Eastern Oregon Small Diameter Wood Study

Completed for:
The Oregon Department of Forestry

THE BECK GROUP

Final Project Report
September 2015

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CHAPTER 1 – EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Oregon Department of Forestry is interested in identifying market based options for allowing forest landowners and managers in Eastern Oregon to diversify their revenue stream. Such a change is needed because the last several decades have seen a sharp decline in the number and types of forest products manufacturing facilities in the region. Another trend that has developed over an even longer time period is that many Eastern Oregon forests are overstocked with small diameter trees and are in need of forest restoration treatments. Since the trees harvested during such treatments are generally small diameter, a particular area of interest is identifying conversion technologies that can utilize them. In addition, aside from simply identifying conversion technologies, developing an understanding of the economics underlying such technologies is an area of interest.

Accordingly, the Oregon Department of Forestry issued a Request for Proposals (RFP) seeking a contractor to:

1) Quantify the small diameter supply and its characteristics;
2) Identify market opportunities for small diameter material in Eastern Oregon;
3) Analyze the concept of developing an integrated small diameter processing facility (i.e., a facility designed to utilize small diameter materials in a variety of ways as opposed to a facility designed for only one conversion technology).

The Beck Group (BECK), a Portland, Oregon based forest products planning and consulting firm, was selected to complete the work. BECK subcontracted the small diameter supply and characterization portion of the study to Mason Bruce & Girard (MBG), a natural resource consulting firm based in Portland, Oregon. Item 1 above was completed by MBG and is documented as a stand-alone report included as **Appendix 1** on page 51 of this report. BECK and MBG are pleased to be a part of this important project.

1.2 RESULTS

BECK assessed small diameter timber in terms of its delivered cost and with regard to the technologies available for converting it to various products. The following sections summarize the results of BECK's work. For the purposes of this report, small diameter wood is defined as trees less than 12" in diameter at breast height.

1.3 Small Diameter Wood Delivered Cost

Delivered cost includes all of the costs associated with acquiring the right to harvest the trees (stumpage, if any) and the costs of felling, yarding, delimbing, loading, and hauling, as well as the overhead and administrative costs incurred by the business carrying out the harvesting activities.

With regard to the delivered cost components, which include felling, yarding, delimbing, and loading, they all increase dramatically as the average tree diameter decreases. This is because many more small pieces need to be handled in order to achieve an equivalent volume of production compared to when the larger diameter material is being processed. The machines cannot process the smaller pieces fast enough to achieve the productivity rates realized when processing larger diameter logs. As illustrated in Section 2.1.1, logging and processing costs are estimated to range from a low of $40 per bone dry ton for sawlog size material (12" to 16" in diameter at breast height) to $64 per bone dry ton for material 8" to 12" in diameter at breast height and to $140 per bone dry ton for material 5" to 8" in diameter at breast height. These estimates illustrate that the smallest size trees cost 3.5 times more to cut, yard, delimb, and load than sawlog size trees ($140/$40).

Small diameter material must also be transported from the woods to a conversion facility. As shown in Section 2.1.2, BECK estimates that the transportation costs range from a low of about $16 per bone dry ton for hauling logs within 25 miles of the plant to a high of $48 per bone dry ton for hauling logs from 100 miles away.

Thus, the total delivered cost for small diameter material is estimated to range between a low of $80 per bone dry ton for 8" to 12" trees transported from 25 miles away ($64 plus $16) to a high of $188 per bone dry ton for 5" to 8" trees transported from 100 miles away ($140 plus $48). These cost estimates are intended as guidelines since actual costs will vary with changes in factors such as tree species, type of terrain for logging, moisture content of the material when transported, type of logging equipment used, etc.

1.4 Biomass Conversion Technologies

BECK provided a high level overview of 9 small diameter material conversion technologies, including biomass heat and power, briquettes, firewood, fuel chips, pellets, post and poles, pulp chips, lumber, and wood shavings. Contained in the analysis for each technology is information such as a brief overview of the technology, raw material specifications, raw material volume requirements, raw material to finished product yield factors, capital costs, and operating costs. Details related to all of that information can be found in report Sections 2.2 through 2.10.

BECK also provided an estimate of the Return-To-Fiber (RTF) value a typical business utilizing these technologies could provide. RTF is a concept commonly used in the forest products industry to identify the maximum allowable delivered cost a business can pay for its raw material and still break even in terms of profit and loss. In this case, the raw material was either small diameter trees, or other forms of wood fiber derived from small diameter trees (such as chips, sawdust, bark, etc.) The results of the RTF analysis are shown in **Table 1.1.**

Table 1.1 – Estimated Return to Fiber Values for Nine Technologies

	Lumber	Pulp Chips	Shavings	Post and Pole	Briquettes	Pellets	Biomass (CHP)	Firewood	Fuel Chips
Sales Value f.o.b. plant, ($/BDT)	206	76	178	195	167	160	107	95	25
Conversion Cost Inc. dep. and owner return @ 15% ($/BDT)	109	19	126	144	126	122	72	60	19
RTF Value ($/BDT)	**97**	**56**	**52**	**51**	**41**	**38**	**35**	**35**	**6**
BDT/Year (BDT)	137,000	84,000	10,200	5,000	9,900	47,000	121,000	9,400	84,000
Cap EX ($ millions)	40	2.5	2.5	1.5	2.0	10	54	0.5	2.0

The units of measurement for all values in a given row in the table are shown in the far left column. See Section 2.11 for a full discussion of the assumptions underlying the RTF analysis. As the data illustrates, most of the conversion technologies provide return to fiber values that are lower than the estimated delivered cost of small diameter material. In other words, most of the businesses cannot afford to pay what it costs to deliver small diameter trees from the forest and still at least financially break even on their operation.

1.5 CONCLUSIONS

The RTF analysis results illustrate the dilemma facing increased utilization of small diameter material. The high cost of harvesting, processing, and transporting small diameter material trees often precludes their exclusive use as a feedstock for the available conversion technologies. Therefore, many of the technologies listed use by-products from other conversion facilities as their raw material rather than using small diameter wood. For example, pellets, briquettes, and biomass cogeneration generally use mill by-products for the majority of their fuel. They may occasionally supplement those sources with other materials such as logging slash, urban wood waste, and small diameter trees. If some of those other materials are high cost, it likely won't destroy the profitability of the entire operation since it will only be a small increment of the total raw material supply.

Other businesses may be able to use the topwood portion of stems that are harvested as sawlogs. This is in contrast to the concept studied in this report, which is utilizing a whole tree that was harvested, but is too small to yield a sawlog. Topwood is a low cost feedstock since the cost of harvesting and yarding is generally covered by the value of the sawlogs produced from the larger portion of the stem.

One possible solution to this dilemma is to develop an integrated processing facility where logs of varying diameter sizes could be delivered and then be processed into varying length and diameter sorts, with each sort then being utilized by a technology that puts the material to its highest value use. Ideally, such a facility would have technologies that utilize both whole stems and by-products (e.g., bark, sawdust, shavings, etc.) However, as described in Chapter 3 of this report, a fundamental issue with the integrated facility concept is that very careful planning and preparation must be taken in the early stages of developing such a facility so that the scale of the various businesses matches their respective raw material needs. For example, a combined post and pole, shavings, and firewood operation would not yield enough by-products in the form of sawdust, fines, and bark to fully satisfy the raw material requirements of a 3 MW cogeneration facility. The bottom line is that finding the right “recipe” for all of the various technology’s fiber requirements to balance and for the businesses to be of an economically viable scale is difficult.

Another possible solution is to use public funds to subsidize the delivered cost of small diameter material. A detailed analysis of this potential solution is beyond the scope of this report. However, the general concept would be that in many areas of the western U.S., decades of fire suppression and little mechanical harvesting (especially on National Forests) have resulted in dense, fire-prone timberlands. When such timberlands burn, significant costs are incurred from firefighting, from the value of lost property, and even from lost lives.

Forest management treatments such as thinning reduce the threat of wildfire. However, treating such forests with mechanical harvesting based forest management prescriptions when no small diameter wood markets exist is cost prohibitive. If, however, some public funds were proactively invested to offset the treatment costs, the effect would be to subsidize the delivered cost of small diameter trees. This in turn, would allow businesses to exist. Ultimately, the result would be that − over time − more and more acres of overstocked forest to be treated and there would be a cost savings in wildfire fighting expenses and in the loss of valuable property. It is expected that those cost savings would be greater than the cost of subsidizing the forest management treatments of small diameter material.

CHAPTER 2 – SMALL DIAMETER MARKET OPPORTUNITIES

The main objective of this report section is to describe and evaluate nine technologies for converting small diameter material into products in Eastern Oregon. Each technology is described in terms of its raw material specifications, market characteristics of the finished products, production characteristics, and location requirements. In addition to describing and evaluating the technologies, the analysis includes an evaluation of harvesting and transportation costs for small diameter trees. At the end of the chapter a Return-To-Log (RTL) and Return-To-Fiber (RTF) analysis is included which provides an estimate of the relative value each technology generates from the raw material.

2.1 RAW MATERIAL COSTS

This report section assesses the cost of harvesting, yarding, delimbing, loading, and hauling small diameter trees. Since these costs are similar across all of the technologies considered, the first two sections of this chapter assess these costs generically. Any slight differences in harvesting and transportation costs or processes between technologies are addressed within the later report sections that are specific to each technology. Note that the following analysis does not include any costs associated with paying landowners stumpage values. In other words, it only addresses the cost of harvesting, processing, and transporting the material to a conversion facility.

2.1.1 Harvesting and Processing Costs

Over the last several decades logging has become increasingly mechanized. Every processing step, including felling, skidding, delimbing, bucking, and loading, is completed operators who work in enclosed machines. These changes have increased productivity and safety. However, they have also significantly increased the required capital the owner of a logging business must commit. An investment of $1.5 to $2.0 million is required for a fully functioning and fully mechanized logging side. As a result, owners must be assured of timber to harvest, markets available for the timber harvested, and the owners must fully utilize the equipment purchased. Maximizing equipment productivity decreases costs on a per unit basis because costs such as depreciation, labor, insurance, etc. are spread across a greater number of units of production.

All of this translates into logging contractors constantly striving to produce the greatest amount of material (board feet or tons) in the least amount of time. However, when the contractor's productivity is limited because the trees to be harvested are small (and, therefore, the volume produced per tree is small) or because the trees to be harvested are spaced far apart and require more time for each one to be harvested, the cost for the contractor to complete the job increases.

