ 178.70
drum chipper	1.5	$ 117.76	$ 176.64
	days	**$/day**	
Overhead	1	$ 500.00	$ 500.00
Job specific costs			
stumpage			$ 320.00
trucking to yard			$ 800.00
Total Costs			**$ 2,320.04**

A customized PATH spreadsheet was used to make these calculations based on the cost structure presented in Table 2. In the absence of an actual market for these low-moisture wood chips, a target ROI of 12% was used, and then the price necessary to reach this goal was determined. This price excludes the cost per ton to deliver these chips to a destination market.

Return on investment is calculated by dividing the profit by the amount of the investment. In a logging operation, the investment includes equipment and any fixed assets, such as a maintenance shop and yard. The investment for any individual harvesting project is the sum of the depreciation that occurs during production. In this example, the investment totals $228. A prices of $39.12 per ton produces revenue of $2,347 from 60 tons of wood chips. The net profit is $27, which yields an ROI of 12% ($27/$228 = 0.12).

Although a 12% return on investment might be desirable, a net profit of just $27 is hardly sufficient to incentivize production. As a potential value-added sideline for a logging business, a more realistic example might involve a full week's production.

Throughput accounting for the costs associated with harvesting, and transport of roundwood, followed by subsequent production of 1,000 tons of low-moisture content wood chips are shown in Table 10. These costs come to $30,972.80.

Table 10. Summary of costs associated with stockpiling roundwood and subsequent production and delivery of 1,000 tons of low-moisture content wood chips (Method 3)

Machine	PMH required	$/PMH	Cost
tracked feller buncher	30	$ 125.50	$ 3,765.00
grapple skidder	35	$ 87.68	$ 3,068.80
grapple skidder 2	20	$ 88.18	$ 1,763.60
loader with slasher	55	$ 71.48	$ 3,931.40
drum chipper	25	$ 117.76	$ 2,944.00
	days	$/day	
Overhead	5	$ 500.00	$ 2,500.00
Job specific costs			
stumpage - roundwood			$ 5,000.00
trucking to yard ($8 per ton)			$ 8,000.00
Total Costs			**$ 30,972.80**

PATH was used to calculate the prices necessary to achieve various levels of ROI for this production situation. The total investment in this production is the sum of the hourly equipment depreciation ($4,300) along with the stumpage cost ($5,000). The stumpage cost would not typically be considered an investment, but the long holding period involved with stockpiling the wood qualifies it as such. The total investment comes to $9,300.

A 10% ROI would require a price of $31.90 per ton, while $30.97 per ton is the minimum necessary to break even. Prices were calculating up through an ROI of 100% ($40.27 per ton). This range is presented in Table 11.

Table 11. Financial benchmarks for production of 1,000 tons of low-moisture content wood chips from stockpiled roundwood at a logger maintenance yard (Method 3)

Financial Benchmarks for Production of 1000 tons of Wood Chips		
ROI Level	**Price ($/ton)**	**Profit**
Break Even	$ 30.97	$ -
10% Return on Investment	$ 31.90	$ 930.00
15% Return on Investment	$ 32.37	$ 1,395.00
20% Return on Investment	$ 32.83	$ 1,860.00
25% Return on Investment	$ 33.30	$ 2,325.00
30% Return on Investment	$ 33.76	$ 2,790.00
35% Return on Investment	$ 34.23	$ 3,255.00
40% Return on Investment	$ 34.69	$ 3,720.00
45% Return on Investment	$ 35.16	$ 4,185.00
50% Return on Investment	$ 35.62	$ 4,650.00
100% Return on Investment	$ 40.27	$ 9,300.00

5 Method 4: Wood Chip Production at a Secondary Wood Processing Facility

The secondary processing site option for creating low-moisture wood chips required an arrangement with an existing wood products business. An animal bedding and wood shavings company that uses roundwood and recycled paper goods to make its product was chosen as the cooperator. This company regularly acquires and maintains a roundwood stockpile in its yard.

This method involved wood chip production at an existing business' secondary processing site. The cooperating business normally keeps a supply of roundwood on hand as one of their production inputs. This roundwood inventory presents an opportunity for exploring production of low-moisture content wood chips as an additional product line. The roundwood inventory is purchased at opportune times throughout the year and often undergoes several months of transpiration drying before it is used in creating their products.

The cooperator made a stockpile of white pine roundwood available for this project. The wood was harvested in fall 2012 and then sold to a sawmill. This mill stored the logs through the winter and kept them under a sprinkler system to prevent drying and staining until they were acquired by the study cooperator on July 23, 2013. Passive transpiration drying began at that point and continued until approximately October 31, 2013, when weather conditions prevented further drying.