The data in **Table 2.1** illustrates how the type of logging system used and the average size of the trees dramatically affects the costs. What is shown are the estimated logging costs by tree size category for harvesting/felling, delimbing, skidding, cutting to length, and loading onto a truck (on a $ per unit basis). As shown, the cost of processing small diameter trees is estimated to be nearly 4 times higher than larger trees. Aside from average tree size, the type of logging system also affects costs. Ground based equipment is less costly to operate than a cable yarding system.

In addition, many other variables affect logging cost, including type of terrain, diesel fuel price, harvesting prescription, seasonality, etc. Therefore, actual costs may differ from the estimates shown in **Table 2.1**. The data in the table is generated from machine operating costs and productivity rates reported in the U.S. Forest Service Fuel Reduction Cost Simulator (FRCS)[1] for the Western U.S. Also note that the "whole tree – ground based" system is comprised of a feller buncher, skidder, processor, and loader. The "whole tree – cable yarding" system is comprised of a feller buncher, yarder, processor, and loader. Cut-to-length logging systems were not modeled as part of this project. However, in harvesting cost research[2] published by the University of Montana Bureau of Business and Economic Research, cut-to-length costs are estimated to be about 17 percent higher on average than a whole tree ground based system.

Finally, note that in the second from right column the costs are reported on a dollars per green ton basis. "Green ton" refers to the weight of the material "as received". In other words, it includes the weight of the wood fiber and the moisture in the wood fiber. In the biomass industry, a common convention is to express costs on a dollars per bone dry ton (BDT) basis. The process of calculating BDT's involves taking a sample of the "as received" material, weighing it, drying it so that all moisture is removed, and then re-weighing it. This allows a calculation of the portion of the weight that is wood fiber and the portion that is water. The costs are then divided by the weight of the wood fiber to express the cost on a $/BDT basis – or the cost of just the wood fiber. The estimated costs on a $/BDT basis are shown in the far right column.

Table 2.1 – Estimated Biomass Harvesting and Processing Costs

Whole Tree – Ground Based				
Tree Size Category	**Logging Cost ($/MBF)**	**Logging Cost ($/CCF)**	**Logging Cost ($/Green Ton)**	**Logging Cost ($/BDT)**
5" to 8" DBH	583	197	69	138
8" to 12" DBH	327	92	32	64
12" to 16" DBH	146	57	20	40
Whole Tree – Cable Yarding				
Tree Size Category	**Logging Cost ($/MBF)**	**Logging Cost ($/CCF)**	**Logging Cost ($/Green Ton)**	**Logging Cost ($/BDT)**
5" to 8" DBH	877	297	104	208
8" to 12" DBH	577	162	57	114
12" to 16" DBH	289	114	40	80

[1] FRCS, accessed at: http://www.fs.fed.us/pnw/data/frcs/frcs.shtml
[2] Estimating Harvesting Costs. 2011. Hayes, Keegan, & Morgan. Accessed at: http://www.bber.umt.edu/pubs/forest/prices/loggingCostPoster2011.pdf

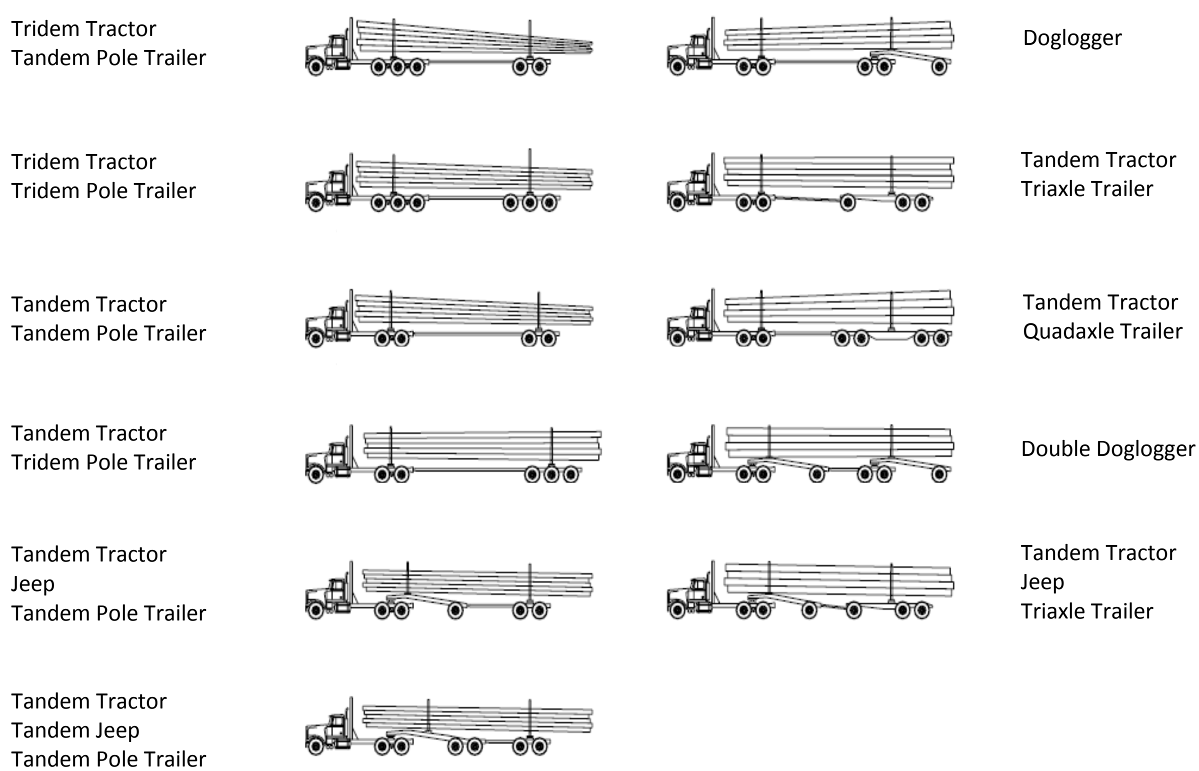
2.1.2 Transportation Cost

Many variables affect the cost of transporting woody material, including species (specific gravity), moisture content, local road weight limits, and truck configuration. However, several rules of thumb can be applied to estimate hauling costs. The following sections describe those rules of thumb and the methods for estimating costs. Please note that even though the focus of this study is on small diameter roundwood, the following analysis also includes estimated transportation costs for chipped/ground material.

2.1.2.1 Maximum Weight Limits and Payload Weights

One of the most important variables affecting transportation cost is the amount of weight (payload) allowed on a truck. In Oregon, the maximum gross weight of any vehicle having at least 4 axles and being at least 34 feet long is 80,000 pounds. Vehicles with special permits can weigh up to 105,500 pounds. For this study, however, a maximum gross weight limit of 80,000 pounds has been assumed. Most log trucks and chip vans are configured with more than four axles (see **Figure 2.1** for examples). A common configuration is tandem tractor and tandem trailer. While there are many configurations, most conventional log trucks can “fold over” so that the trailer rides on the back of the semi-tractor when not loaded. This not only saves wear on the trailer tires, it also allows for greatly increased maneuverability, which allows log trucks to more easily turn around on landings than chip vans.

Figure 2.1 – Log Truck, Trailer, and Axle Configurations



It is also important to separate the weight of the truck and trailer (the tare weight) from the weight of the material being transported (the payload). Both weights contribute to the maximum allowable gross weight, but the entity paying the transportation cost seeks to maximize the payload weight.

Again, tare weights vary depending on the truck configuration, but a general rule of thumb is that the semi-tractor weighs about 16,000 pounds and chip trailers usually weigh about 14,000 pounds. Thus, the total tare weight of a semi-tractor and chip van is approximately 30,000 pounds, which leaves a payload of about 50,000 pounds or 25 tons. For log trucks, the semi-tractor normally weighs about 16,000 pounds, and a "typical" log trailer weighs about 9,000 pounds, which is considerably lighter than the 14,000 pound weight of a chip van. As a result, log trucks can commonly have a payload of about 27.5 tons (provided the distribution of axles is such that it conforms to state laws).

2.1.2.2 Log Hauling Cost Estimate

Table 2.2 on the following page illustrates estimated log hauling costs by species on a $/MBF, $/Green Ton, and $/Bone Dry Ton basis. The key assumptions associated with the hauling cost estimates are:

- Log trucks have a 27.5 ton payload
- The hourly operating cost (including fuel) for log trucks is $85 per hour. Actual costs may fluctuate somewhat higher or lower depending on truck configurations, diesel fuel costs, etc. However, for the purpose of roughly estimating transportation costs, the $85 per hour value is judged to be appropriate. Loading and unloading time for each load is a total of 0.8 hours
- For each round trip, the log truck will travel 20 miles at an average speed of 15 mph and the balance at an average speed of 50 mph. The formula used for determining the cost of the truck is to calculate the time the truck will be operating and multiply that amount by the hourly operating cost. As an example, for a 200 mile round trip – 20 miles would be spent traveling at 15 miles per hour, so that leg of the trip would take 1.33 hours. The balance of the distance (180 miles) would be covered at an average speed of 50 miles per hour, which translates into 3.6 hours. In addition there is 0.8 hours for loading and unloading. Thus, the total time for the trip is 1.3 + 3.6 + 0.8 = 5.7 hours. The final step is to multiply the total time by the hourly operating cost: 5.7 hours x $85/hour = $487 dollars in total cost for the truck for that trip.
- The per unit costs are calculated by dividing the total cost of the truck per trip by the board feet per truckload. While the weight on each truck is constant at 27.5 tons, the board footage varies depending on the species specific gravity and moisture content. The values for moisture content and specific gravity used in the analysis were: Ponderosa Pine has an average specific gravity of 0.38 and average moisture content of 63 percent (i.e., 63 percent of the weight is water); Douglas fir is 0.45 SG and 53 percent average moisture; Lodgepole pine is 0.38 SG and 50 percent average moisture; Western larch is 0.48 SG and 52 percent average moisture; and Grand fir is 0.35 SG and 61 percent average moisture. The average log size assumed in the analysis was a 16 foot log with a 6" small end diameter (SED).

Table 2.2 – Estimated Log Hauling Cost

1 way Distance (miles)	Round Trip Time (hours)	Total Cost ($)	Volume per Truckload (board feet)	Hauling Cost ($/MBF)	Hauling Cost ($/GT)	Hauling Cost ($/BDT)
Ponderosa Pine						
25	2.7	232	4,200	55	9	22
50	3.7	317	4,200	76	13	30
75	4.7	402	4,200	96	16	38
100	5.7	487	4,200	116	19	46
125	6.7	572	4,200	136	23	53
150	7.7	657	4,200	157	26	61
Douglas Fir						
25	2.7	232	4,490	52	9	17
50	3.7	317	4,490	71	13	23
75	4.7	402	4,490	90	16	30
100	5.7	487	4,490	109	19	36
125	6.7	572	4,490	127	23	42
150	7.7	657	4,490	146	26	48
Lodgepole Pine						
25	2.7	232	5,660	41	9	16
50	3.7	317	5,660	56	13	22
75	4.7	402	5,660	71	16	28
100	5.7	487	5,660	86	19	34
125	6.7	572	5,660	101	23	40
150	7.7	657	5,660	116	26	46
Western Larch						
25	2.7	232	4,290	54	9	17
50	3.7	317	4,290	74	13	23
75	4.7	402	4,290	94	16	30
100	5.7	487	4,290	114	19	36
125	6.7	572	4,290	133	23	42
150	7.7	657	4,290	153	26	48
Grand Fir						
25	2.7	232	4,780	63	9	21
50	3.7	317	4,780	86	13	28
75	4.7	402	4,780	109	16	36
100	5.7	487	4,780	132	19	43
125	6.7	572	4,780	155	23	51
150	7.7	657	4,780	178	26	59

2.1.2.3 Biomass Hauling Cost Estimate

Sometimes biomass is converted from roundwood form into small pieces (ground/chipped) before it is transported from the forest to a conversion facility. **Table 2.3** illustrates the estimated transportation costs for material (biomass) in this form. The costs are expressed on a $/BDT basis since that is the industry convention when conducting transactions for this type of material. The key assumptions associated with the analysis are:

- The chip van used to transport the material has a capacity of 4,000 cubic feet, which is a relatively large cubic volume for a chip van. A van of that size is typically more than 50 feet long. While a longer trailer is good from the perspective of maximizing payload, it has a drawback in that it may not be able to access log landings because it cannot navigate the sharp turns on logging roads or because of an inability to turn around. Also note that, depending on the moisture content of the material, the maximum gross vehicle weight is reached before the van is full (on a space basis). Thus, if it is known that the moisture content will be at the upper end of the typical range (i.e., 40 to 50 percent), then it may be a good idea to use shorter chip vans to allow better access.
- The chip vans have a 25 ton payload capacity.
- The hourly operating cost (including fuel) for chip vans is $85 per hour. Actual costs may fluctuate somewhat higher or lower depending on truck configurations, diesel fuel costs, etc. However, for the purpose of roughly estimating transportation costs, the $85 per hour value is judged to be appropriate.
- Loading and unloading time for each load is a total of 0.5 hours
- For each round trip, the chip van will travel 20 miles at an average speed of 15 mph and the balance at an average speed of 50 mph. The formula used for determining the cost of the truck is to calculate the time the truck will be operating and multiply that amount by the hourly operating cost. As an example, for a 50 mile round trip – 20 miles would be spent traveling at 15 miles per hour, so that leg of the trip would take 1.33 hours. The balance of the distance (30 miles) would be covered at an average speed of 50 miles per hour, which translates into 0.60 hours. In addition, there is 0.5 hours for loading and unloading. Thus, the total time for the trip is 1.33 + 0.60 + 0.50 = 2.43 hours. The final step is to multiply the total time by the hourly operating cost: 2.4 hours x $85/hour = $207 dollars in total cost for the truck for that trip.
- The "per unit" costs are calculated by dividing the total cost of the truck per trip by the payload weight board feet per truckload. While the weight on each truck is constant at 25 tons, the cost per bone dry ton varies depending on the species specific gravity and moisture content. Rules of thumb for moisture content and specific gravity are: Ponderosa Pine has an average specific gravity of 0.38 and average moisture content of 63 percent (i.e., 63 percent of the weight is water); Douglas fir is 0.45 SG and 53 percent average moisture; Lodgepole pine is 0.38 SG and 50 percent average moisture; Western larch is 0.48 SG and 52 percent average moisture; and Grand fir is 0.35 SG and 61 percent average moisture. However, biomass is generally left at the site for a period of time so that it dries before being shipped. Depending on the amount of time it is left to

dry and the weather conditions, the moisture content percentage may drop as low as the mid-20 percent range.

- For the species with lower specific gravity (i.e., pines and grand fir), with moisture contents at the low end of the range, the chip vans run out of space before reaching their maximum payload.
- Biomass has a volumetric expansion factor of 2.5 when going from solid wood to chipped/ground material.

Table 2.3 – Biomass Hauling Cost

1 Way Distance (miles)	Round Trip Time (hours)	Total Cost ($)	Hauling Cost @ 50% MC ($/BDT)	Hauling Cost @ 40% MC ($/BDT)	Hauling Cost @ 30% MC ($/BDT)	Hauling Cost @ 20% MC ($/BDT)
Ponderosa Pine						
			12.8 BDT/TL	**15.3 BDT/TL**	**17.9 BDT/TL**	**19.0 BDT/TL**
25	2.4	232	18	15	13	12
50	3.4	317	33	27	24	22
75	4.4	402	48	40	34	32
100	5.4	487	63	52	45	42
Douglas Fir						
			12.8 BDT/TL	**15.3 BDT/TL**	**17.9 BDT/TL**	**20.4 BDT/TL**
25	2.4	232	18	15	13	11
50	3.4	317	33	27	24	21
75	4.4	402	48	40	34	30
100	5.4	487	63	52	45	39
Lodgepole Pine						
			12.8 BDT/TL	**15.3 BDT/TL**	**17.9 BDT/TL**	**19.0 BDT/TL**
25	2.4	232	18	15	13	12
50	3.4	317	33	27	24	22
75	4.4	402	48	40	34	32
100	5.4	487	63	52	45	42
Western Larch						
			12.8 BDT/TL	**15.3 BDT/TL**	**17.9 BDT/TL**	**20.4 BDT/TL**
25	2.4	232	18	15	13	11
50	3.4	317	33	27	24	21
75	4.4	402	48	40	34	30
100	5.4	487	63	52	45	39
Grand Fir						
			12.8 BDT/TL	**15.3 BDT/TL**	**17.5 BDT/TL**	**17.5 BDT/TL**
25	2.4	232	18	15	13	13
50	3.4	317	33	27	24	24
75	4.4	402	48	40	35	35
100	5.4	487	63	42	46	46

2.2 BIOMASS HEAT AND POWER

2.2.1 Technology Overview

The conversion of small diameter trees to heat and/or power can be accomplished using two technologies: 1) *gasification* coupled with an internal combustion (IC) engine and 2) *direct combustion* in a boiler coupled with a steam turbine. Regardless of whether the material is directly combusted or gasified, the process uses the energy released to generate heat, power, or both.

More specifically, Gasification is the process of breaking down biomass fuel by heating it in an oxygen starved environment. The heating process produces a combustible gas (called syngas or producer gas). The syngas is collected, cleaned and then used as fuel in an IC engine to generate heat and power. There are several important points concerning this technology. First, the syngas contains tars and particulate matter that must be cleaned (removed) prior to combustion in the IC engine. This is typically accomplished by cooling the syngas. Second, this technology is not well proven when using forest derived fuels. This is because fuel made from small diameter trees tends to have varying particle size and varying moisture content, which has been problematic for the efficient operation of gasification systems. A potential benefit of this technology is that biochar is produced as a by-product. That material can be sold as a soil amendment and, thereby, create another revenue stream. Since BECK is not aware of any gasification systems currently operating when using forest derived fuels, the remainder of this section focuses on direct combustion technology.

Direct combustion, on the other hand, is the process of burning biomass. Combustion occurs in a chamber where volatile hydrocarbons are formed and burned, thereby creating heat energy in the form of hot flue gases. There are two common designs to direct combustion systems – fixed and fluidized bed. Each refers to the manner in which the material is combusted. The most common is the fixed bed design in which biomass is burned on a grate. A fluidized bed design, in contrast, combusts the biomass in a hot bed of suspended, non-combustible particles such as sand. High velocity air is injected from underneath the fluidized bed to distribute and suspend the fuel as it combusts. In either case, the hot flue gases resulting from combustion are fed into a boiler to create steam. That steam, in turn, can be used to heat a building, supply heat to a manufacturing process, generate electricity, or all of the above. Direct combustion technology has been proven in thousands of applications using biomass fuels having widely varying moisture content and particle size.

2.2.2 Raw Material Specifications

In the Western U.S. the vast majority of the trees are various types of softwoods, which all have fairly consistent higher heating values ranging from 8,100 to 9,700 British Thermal Units (BTU's) per pound. Thus, there is relatively little difference in the amount of heat provided by the various species.

More importantly for biomass heat and power is the moisture content of the fuel. It affects biomass heat and power in two ways. First, the amount of moisture in the fuel affects the amount of heat (BTUs) that can be recovered from each pound of fuel received. The moisture in the fuel must be "boiled off" in the combustion process and in doing so significantly reduces the amount of energy recovered. Thus, as moisture content goes up, boiler efficiency goes down – meaning that more fuel must be purchased to produce the same amount of heat/power. Direct combustion systems can operate on fuel ranging between 20 and 60 percent moisture content (wet basis). For direct combustion, moisture content is not really a technical issue as the boilers are designed to operate across a range of fuel moisture contents. For gasification, however, varying moisture content reduces the ability of the technology to operate effectively.

The second reason that moisture content is important relates to transportation costs. As the average moisture content increases, an increasing proportion of the weight on a truck is water rather than wood fuel. This, in turn, means that as the average moisture content increases, there are fewer bone dry tons of material on each truckload to absorb the cost of operating the truck. Thus, delivered fuel costs increase as moisture content increases.

Fuel particle size is the other critical specification. Typically fuel specs will call for particles to be three inch minus for any one dimension and for no more than 10 percent of the fuel in any individual truckload delivery to be larger than 3 inch minus and smaller than 5 inch minus in any one direction.

2.2.3 Market Characteristics

The markets for the products produced by biomass heat and power facilities include the market for electrical power and the market for thermal energy. Producing power from biomass is more costly than power produced from other sources such as coal, natural gas, and hydro. However, biomass is considered a renewable power source.

PURPA, the Public Utilities Regulatory Policies Act of 1978, established the principles governing the sale of power from small renewable power facilities to utilities. That act required regulated utilities to purchase power from facilities meeting certain criteria (Qualifying Facilities or QFs) at the utility's "avoided cost". The avoided cost is the cost that the utility would have incurred to produce the same power but for the existence of the small independent producer. The calculation of avoided cost and inclusion of that rate in a contract was left to each state to interpret.

Subsequent federal laws and regulations required the regulated utilities and power marketing agencies to "wheel" this power across their systems to other buyers if requested and established mechanisms to value that service. This "open access" transmission principle often allows renewable energy producers to move their electricity from low valued markets to higher valued markets in other states. Projects greater than 20 MW using this wheeling service, as opposed to selling to the local utility at avoided costs, register with the Federal Energy Regulatory Commission (FERC) as Exempt Wholesale Generator (EWGs) as opposed to QFs.