The starting point moisture content for this wood is not known.

Two loads of wood chips were produced from this stockpile on December 12, 2013. The cooperator retained the wood chips for use in its animal bedding production, so load weights were not determined.

Wood chip samples for moisture testing were obtained from each load. Samples were collected by placing a tarp on the ground below the chipper shoot and behind the chip trailer. This tarp collected chips that did not fall into the van. The wood chipper operator would periodically place his loader grapple in front of the stream of chips. This placement caused some of the chips to fall onto the trap and ensured that that collected sample included chips from multiple tree stems.

The wood chip moisture content of the samples that were collected was tested using an Agratronix Wood Chip Moisture Tester. Thirty-two moisture tests were made for each load. This tester gives moisture content readings on a wet basis. The average green moisture content for each sample was converted to a dry basis using the formula in Equation 2.

Equation 2 $$DMC = WMC / (100 - WMC)$$

where:

- DMC = dry basis moisture content.
- WMC = wet basis moisture content.

The average dry basis moisture content of the Load 1 sample was 37.2%. The average dry basis moisture content of the Load 2 sample was 46.0%. The average dry basis moisture content of both loads was 41.6%. A summary of transpiration drying conditions and moisture content measurements is shown in Table 12.

Table 12. Secondary processing business roundwood stockpile drying information and wood chip moisture (Method 4)

Stockpile Location: wood yard	**92124 US-11, Adams, NY 13605 S Aspect Slope**			
Transpiration Drying Period		7/29/13 - 10/31/13		
Number of Days		111 days		
	Max	Average	Min	
Mean Temperature	82° F	59° F	31° F	
				total
Precipitation	1.22"	0.11"	0.0"	9.15"
Start Point MC:	not known	species:	white pine	
Wood Chip Moisture Measurements				
		Agratronix		Average
	Load 1	Load 2		
Mean MC	37.2%	46.0%		**41.6%**

5.1 Method 4 PATH Throughput Accounting Measurements

PATH was used to make a financial analysis of producing low-moisture content wood chips at an existing secondary wood processing business. The scenario used in this test forms the basis for a hypothetical business model of this approach.

Producing low-moisture content wood chips as an additional product line at an existing secondary processing business involves several steps. Roundwood must be purchased well in advance of anticipated chipping so that transpiration drying can take place. Once acquired, the roundwood must be stacked and position and positioned in a manner that takes advantage of sunlight exposure and air circulation. After drying has taken place, chipping equipment must be subcontracted (or owned outright). Covered storage of the wood chip inventory that is produced is necessary to prevent addition of moisture to them. These steps involve material costs, equipment costs, and the cost of capital that is tied up while the roundwood is drying. This cost might be the actual interest charged on a line of credit or the opportunity cost of using a firm's liquid capital.

A set of example calculations was used for this financial analysis. A quantity of 1,000 tons of low-moisture content wood chips was used as a minimum production level to make the undertaking worthwhile, based on and interview with study cooperators. To produce this amount of low-moisture chips, a larger quantity of roundwood must be acquired to account for the loss of weight from drying. Cost estimates for roundwood for stockpiling were made using 1,200 tons. An initial roundwood price of $15 per green ton was used in the analysis. An annual interest rate of 5% annually was used and the assumption was made that capital would be tied up for a full year.

Two pieces of equipment are required for chip production: a log loader and a disk chipper. The log loader is an existing piece of equipment at the cooperator's facility and is operated at a cost of $75 per machine hour. A total of 35 hours were needed for unloading, stacking, and feeding the chipper. A disk chipper can be contracted for several days of chipping at a cost of $200 per machine hour. Approximately 20 hours of chipping is required. Machine cost rates were calculated using the PATH 2.0 spreadsheet. Chips can be collected and stored with existing material handling equipment at the operation for a cost of $2,000.

A portion of the daily overhead of the business should be attributed to this new product line. A total of $600 was used to account for this, assuming $100 per day for six days. This rate is based on interviews with study cooperators.

A summary of the example costs is shown in Table 13. The total investment required includes the cost of the roundwood and the cost of capital.

Table 13. Summary of costs and investment associated with production of 1,000 tons of low-moisture content wood chips at a secondary wood processing facility (Method 4)

items	amount	price	cost
roundwood	1200 tons	$15.00	$ 18,000
loader (in house)	35 hours	$75.00	$ 2,625
chipper (contracted)	20 hours	$200.00	$ 4,000
handling & storage			$ 2,000
overhead			$ 600
opportunity cost of capital			$ 900
			$ 28,125
Investment (material + cost of capital)			$ 18,900

The foregoing cost assumptions were used to calculate the financial results for a range of wood chip prices. Delivery costs were not accounted for, so all prices are considered the amount received for wood chips purchased at the facility. Prices of $25 per ton and under resulted in a net loss. Prices of $30 per ton showed a modest ROI of 20.5%. At a price of $50 per ton, an ROI of over 126% is realized.