A number of states, including Oregon, have created Renewable Portfolio Standards (RPS) requiring the Investor Owned Utilities (IOUs) in those states to generate a certain amount of power from renewable sources. The RPS requirements are what create the market for renewable power. However, in recent years in the U.S. West, the combination of low natural gas prices and the utilities generally meeting their requirements for renewable power have translated into very weak markets for renewable power. During the 2010 to 2011 timeframe, renewable power purchase agreements for biomass power projects were frequently in the $80 to $90 per MWH range. Currently, however, the utilities are essentially current on the RPS requirements and are generally not interested in purchasing additional renewable power. This means that biomass projects must sell their power at Avoided Cost rates, which are frequently in the $50 to $60 per MWH range. Selling biomass power at those rates make project economics very difficult. The market for renewable power in Oregon is expected to pick up again in the 2017 to 2019 timeframe as the next tier of renewable power in Oregon's RPS takes effect.

With regard to selling thermal energy, the market for that revenue stream is largely dictated by the value of natural gas. For example, according a Northwest Power & Conservation Council[3] (NPCC), natural gas prices are expected to average $5.27 per Million BTU in 2019 at the Citygate[4]. The price of thermal energy to a specific user will be higher after accounting for additional service and delivery charges by the local utility. BECK estimates that this might typically be in the range of $6.50 to $7.00 per million BTU.

It is difficult to predict what a thermal user might be willing to pay for heat because there are many variables affecting that decision. However, it is not unreasonable to assume that steam produced from a biomass boiler could be sold for about $13 to $14 per thousand pounds. The pounds of steam sold per hour will vary depending on the characteristics of the thermal user. However, as an example, assuming the thermal user is a sawmill that uses an average of 10,000 pounds of steam per hour for lumber drying for 8,200 hours per year, steam valued at $13 to $14 per thousand pounds translates into $1.0 to $1.1 million in revenue annually from steam sales.

2.2.4 Production Characteristics

The equipment required to operate a biomass heat and power facility is extensive. Beginning in the forest where fuel is collected, grinding/chipping operations typically consist of a horizontal grinder and a tracked loader equipped with a fully rotating grapple to feed fuel into the grinder. Additionally, some operations use a tracked bulldozer to push slash and stems into piles for efficient feeding into the grinder. There also is usually a support truck loaded with tools and spare parts and a fire truck. The operation must also include a sufficient number of tractor-trailer trucks and chip vans to assure that the grinder can operate continuously while emptying the fuel into chip vans rather than running it onto the ground.

At the plant, the main pieces of equipment include a truck scale for weighing incoming trucks and truck dumpers for emptying the fuel out of trucks. Storage depends on the size of the plant. Some may store all fuel in silos and use systems to convey the fuel to the boiler. Larger

[3] Accessed at: https://www.nwcouncil.org/media/6293/SixthPowerPlan_Appendix_A.pdf
[4] Citygate refers to a point or measuring station at which a distributing gas utility receives gas from a natural gas pipeline company or transmission system

plants may store the fuel in an outdoor storage pile and use a reclaim system to convey the fuel from the pile to the boiler. The plant will also include a furnace and boiler for converting the hot gases of direct combustion into steam. The boiler may include pieces of additional equipment for superheating the steam, deaerating the water, and controlling emissions. Connected to the boiler is a steam turbine generator that produces electricity. Finally, cooling towers are used to reject waste heat to the atmosphere. An extraction condensing type turbine can extract steam at a given pressure, which can be used to heat some process or to heat a building space. Some small plants may use chip vans with walking floors for self-unloading, but doing so comes with a penalty of lower payload.

The capital cost typically ranges between $4 and $8 million per megawatt (MW) of power producing capacity. Larger plants (i.e., greater than 20 MW of capacity are at the lower end of the capital cost per megawatt range, while plants under 3 MW are at the higher end of the capital cost per megawatt range. Thus, the capital investment required for a biomass heat and power facility is significant even for relatively small systems.

In terms of staffing and labor costs, relatively little difference exists in the amount of labor needed to operate either a large or small facility. For example, a relatively small plant producing 4 MW may have a total staffing of 8 to 10 persons, including 8 operators, 1 clerical assistant, and a general manager, with their annual fully loaded labor cost likely being in the range of $650,000 to $750,000. A 20 MW plant, in contrast, will require about 13 to 15 staff people, including a plant manager, a clerical assistant, a fuel manager, and about 12 operators. Their fully loaded cost will be in the range of $900,000 to $1,000,000.

The scale of biomass heat and power plants ranges between about 1 MW on the very small end to as high as 50 MW on the large end. Small plants typically do not have high fuel costs, but high labor and high capital costs relative to their capacity to produce power make the economics of small projects virtually impossible. In general, a special set of circumstances is required for a 5 MW or less plant to be economically feasible (i.e., very low fuel costs, an ideal steam host that can use heat 24 hours per day, 7 days per week, 365 days per year, and a power sales contract with a high value on the power).

Large plants, on the other hand, have capital costs and operating costs that are relatively low. The frequent difficulty for large plants is that they require more fuel and, therefore, typically have to reach farther to procure the required amount. All of this translates into relatively high fuel delivered costs being a common characteristic of large plants.

Regarding fuel usage rates, a general rule of thumb is that a biomass heat and power plant uses 8,000 bone dry tons of biomass per MW of power produced.

2.2.5 Location Requirements

Key site requirements for biomass heat and power projects include: 1) adequate space – the footprint of the boiler/turbine and cooling towers is small (less than an acre). However, space also is required for storing fuel and for the equipment needed to interconnect the facility to the electrical power grid. Regarding interconnection, a frequent misperception is that if transmission or distribution lines are near the project site, it will be easy to connect the project to the electrical grid. This may not be the case because the voltage of those lines may differ from the voltage at which the power is produced. If this happens to be the case, the use of costly transformers to interconnect would be required. A much better starting point for prospective biomass projects is to have an existing substation located on or very near the site. The substation would likely have the equipment already in place for more cost effectively interconnecting the project to the electrical grid.

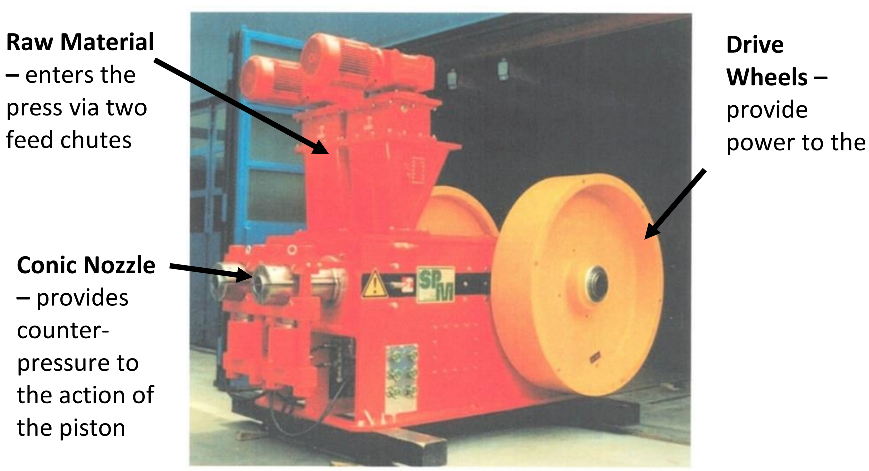
2.3 BRIQUETTES

2.3.1 Technology Overview

Wood briquette (also fire logs or fuel bricks) manufacturing is a technology for densifying wood fiber and then combusting it for thermal heating (most common use). Similar to the process used for making wood pellets, small wood particles are compressed under high pressure to form the wood briquettes. However, the dimensions of the briquettes are much larger than pellets – generally about the size of a mortar brick.

Figure 2.2 illustrates how the briquetting technology works. Appropriately sized and dried material is feed by gravity into two chutes from the top of the machine. Two large drive wheels power a piston which presses the raw material through a conical nozzle that provides counter pressure to the action of the piston. The counter pressure compacts and heats the wood as the pressure increases. As the wood heats, the lignin portion of the fiber "plasticizes" and helps the material flow through the nozzle. As the material exits the nozzle it takes the shape of the cone and it is cooled to "set" the briquette in its final form. No added adhesives are used in the manufacturing process. Finished briquettes are dense and durable, which means they can be economically transported long distances with little degradation. Finished briquettes typically contain less than 10 percent moisture (by weight). Briquettes are similar in density to pellets (about 40 pounds per cubic foot), but no grading standards exist for briquette quality. The shape and size of briquettes vary, but most are between about 2 inches in height and width and about 5 inches in length.

Figure 2.2 – Wood Briquetter



Source: Pawert – SPM AG, Basel Switzerland

2.3.2 Raw Material Specifications

Briquetting requires raw material (wood fiber) to be dried to approximately 12 percent moisture content (MC). It also must be milled to a uniform size (< ¾") and then compressed with either a hydraulic or mechanical press. Bark can also be used for a portion of the feedstock for briquette manufacturing. However, using bark increases the ash content of the material, which makes it less desirable for the end user.

As was shown in the raw material cost and transportation section, a significant disadvantage of making briquettes (or pellets) from roundwood is that the entire high cost of harvesting and transporting small diameter material must be borne by the economics of the manufacturing process. In contrast, when mill residues are used as the feedstock, the cost of collecting, sizing, and sometimes drying that material has already been absorbed by the lumber manufacturer. Therefore, the only costs associated with those materials are the cost of transportation and their market value. In addition, cost savings are realized at the conversion facility when mill residues are used because they are frequently already reduced to a size appropriate for briquetting and they may already be dry enough for briquetting.

2.3.3 Market Characteristics

In Oregon, briquettes sell for nearly $400 per ton at retail when sold in 30 pound bundles with each bundle containing 6 five pound briquettes. The $400 per ton cost translates into about $6 per bundle. Typically, however, wood briquette users using the material to heat their homes purchase briquettes in quantity and are able to obtain the material at a lower cost per ton, with prices ranging between $225 to $300 per ton, depending on manufacturer and region.

Briquette manufacturers typically sell their material for about $150 per ton (f.o.b. their plant). Thus, the difference between the retail value and the manufacturers selling price is about $75 to $100 dollars. Within that price differential the cost of transporting the pellets to market and the retailers markup must be accounted for. Retailers typically aim to capture at least a $50 per ton markup. Thus, the amount of margin left for transportation varies between $25 and $50 per ton. When finished briquettes are palletized (1 ton per pallet), flatbed trucks can generally haul about 22 tons of pellets. Therefore, if available margin for transportation is $25 per ton, the total cost for the truck cannot exceed $625. If the available margin for transportation is $50 per ton, the total cost for the truck cannot $1,250.