Perhaps the least certain cost involved in this analysis is the price of roundwood. For this reason, a sensitivity analysis was done using roundwood prices ranging from $15 to $40 per green ton, at $5 intervals. These prices have a significant impact on ROI. A positive ROI is realized in most cases only if wood chip prices exceed roundwood prices by approximately $20 per ton. A summary of these results is shown in Table 14.

Production of low-moisture content wood chips in this manner has the potential to be profitable, but only with the right combination of raw materials costs and product price.

Table 14. Financial results from production of 1,000 tons of low-moisture wood chips using Method 4 at various levels of chip prices and roundwood costs

			roundwood price per ton					
wood chip	wood chip		$15	$20	$25	$30	$35	$40
quantity	price/ton	revenue	ROI	ROI	ROI	ROI	ROI	ROI
1000	$20.00	$20,000	76.6%	-44.5%	-53.5%	-60.0%	-64.9%	-68.8%
1000	$25.00	$25,000	-12.0%	-29.1%	-40.6%	-48.9%	-55.2%	-60.1%
1000	$30.00	$30,000	7.2%	-13.6%	-27.7%	-37.8%	-45.4%	-51.4%
1000	$35.00	$35,000	26.3%	1.8%	-14.8%	-26.7%	-35.7%	-42.7%
1000	$40.00	$40,000	45.5%	17.2%	-1.9%	-15.6%	-26.0%	-34.1%
1000	$45.00	$45,000	64.6%	32.6%	11.0%	-4.5%	-16.2%	-25.4%
1000	$50.00	$50,000	83.7%	48.0%	24.0%	6.6%	-6.5%	-16.7%

6 Discussion

Although none of the methods attempted in this study produced wood chips with a moisture content level of less than 30%, all of the methods have the potential for creating feedstock for further drying. As one study cooperator put it “take what drying you can get without an energy input and then figure out the next step.” Cooperators agreed that a market demand for these low-moisture content wood chips would motivate producers to create cost-effective drying methods.

Important considerations for each of the four methods from this study are discussed in this section.

6.1 Method 1: Stockpile of In-Woods Material

Stockpiling tree stems in the woods provided a significant amount of drying. The timing of the felling meant that the drying took place at an opportune time of the year, during the summer months. Felling the trees when they were leafed out also contributed to the drying rate. A significant amount of drying took place immediately after felling, while the leaves were still green and attached.

Whole tree harvesting operations in the Northeast often have an excess of felling capacity. This capacity provides the opportunity to do felling weeks or months ahead of time, as was done for the study. In practice, market and cash flow demands mean that most felled timber is harvested soon thereafter. There is an opportunity to leave a portion of the felled trees for later harvesting, or to leave the trees that were felled first until the end of the harvest before they are skidded and processed. In this way, a portion of any given harvest could be used to meet the demand for low-moisture content wood chips.

The tracked, swing boom feller buncher used in this approach is one of the most cost-effective means of controlling undesirable understory species. Unfortunately, it is also a very expensive machine to own and operate. Using one company’s excess felling capacity to achieve a silvicultural goal and using the more commonly available equipment of another logging company for skidding and processing has a great deal of appeal and potential for landowners. A disadvantage in this approach is that most wood chips are sold by green weight, which means that markets actually penalize moisture loss. Markets for low-moisture content wood chips would have to pay a high enough rate to offset the revenue loss from the portion of the dried wood that is sold to green-weight based markets.

Summer season harvesting has demonstrated silvicultural advantages in certain forest types such as the one that was treated here. For example, cutting leafed out undesirable beech trees has been shown to result in a lesser amount of stump sprouting than cutting the same trees during the dormant season.

The timing of this sort of operation can limit its potential. Timber that has been felled should be skidded and processed before wet weather begins to dominate the fall season. Waiting until winter to skid the wood is not feasible, as bunched stems become frozen in place and may be impossible to locate.

Although this decoupled felling and skidding approach is a multistep process, it does requiring less handling than methods that move green wood for stockpile drying and chipping on other sites. When the wood does not leave the harvesting site until the wood chips are produced, it reduces overall costs and improves the energy return on investment (EROI) ratio.

All in all, this stockpiling in-woods approach can serve as an occasional, opportunistic method of achieving partial drying before final drying is accomplished in a separate process.