A key market advantage of briquettes over wood pellets is that briquettes can be burned in a homeowners existing wood stove or fireplace. This creates a fairly broad potential market for briquettes. Users of wood pellets, in contrast, must purchase a stove specifically designed to burn wood pellets. Such stoves can cost several thousand dollars, and this expense represents a hurdle to wider adoption of wood pellets as a heating fuel.

Another key market factor in the use of wood briquettes and wood pellets is the price of alternate heating fuels, especially natural gas. Many areas have a natural gas distribution system such that homeowners are supplied with the gas via a connection between their home and the distribution system. When natural gas prices are low (as they currently are), it is difficult for wood pellets to be a cost competitive heating fuel, as shown in **Table 2.4**. However, when the alternative is fuel oil or propane, switching to firewood/briquettes is cheaper. As a general rule, the availability of natural gas is somewhat limited in Eastern Oregon. Therefore, the opportunities for briquette markets for home heating should be relatively high. It should be noted, however, that a hurdle to briquette use in such regions is that many homeowners prefer to cut their own firewood at the cost of their own time and the relatively minor expense of owning and operating a chainsaw and pickup truck.

Table 2.4 – Comparison of Cost among Various Heating Fuels

Fuel Type	Fuel Unit	Fuel Price Per Unit (dollars)	Fuel Heat Content Per Unit (BTU)	Fuel Price Per Million BTU (dollars)	Heating Appliance Type	Approx. Efficiency (%)	Fuel Cost Per Million BTU (dollars)
Coal	Ton	200.00	25,000,000	8.00	Furnace	75	**10.67**
Natural Gas	Therm	1.00	100,000	10.02	Furnace	82	**12.22**
Firewood	Cord	200.00	17,000,000	11.76	Stove	63	**18.67**
Briquettes	Ton	250.00	17,000,000	14.71	Stove	78	**18.85**
Electricity	Kilowatt Hour	0.12	3,412	35.13	Baseboard	100	**35.13**
#2 Fuel Oil	Gallon	4.02	138,690	28.99	Furnace	78	**37.17**
Propane	Gallon	2.93	91,333	32.11	Furnace	78	**41.17**

2.3.4 Production Characteristics

The scale of briquetting operations tends to be much smaller than pellet manufacturing. This is primarily driven by the capacity of the briquetting machines, which are typically designed with capacities ranging between 0.25 to 2.0 tons of finished product per hour. The plants are highly automated and can essentially operate 24 hours per day, 7 days per week, 365 days per year. Typically, however, scheduled downtime of several weeks per year is taken for maintenance.

Given those operating rates, plants commonly operate about 8,400 hours per year. This means that a plant with a production capacity of 2.0 tons per hour can produce nearly 17,000 tons of briquettes per year. Assuming the briquettes are about 8 percent moisture content when finished, this translates into about 15,600 bone dry tons of feedstock annually. If the feedstock is clean wood fiber, this, in turn, translates into nearly 35,000 green tons of raw material required per year (assuming 50 percent average moisture and bark being 10 percent by weight).

The equipment required for making briquettes is relatively straightforward and includes a truck scale for weighing incoming material, a wheeled loader for unloading stems from the trucks and feeding the stems into the manufacturing process. The manufacturing process includes a debark machine and the appropriate transfers and conveyors for removing the bark from the stems. Hammermills and screens are needed for sizing the feedstock to the appropriate size prior to briquetting. A dryer is also necessary to reduce the moisture content of the incoming feedstock to the appropriate levels for briquetting. A briquetting machine (as previously described) is required for converting the feedstock into briquettes. At the back end of the plant, packaging equipment is needed for packing the briquettes into a form suitable for transport. An order of magnitude capital cost estimate for this equipment, land/building, and installation is $2.5 to $3.0 million.

Regarding drying, it is a common practice in both the pellet and briquette industries to use bark or, in some cases, the fines screened from the finished product as fuel for the dryer. Generally, when using biomass to fuel the dryer, about 15 percent of the weight of the finished product produced will be the amount of fuel required. For example, a briquetting plant producing 10,000 tons of pellets per year would use about 1,500 dry tons of fuel per year to dry the feedstock to the appropriate moisture content. As a general rule of thumb, a biomass drying system will have a higher capital cost than a natural gas system, but will have lower operating costs while in use.

2.3.5 Location Requirements

The location requirements for briquette manufacturing are not restrictive. Key requirements include space and buildings, with a 100’ x 100’ building on a 5 to 10 acre site being adequate. Briquette manufacturing requires a fairly robust, 3 phase electrical service. Thus, the electrical service must be industrial in nature. Anytime a technology involves drying using biomass fuel, there are potential air quality permitting issues. The nature and extent of those issues depends on the site location and the scale of the operation.

2.4 FIREWOOD

2.4.1 Technology Overview

The production of firewood is perhaps the lowest tech and lowest capital cost option of any considered in this report. However, it can be a profitable source of extra income for people already involved in forestry and forest products (e.g., loggers, truckers, arborists, foresters, etc.) There are also firms that are full-time firewood production operations.

The process consists of converting tree stems into firewood blocks and then splitting and drying the material before it is burned to produce heat. While this process can be accomplished entirely with hand tools and by letting the material air dry, mechanized equipment exists for cutting stems to firewood lengths and splitting. There are also conveyors that are used to carry material away from the conversion equipment to an area where it can be stacked, sorted, or prepared for drying.

While some commercially made firewood dry kilns exist, “homemade” type drying systems appear to be more commonly used. They typically involve converting an old shipping container into a firewood dry kiln. A shipping container equipped with fans for circulating air, and vents for ejecting moisture laden air can be coupled with a relatively small wood-fired boiler to efficiently dry firewood.

Homeowners who heat their homes with firewood tend to purchase in relatively large quantities (e.g., 1 to 2 cords per delivery). Note that a cord of Douglas fir firewood at 15 percent moisture content is estimated to weigh 1.2 bone dry tons and 1.4 green tons. A cord of pine firewood is estimated to weigh 1.0 bone dry ton and 1.2 green tons. There is also a market for "ambiance" firewood (i.e., occasional use of firewood in a home fireplace, backyard fire pit, or during camping trips). These users are typically found in urban settings and do not necessarily have access to their own firewood or the space to store a large volume of firewood. Therefore, they are willing to pay a relatively high price for several small bundles of firewood to be used occasionally.

2.4.2 Raw Material Specifications

The raw material requirements for firewood are not restrictive. However, homeowners who use firewood for home heating generally prefer to have pieces from larger trees because larger piece size translates into slower burning rates and less need for the home owner to re-stoke the fire. There also are some differences in the heating value by species. **Table 2.5** displays the higher heating value for several species commonly found in Eastern Oregon.

Table 2.5 – Higher Heating Values of Common Eastern Oregon Tree Species

Species	Higher Heating Value (BTU per Pound)
Douglas fir	8,900
Lodgepole pin	8,600
Ponderosa pine	9,100
True firs	8,300
Western hemlock	8,400
Western Red Cedar	9,700

2.4.3 Market Characteristics

In 2013, Oregon was estimated to have a total of 1.516 million housing units, with about seven percent using wood as the primary heating fuel. This information is displayed in **Table 2.6**. Note that in Eastern Oregon,[5] the percentage of homes heated with wood increases to over 13 percent. Thus, while there are not large metropolitan areas to consume bundles of firewood, there are a relatively large percent of the homes heated with firewood. Assuming the typical home in Eastern Oregon uses 4 cords of firewood per winter, the size of the market is estimated to be about 106,000 cords or 117,500 BDT per year (26,721 homes x 4 cords/home x 1.1 BDT per cord).

[5] Includes: Baker, Crook Deschutes, Gilliam, Grant Harney, Hood River, Jefferson, Klamath, Lake, Malheur, Morrow, Sherman, Umatilla, Union, Wallowa, Wasco, and Wheeler Counties.

Table 2.6 – Primary Heating Fuels Used in Oregon Housing Units

County	All Oregon Number of Housing Units	Percent of Total (%)	Eastern Oregon Number of Housing Units	Percent of Total (%)
Utility Gas	580,354	38.3	62,311	31.2
LP Gas	24,824	1.6	7,317	3.7
Electricity	741,687	48.9	91,159	45.6
Fuel Oil	45,828	3.0	9,230	4.6
Coal	139	0.0	72	0.0
Wood	107,585	7.1	26,721	13.4
Solar Energy	639	0.0	124	0.1
Other Fuel	11,068	0.7	2,252	1.1
No Fuel Used	4,332	0.3	583	0.3
Total	**1,516,456**	**100.0**	**199,769**	**100.0**

The value of firewood depends on factors such as whether it is green or dry, the species, whether it has been split, and whether it is customer pick-up or delivered. Prices in the Portland metro area, for example, average about $200 to $250 per cord for delivered Douglas fir firewood or about $175 per cord if 2 cords are purchased at once. Seasoned pine firewood, on the other hand, typically sells for about $125 to $150 per delivered cord in Central Oregon. Some large firewood producers may offer even deeper per cord discounts for customers purchasing even larger quantities.

2.4.4 Production Characteristics

As previously described, the production process for making firewood can be very simple, involving only the use of hand tools. However, for the purposes of this analysis it is assumed that the firewood operation will be of a larger scale and involve mechanized equipment. Some of the highest production mobile firewood processors can generate about 10 cords per hour. Thus, a single firewood processor of that scale that operated 2,000 hours per year at 85 percent uptime and at an average uptime production rate of 7.5 cords per hour would produce nearly 13,000 cords per year or a little over 14,000 bone dry tons per year.

Such systems typically require a log loader to place stems onto a log deck having transfer chains. The transfers move the firewood perpendicular to the long axis of the stem until it drops into a trough, which begins to move the stem in a direction parallel to the long axis of the log. The log is moved forward until it encounters a cut-off saw, which can either be a chainsaw type or a circular blade. That saw cuts the pieces to 16” lengths, which is a standard in the industry, although some customers prefer shorter or longer lengths. Once a firewood block has been cut from the stem, gravity is used to drop the piece into a trough, which has a splitting wedge at one end and a hydraulic ram at the other. The ram engages and rives the piece against the splitting wedge. A conveyor system is typically mounted behind the splitting wedge so that finished pieces can be carried away for sorting and/or stacking or prepared for drying. Some systems also utilize a trommel screen right after the conveyor to remove some of the small bark and wood splinters that develop during the splitting process.