6.2 Method 2: Landing Stockpile

This method resulted in some drier feedstock for wood chips, but creates similar logistical challenges to the first method. It is possible to leave just a portion of the harvested wood on the landing site to dry. A producer could have stockpiled wood on a number of landing sites. Most of the wood harvested on any given site would be processed right away for other markets, leaving only the wood destined for chipping and minimizing the amount of cash flow disruption that comes from holding an inventory.

Any stockpile landing site must be accessible at the later date when chipping is planned. Many winter harvesting sites are muddy and inaccessible for much of the year. Furthermore, landowners who harvest timber infrequently are often uninterested in allowing stockpiles of wood to linger on their property for several months. There is also some risk of theft of the wood by people who will take it for firewood.

It is desirable to have sufficient space on a landing to hold enough wood to produce 5 to 10 trailer loads of wood chips. Space on landing sites is often limited. Creating large piles can inhibit drying.

Producers that have access to good landing sites for stockpiles can make advantageous use of this method. While this approach does have some logistical challenges, it also limits the amount of trucking necessary because the wood does not leave the harvesting site until the wood chips are produced. This reduces overall costs and improves the Energy Return on Investment (EROI) ratio.

6.3 Method 3: Roundwood Stockpile at Maintenance Shop

A logger with a maintenance shop or other dedicated site for stockpiling roundwood can produce high-quality wood chips. The added cost of transportation to the site distinguishes this method from the Methods 1 and 2. The benefits that counteract additional transportation include greater control of inventory and convenience in later production.

Holding an inventory always poses a certain amount of opportunity cost, inconvenience, and risk, but it also presents an opportunity. Logging operations are typically producing and trucking loads of roundwood on a regular basis. The amount of wood chips needed to satisfy a local heating market is likely to be just a fraction of a logging operation's annual production. With this in mind, loads brought to a stockpile location can be done opportunistically. For example, when the demand for wood in other markets is slow or subject to quota, loads can be devoted to the stockpile. The mobile nature of timber harvesting means that some job sites will be closer to the maintenance shop than others. Taking advantage of shorter trucking distances to meet anticipated stockpile requirements makes financial and logistical sense. Finally, it may be convenient to stockpile loads of roundwood during times when cash flow from other sources is particularly good.

Equipment availability for handling and chipping is an important consideration in this method. A log loader must be present on site for unloading and stacking. An older spare loader of this type is fairly common at a logger's maintenance shop. Demand for the wood chips would have to be significant to justify keeping a dedicated chipper on site. Without a dedicated chipper, scheduling chip production becomes a challenge. A chipper that is ordinarily used in harvesting operations would have to be moved to the stockpile site during the transition periods between operations at other harvesting sites. An alternative to more frequent chipper transportation is large batch chipping over a period of days or weeks, with the intention of creating a large wood chip inventory for further drying.

Althought this study has shown that passive transpiration drying is insufficient to meet the targeted moisture content levels, further drying of wood chips might be achieved on site. With sufficient market incentives, loggers producing wood chips in this setting will likely find efficient and profitable ways of handling and drying wood chips before delivering them to heating facilities.

6.4 Method 4: Wood Chip Production at a Secondary Wood Processing Facility

Stockpiling roundwood for wood chip production at a secondary wood processing facility has significant potential as a business opportunity. A business that carries an inventory of roundwood as an input for multiple products would incur the least opportunity cost during the drying period. Having more than one use for the roundwood serves to minimize the risk involved in maintaining an inventory for later use. The cooperator for this study method produces animal bedding products. Low-moisture content is desirable for this product line, so the same transpiration drying that is helpful in producing improved wood heating fuel chips also benefits these other products.

A secondary wood processing facility usually has dedicated on-site equipment used for loading and movement of materials. This dedicated equipment is a definite advantage over the other stockpile methods examined in the study. On-site capabilities make transportation of equipment for production of small batches of wood chips unnecessary. A dedicated wood chipper is especially useful.

Accurate inventory records are advisable and should include the date of acquisition, and the dates when periodic moisture testing of the roundwood is performed. Rotation of piles to increase exposure to sunlight and air may be necessary. As with each of the other methods, further drying will be necessary to achieve the desired moisture content.

7 Conclusions

Discussions with cooperators in this study have resulted in the number of general conclusions about the production of low-moisture content wood chips. These conclusions are described in this section.

Inventory costs are a major obstacle in passive drying of stockpiled wood. Keeping the length of inventory time as short as possible is one means of minimizing these costs. Moisture tests of wood stockpiled in this study showed that wood that was harvested in the growing season tended to have starting point moisture content levels as low as or lower than wood harvested in the dormant season. For example, stockpiles of roundwood cut in the summer an average starting point moisture content of 51.9% and the stockpile of roundwood cut in the winter and stored at the maintenance shop had a starting point MC of 79.4%. The summer-cut landing stockpile stored at the landing site had a starting point MC of 63.1% and the winter-cut landing stockpile had a starting point moisture content of 61.5%. Although the winter cut stockpile started out slightly drier in this case, the summer-cut stockpile started drying immediately. From a drying or inventory cost standpoint, stockpiling wood harvested in the dormant season is clearly not advantageous.

Because most drying occurs through cut ends, shorter lengths for roundwood should increase the rate of drying. The roundwood stockpiled at the maintenance shop in this study was nominally 16 inches in length. When stacked, the center portion of the pile had little exposure to air and sunlight. Cutting and stacking 8-inch stems would create greater exposure and should be expected to speed the rate of drying. It should be noted, however, that short stems take more time to cut, stack, and then later feed into a chipper.

Stem diameter also impacts the rate of drying. Large-diameter stems create higher quality because they lower the ratio of bark in the chips. However, particularly large stems will experience less drying than smaller stems over the same time period.

Piling methods for stockpiles can impact the rate of drying. Larger and taller stacks limit the airflow and sunlight exposure to some of the stems. Smaller stack heights and layered stacking can increase airflow. For example, stacking some of the stems in a perpendicular fashion every three feet or so in height, with the piling resuming in the normal direction above them can increase the air circulation (and sunlight exposure, to a lesser extent) for the interior of the pile.

Sunlight plays an important role in transpiration drying. Stockpile locations should be selected to maximize solar drying potential. Whenever possible, sites with unobstructed southern sun exposure should be selected. Wood should be piled in such a way that the butt end of whole stems face south. For roundwood, one cut face of the stems should face south.

Splitting stems and roundwood before stockpiling has been suggested as one means of facilitating passive drying. Splitting exposes more of the inside of the wood to sunlight and air. Hydraulic add-on devices can be placed on a log loader to split the wood and allow the operator to peel away large section of the stem. Short of an investment in these “wood-cracker” type devices, a skilled loader operator can often find ways to split stems of whole trees by pulling on a fork in the stem.

Stockpiling wood for drying on landing sites (as in Method 2) requires moving equipment back to the site when the wood is ready for chipping. Each trailer load of wood chips (30-40 tons) requires approximately 45 minutes to produce. Moving equipment for only one or two trailer loads of wood is not cost-effective. A minimum stockpile of five loads is suggested or whatever amount is equal to at least one full-day or production (factoring in wait times for trucking).

Damp and rainy weather during chipping can undo much of the transpiration drying that occurs during stockpiling. Moisture on the outside of the stems during these conditions can readily become incorporated in the wood during chipping, which was observed in some of the wood chips produced in Method 1 (in-woods stockpile). The wood chips produced during or after rainy weather had a measurably higher moisture content than chips produced in dry conditions. Wet conditions should be avoided during chip production.

Chip storage that is dry, heated, and well-ventilated can achieve further passive drying. Some of the wood chips that were produced from the roundwood pile (Method 3) were placed in a bin inside of the maintenance shop at that site. Wood chips in this bin were approximately 2 feet deep. After two weeks of storage, the moisture content dropped from 38.7% (dry basis) to 32.7%. Most of this drying took place in the upper portion of the bin, where the moisture content dropped to 24% after only four days of storage. Storage of wood chips on a heated concrete slab at a depth of 2 to 4 inches has the potential to achieve a significant amount of additional drying in a short period of time (48 hours).

In summary:

- Stockpiled roundwood should be harvested during the growing season rather than the dormant season.
- Shorter roundwood lengths can achieve more drying than longer lengths. (For efficient chipping, 12-foot lengths may be a good compromise).
- Stems should be large enough to provide a high concentration of wood chips with a low bark ratio (greater than 6 inches on butt end) but not so large that they dry too slowly (less than 16 inches on butt end).
- Smaller roundwood piles can achieve more drying than larger piles (shorter pile heights mean less wood that isn't exposed to sunlight and air).
- Piles that are layered on perpendicular roundwood stringers can promote greater airflow.
- Sunlight exposure of stockpiled wood should be maximized-southern aspect is most desirable.
- Splitting stems before piling can help facilitate drying.
- Damp and rainy weather during and preceding chipping should be avoided, with ample evaporation time allowed between rain and chipping.
- Maximizing stockpile volumes (not pile size) will achieve the best economies of scale with respect to equipment transport.
- Chip storage in dry, heated, and well-ventilated areas can achieve further passive drying.

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