Two laborers can run the equipment: one to load and unload material and one to operate the firewood processor. If the business offers firewood delivery services, an additional full or part time person may be required as well. An order of magnitude estimate for the required equipment is $300,000 to $500,000, which would include a mobile, high production firewood processor; log transfers; conveyors; and trommel screen. It would also include a front-end loader for moving logs and finished product, a delivery truck, and a shipping container refurbished as a wood-fired firewood dry kiln.

2.4.5 Location Requirements

The location requirements for a firewood operation are not restrictive. Since the operation can be mobile, a key consideration is to locate it close to the raw material, so as to reduce log transportation costs, or locate it closer to the markets to reduce the transportation cost of the finished product. Since the finished product is dried, it is likely more effective (from a transportation cost reduction perspective) to locate the operation closer to the raw material.

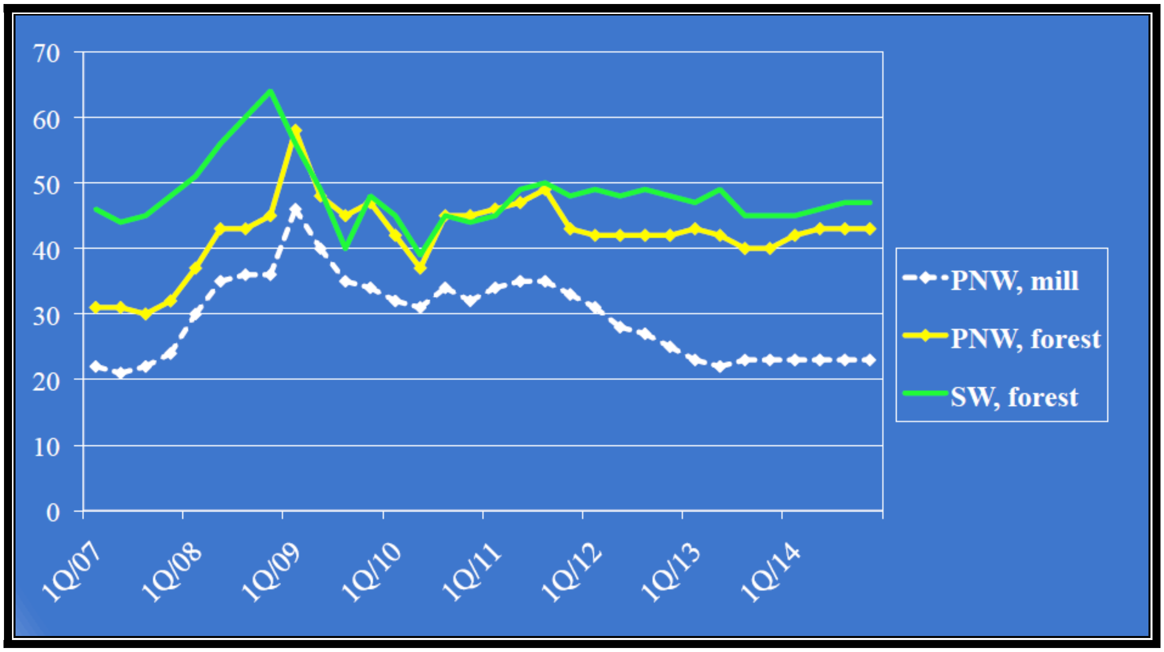
2.5 FUEL CHIPS FOR BIOMASS HEAT AND POWER

2.5.1 Technology Overview

Wood-fired boilers can burn a wide range of wood species and types of wood fiber, including bark, sawdust, chips, planer shavings, and ground logging slash. Given the ability of boilers to utilize a variety of fuels, businesses have been developed to facilitate the use of forest derived materials (i.e., chipping and grinding small diameter trees and logging slash) that supply the boilers.

It is important to note, however, that forest derived fuels tend to be more costly than mill residues (**Figure 2.3**), as reported by North American Wood Fiber Review. As shown in the figure, since 2010, Pacific Northwest mill residues (sawdust and bark) have had average delivered values of about $10 to $20 per bone dry ton less than Pacific Northwest forest residues. As described in the biomass heat and power technology section, this is because the cost of collecting and processing mill residues is “subsidized” by the process of producing lumber. In contrast, the full cost of collecting, processing, and transporting forest derived fuel must be reflected in its delivered value.

Figure 2.3 – Delivered Values of Mill Residue Fuel versus Forest Derived Fuel



2.5.2 Raw Material Specifications

The raw material requirements for fuel chips are not restrictive. Virtually any type of woody biomass can be ground and chipped for use as fuel. However, as described in the biomass heat and power section, piece size and moisture content are important raw material requirements.

2.5.3 Market Characteristics

The market for biomass fuel chips is wood fired boilers, especially large industrial scale boilers as might be found at sawmills or pulp and paper mills. Smaller scale wood fired boilers are used in many places, but it is fairly common for those applications to specify wood pellets as a heating fuel as opposed to fuel chips from forest materials. This is because smaller systems tend to operate more efficiently when the fuel is very consistently sized and has little variation in moisture content (i.e., wood pellets). The drawback to that approach is that pellets typically cost about $200 or more per ton versus a cost of roughly $50 per bone dry ton for fuel chips.

2.5.4 Production Characteristics

The production characteristics associated with fuel chips (for operations supplying industrial scale boilers) are very similar to those described in **Section 2.8.4**. Please review that section for information concerning production characteristics.

2.5.5 Location Requirements

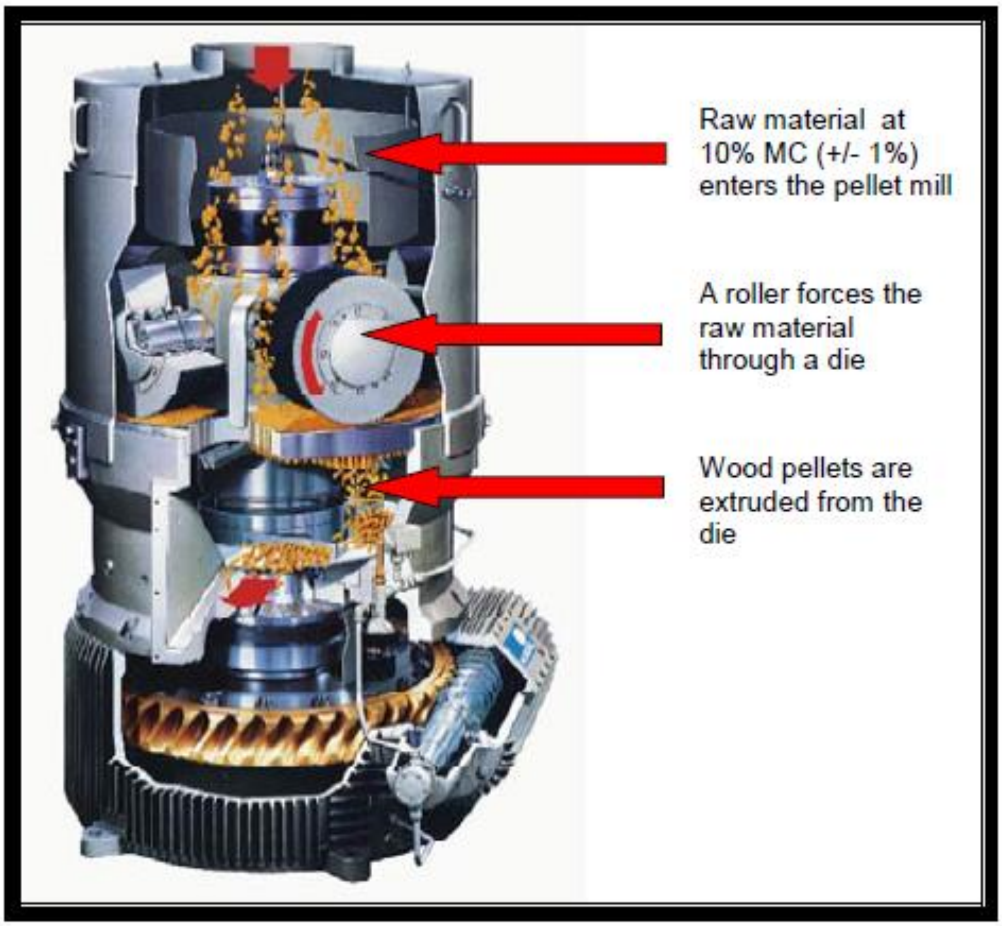
Similarly, the location requirements for fuel chips are virtually identical to those for a pulp chipping operation. Therefore, please see **Section 2.8.5** for a discussion of the location requirements

2.6 PELLETS

2.6.1 Technology Overview

Wood pellets are a biomass fuel that is burned to heat buildings or co-fired with coal to generate electricity. The manufacturing process involves drying wood fiber to approximately 10 percent moisture content and then milling them to a uniform size (+/- 1/8”). This material is then compressed with a die and roller to a density of about 40 pounds per cubic foot (See **Figure 2.4**).

Figure 2.4 – Pellet Mill Cut-Away Diagram



2.6.2 Raw Material Specifications

In the Western U.S., wood pellets are generally manufactured from sawmill by-products such as sawdust and planer shavings. The advantages of those feedstocks are that: they are sometimes already dry (i.e., shavings); they are already in a size and form that requires little additional processing prior to pelletizing; and in some regions of the west, sawdust and, to a lesser extent shavings, have limited market value for other users.

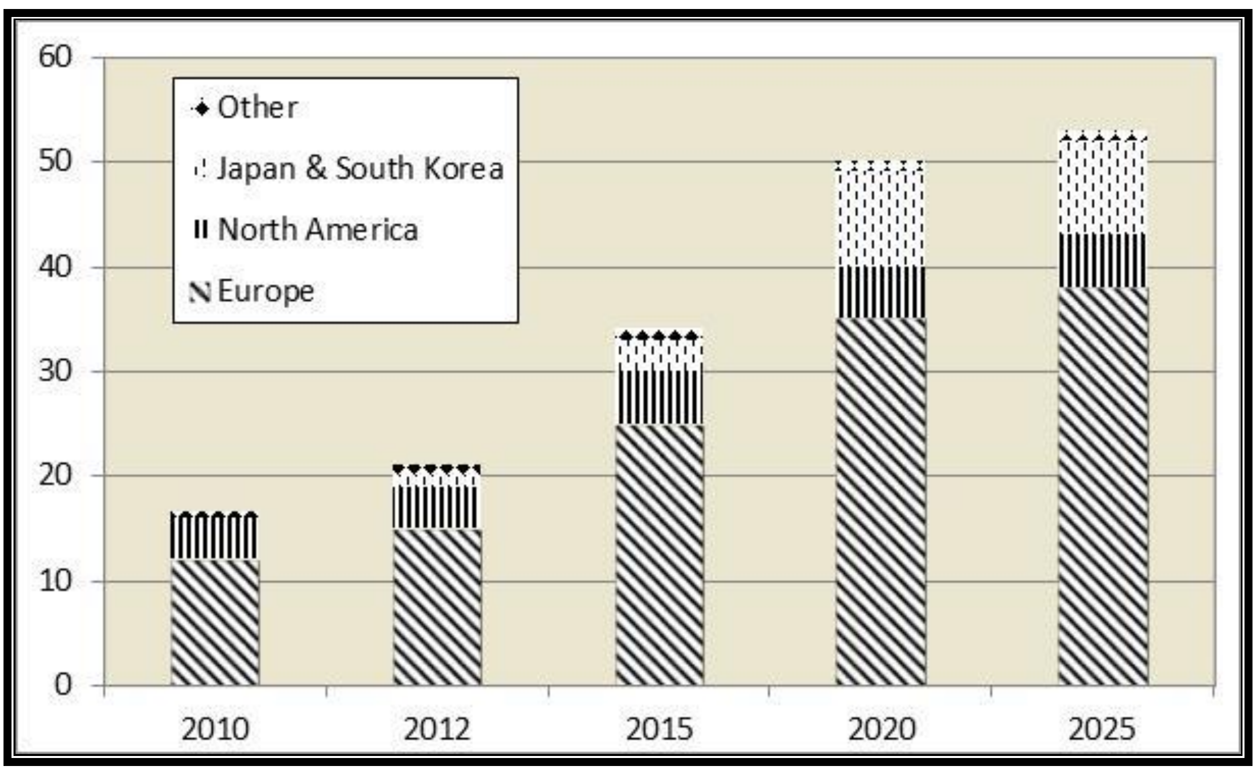
In contrast, roundwood, as a feedstock, requires extra costs for chipping/grinding and hammer milling the incoming stems into a form suitable for pelletizing. In addition, roundwood is usually purchased on a weight basis. About 10 to 15 percent of the weight of roundwood is bark, which is typically not used in the manufacture of pellets. Thus, the cost of the actual wood fiber is increased by the proportion of bark included. Finally, unless it comes from standing dead trees, roundwood has to be dried because its moisture content is too high for pelletizing.

Pellet plants range in size from plants as small as 5,000 to 10,000 tons per year to plants producing more than 500,000 tons of pellets per year. There can be virtually no yield loss in going from the incoming feedstock to finished pellets. Thus, the output of a plant can mirror relatively closely the incoming raw material requirement. However, it is a fairly common practice to screen fines from the finished product and use those fines as fuel for a dryer, which dries the pellet feedstock to the appropriate moisture content.

2.6.3 Market Characteristics

Wood pellets have two main uses. The first is for space heating, including residential, commercial, and industrial buildings. The second is for co-firing with coal in the production of electrical power. The global market for wood pellets has grown rapidly. In 2013, the global market for wood pellets was estimated to be 23.6 million metric tons. Since 2001, the size of the market has grown by an average of 21 percent annually. Of the consumption in 2013, 4.0 million metric tons was burned in North America, primarily for space heating. 1.0 million was utilized in Asia. Europe used 10.0 million for space heating and 9 million for co-firing. The market is forecast to grow to over 50 million metric tons by 2025 (see **Figure 2.5**).

Figure 2.5 – Forecasted Global Pellet Demand (Millions of Metric Tons)



Source: Poyry & Wood Pellet Association of Canada

As shown in the figure, the North American market is forecast to be relatively stable due to its market being primarily for space heating. This fact offers a potential advantage to a pellet producer in Eastern Oregon manufacturing pellets (as a replacement fuel for homeowners replacing more costly propane and heating oil) for domestic space heating in the region.

Also illustrated in **Figure 2.5** is data showing that the Asian market is forecasted to be a significant part of the growth, with the main use being for co-firing. Up to this point, much of the demand from Asia has been satisfied from pellet manufacturers in Vietnam and from a relatively small amount of pellets that are exported from Canada and the Western U.S.

Many believe that further development of an Asian market will be an opportunity for wood pellet manufacturers on the U.S. and Canadian West Coast. However, several obstacles exist. First, there are a number of existing pellet manufacturers in British Columbia that have access to low cost feedstocks (i.e., mill residues that have limited market value aside from use as pellet feedstock) and well established logistics, including networks for transporting pellets from the mill via rail and truck to port facilities, storage and handling infrastructure at the port, and ports with sufficient depth to accommodate large bulk carriers. Such world class pellet handling logistics in the Pacific Northwest are not well established.

Second, while there may be an ample supply of feedstock available from pulpwood, the economics of manufacturing pellets using pulpwood feedstock are less cost-effective than using mill by-products. This is because the full cost of harvesting and hauling the pulpwood must be borne by the pelleting operation. When mill residues are used, the cost of harvesting and hauling the material to a centralized location is “subsidized” by the sawmill.

Additional information about pellet markets can be inferred from the Wood Briquette section since both products can be used for home heating. Remember, however, that use of wood pellets require homeowners to purchase a special pellet stove. Wood briquettes can be utilized in an existing fireplace or wood stove.

2.6.4 Production Characteristics

Assuming that the incoming feedstock is clean (no bark) chips produced from small diameter roundwood, the process of pellet manufacturing includes the following steps:

1. Fiber Preparation – incoming raw material must be screened to remove tramp material such as metal, stones, dirt, glass, etc.
2. Drying – the incoming chips must be dried to the moisture content appropriate for pelletizing (i.e., about 10 percent moisture – wet basis). This is accomplished with either a rotary drum drier or a belt drier.
3. Grinding – the raw material must be ground to a size of approximately plus or minus 1/8” prior to being pelletized. The grinding process is completed using a series of hammermills, with each successive mill providing a more finely ground product.
4. Conditioning – just prior to entering the pellet mill, the feedstock is *conditioned*. This stage is commonly accomplished by injecting steam into the finished raw material. This contact of the hot steam with the wood fiber raises the temperature of the material and

creates a very fine film of moisture on the surface of the feedstock. Conditioning also lowers the amount of mechanical energy needed to force the material through the pellet dies.

5. Pelleting – as shown in **Figure 2.4**, the raw material enters the pellet mill die cavity, and the roller then forces the material to exit the die cavity. A cut-off knife on the underside of the dies cuts the pellets off at the desired length – most pellets are about one quarter to five sixteenths inch in diameter and three quarters to one and one half inches long. Incoming feedstock generally weighs about 10 pounds per cubic foot compared to finished pellets weighing about 40 pounds per cubic foot.
6. Cooling – as the material is forced through the dies, the pressure increases, which, in turn, causes the temperature of the pellets coming out the dies to increase to about 200 degrees Fahrenheit. Pellets exiting the dies need to be cooled so that they are more durable and become "set" in their final form.
7. Screening – after the pellets are cooled they are screened to remove any fines that may have been generated during the process.
8. Bagging and Palletizing – for pellet plants making pellets for the home heating market, the final step in the process is bagging the pellets into 40 pound plastic bags. This is accomplished by feeding the pellets into a bagging bin. A fixed amount of pellets is fed from the bin into a plastic bag. The bags are then placed on pallets – usually 50 bags per pallet, with each bag weighing 40 pounds. Thus, a single pallet contains a ton of pellets. The pallet is then shrink wrapped and a slip cover is placed over it to protect the pellets from moisture.

Thus, the main pieces of equipment for the pelletizing process include various conveyors and transfers, hammermills, a dryer, a feedstock conditioner (steam), pellet mills, pellet cooler, screening system, and a bagger/palletizer. An order of magnitude factor for estimating capital costs for relatively large pellet plants (e.g., > 100,000 tons per year) is $175 to $225 per ton of pellet manufacturing capacity per year. For example, a 100,000 ton per year plant would have an estimated capital cost of $17.5 to $22.5 million. BECK is not aware of a rule of thumb factor for the capital cost at smaller plants, (e.g., < 50,000 tons per year). However, it is likely to be greater than $225 per ton of capacity since soft costs, such as permitting, engineering, etc., are likely to be a higher percentage of the total cost.

2.6.5 Location Requirements

Pellet manufacturing is a power intensive process. Therefore, a robust electrical service is required. A general rule of the thumb is that every ton per hour of manufacturing capacity requires 100 horsepower of electrical motors to operate the pellet mill. For example, a pellet mill with a capacity of 5 tons per hour requires a 500 horsepower motor. A number of additional motors are required for conveyors, hammermills, etc. As an example, a 50,000 ton per year mill requires about 2,500 connected horsepower of electrical motors.

Another consideration for pellet manufacturing is that during certain times, bagged Douglas fir pellets can be in high demand in the U.S. Northeast. Existing pellet manufacturers in the Pacific

Northwest have shipped pellets by rail all the way to the U.S. Northeast. Therefore, locating at a site with a rail siding potentially could be an important consideration.

2.7 POST AND POLE

2.7.1 Technology Overview

This technology involves the processing of manufacturing tree stems into finished products (posts and poles) that still have a round cross section and range in length from 8 to 20 or more feet and in diameter from 2 inches to as much as 10 inches.

The main piece of equipment for producing such products is either a post peeler or a doweller. A peeler is a machine that removes the bark and a thin layer of wood fiber from the outer surface of a log while maintaining the natural taper of the log. The post and pole doweller is a machine that feeds the long axis of a log through a rotating set of knives to produce a post or pole that has a fixed diameter along its entire length. Dowelling machines are much more productive than peeling machines, but have a higher capital cost. In addition, some customers prefer that the post and poles have the natural taper, while others prefer dowels that have a uniform diameter along the entire length of the log. Therefore, it is fairly common that post and pole manufacturing plants have both peelers and dowellers on site.

2.7.2 Raw Material Specifications

Relative to some of the other technologies considered in this report, post and poles have more stringent raw material specifications. For example, the following is a description of the incoming log specifications at a post and pole plant operating in Eastern Oregon. The operation buys three species of logs: lodgepole pine, ponderosa pine, and white fir. Regardless of species, logs are received in lengths of 16, 18, 24, and 32 feet, with a 6 inch over length allowance on all logs. Also, regardless of species, logs can be no larger than 10" in diameter at the large end. Finally, logs can be no less than 4" on the small end.

Regarding the pricing of delivered raw material, there are differences by species. The following prices were current as of 2012: $36 to $38 per green ton for lodgepole pine, $30 to $32 per green ton for ponderosa pine, and $28 to $30 per green ton for white fir. All prices are for logs delivered to the post and pole yard.

The typical post and pole plant in the U.S. West consumes about 10,000 bone dry tons of raw material annually.

2.7.3 Market Characteristics

The post and pole market is a consumer of small diameter roundwood. According to a study conducted by the U.S. Forest Service, the post and pole industry in 12 western U.S. states produced an estimated 60,000,000 linear feet of treated and untreated posts and poles of varying diameter in 2001 (the most recent data available). Of that amount, about one-third was produced in Montana and one-quarter in Oregon, the first and second leading post and pole producing states, respectively. A significant market for posts and poles is the vineyard industry in California and, to a lesser extent, Oregon.

Although a number of species are commonly used in the western U.S. for the manufacture of posts and poles, Lodgepole pine is a preferred species because the bark is thin, which makes for relatively easy processing. The trees tend to grow in densely stocked stands, have smaller branches (small knots), and occur in nearly pure stands. This means that the stems tend to be very straight, with little taper and defects, which results in posts and poles with desirable characteristics. In addition, Lodgepole pine trees tend to have a large sapwood area. This means that the chemical preservative is readily absorbed by this species.

Post and Pole manufacturers in the Western U.S. produced an estimated 60 million linear feet of treated and untreated material in 2001. The production falls into four general post and pole size classes. **Table 2.7** shows the relative amount of production in each size category produced in 2001 (the most recent data available).

Table 2.7 – Size Distribution of Post and Pole Production in the Western U.S.

Size Class	Percent of Production (lineal foot basis)
2.0 to 2.9 inches	13
3.0 to 4.9 inches	56
5.0 to 6.9 inches	26
7.0 inches and larger	5
Total	**100**

Table 2.8 shows the prices obtained per linear foot (f.o.b. the plant) for both treated and untreated material. As shown in the table, treating provides manufacturers with an average increase in value of 12 percent (unweighted by volume in each size class) and by 16.5 percent (weighted by volume in each size class).

Table 2.8 - Post and Pole Average Sales Value by Diameter Class and Treated Versus Untreated

Size Class	Treated ($/lineal foot)	Untreated ($/lineal foot)
2.0 to 2.9 inches	0.36	0.33
3.0 to 4.9 inches	0.6	0.49
5.0 to 6.9 inches	1.12	1.02
7.0 inches and larger	1.84	1.75

2.7.4 Production Characteristics

Post and pole operations in the Western U.S. use several methods for preparing the posts and poles for "peeling" or dowelling. For example, a fairly common procedure is to use tracked loaders equipped with forest harvesting processing heads in the log yard to cut whole length stems to the desired lengths (e.g., 6' to 16'). Then the bucked lengths are sorted into mobile bins by diameter, and the bins are transported to the peeler or doweller for further manufacturing. This "pre-sorting" process allows the plant to run efficiently since all of the material being processed at a given time is uniform in size.

Another common practice is for logs from the log yard to be placed on log transfer decks. The logs are then advanced to chop saws, which buck the whole length stems into post and pole standard lengths. This process is less costly than bucking and sorting logs to size in the log yard. However, it also means the post and pole plant must process material of varying sizes simultaneously, which can lead to lower efficiency. The posts and poles under this scenario are sorted to size classes after they are peeled or dowelled.

As previously described, posts and poles are produced by either a peeling or dowelling machine. It is common for post and pole plants to have additional pieces of equipment for producing posts and poles with pointed ends or for boring into the posts for producing a mortise/tenon type joint for making wooden fences.

Finished posts and poles are sorted into bins and then wrapped with metal banding for shipment to customers. For posts and poles that are to be treated, they are typically stored in a yard for air drying prior to application of the chemical treatment. Chemical preservatives are applied using standard pressure treating equipment.

The equipment required for post and pole manufacturing includes a front-end loader for unloading log trucks and loading finished product onto trucks; a tracked loader equipped with a processing head for bucking and sorting tree length stems; and a post and pole peeler and/or dowelling machine, including log deck, transfers, outfeed conveyors, outfeed sort transfers, waste conveyers and a dust/chip blower. An order of magnitude capital cost estimate for all of this equipment, including land and building, is $2.0 to $2.5 million.

Depending on the scale of the plant and the degree of automation designed into the process, post and pole plants require 5 to 15 employees.

2.7.5 Location Requirements

Similar to the other technologies considered in this report, the site requirements include access to a highway that has been designed to allow long and heavy trucks to easily enter and exit the site from the highway (e.g., turn lanes and road width adequate to accommodate trucks with a wide turning radius). In terms of space, a post and pole facility can be located on a site of about 10 acres in size. The site will also need a truck scale for weighing incoming and exiting log trucks since the raw material is purchased on a dollars per ton basis.

2.8 PULP CHIPS

2.8.1 Technology Overview

Whole Log Chipping (WLC) is the process of converting small diameter stems of roundwood into clean pulp chips (i.e., no bark included), which can be used in the manufacture of pulp and paper. In the Western U.S., historically, sawmill by-products have supplied about three-quarters of the pulp chips consumed at pulp and paper mills. However, during periods of reduced activity in the sawmill industry, the proportion of WLC has increased to much higher levels. WLC chips tend to be higher quality (i.e., chips that are more uniform in size) than mill residual chips.

The technology involves using either mobile or stationary chippers to process small diameter trees into chips. The chips are then transported to pulp and paper mills where they are eventually manufactured into paper.

2.8.2 Raw Material Specifications

The raw material requirements for making wood shavings are not restrictive (i.e., a wide range of material sizes and species can be used). Common specifications for the feedstock are a minimum small end log diameter of 3 inches, a maximum diameter of 20 inches, and a minimum length of 8 feet. These specifications are very similar to “pulpwood” specifications at a whole tree chipping operation. Existing chipping operations typically pay $25 to $35 per green ton (delivered) for material meeting these specifications.

A mobile chipping operation, when operated at its full productive capacity, can consume between 60,000 and 70,000 bone dry tons of chips per year (i.e., 120,000 to 140,000 green tons). Thus, the scale of this technology is relatively large compared to some of the other technologies evaluated in this report.

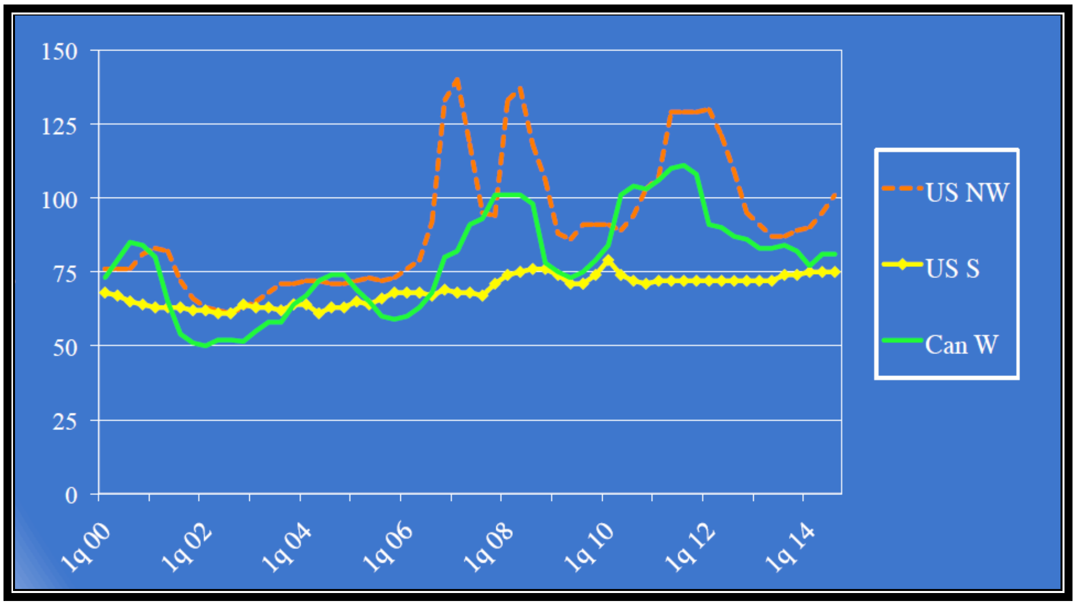
2.8.3 Market Characteristics

Pulp and paper mills are a key market for WLCs. Unfortunately, no pulp and paper mills are nearby in Eastern Oregon. The closest mills are International Paper’s mill in Springfield, OR; Boise’s pulp and paper mill in Wallula, WA; and several mills located in the Vancouver/Longview area of Washington. In addition, Collins Pine Company operates a hardboard plant and particleboard plant in Klamath Falls, OR. Chips are purchased for both operations, but the prices they pay are significantly lower than the pulp mills. Finally, Roseburg Forest Products operates a chip export terminal in Coos Bay, OR. During the last several years mobile chipping operations in the Klamath Falls region have been producing chips that are exported through Coos Bay.

Figure 2.6 illustrates the historic average delivered value of pulp chips in the Pacific Northwest (red line), U.S. South (yellow line), and Western Canada (green line), as reported by North American Wood Fiber Review. As shown in the figure, the prices in the Pacific Northwest have been the most volatile of the three regions, with prices varying from lows of about $60/BDT to highs of over $140/BDT. During periods of high delivered chip values, chipping operations in Eastern Oregon can deliver chips at competitive values. However, when average delivered prices drop below a certain level (the amount varies depending on the location of the chipping operation and the final destination), chipping operations in Eastern Oregon are not price competitive and tend to be the first supply sources cut off from further deliveries by the pulp mills.

It should be noted, however, that some of the pulp mills, especially the North Pacific Paper Corporation (NORPAC) mill in Longview, require a certain proportion of pine chips in their supply mix. The pine chips are lighter in color and allow the mill to more easily produce paper in the desired light color. Pine is not found in large quantities west of the Cascade Mountain Range. Therefore, some mills buy pine chips from Eastern, OR at all times. The total market for pulp chips in Oregon, Washington, and the Inland Region is estimated to be about 13.0 million BDT per year. The demand estimate includes all pulp and paper mills, chips that are exported, and chips used by hardboard and MDF manufacturers.

Figure 326 – Historic, Average Delivered Value of Pulp Chips by Region ($/BDT)



2.8.4 Production Characteristics

Chipping operations can be either mobile (using diesel powered engines) or stationary (using electric motors). For the purposes of this analysis, it has been assumed that mobile chipping operations would be utilized in Eastern, Oregon. The primary reasons for this decision are that the reduced capital cost and the ability to move the chipper closer to markets (if required) are viewed as options for lowering risk given the volatility of the chip market.

In mobile operations, a wheeled log loader (front end load) feeds from a log deck to a loader on or at the chipper. The loader at the chipper feeds the stems into the chipper. Bark and fines drop out the bottom of the chipper and are cleared away by a front-end loader. The chips that make it through the screens (i.e., the finished product) are dumped into a pile on the ground to await loading into chip vans. Some operations may feed the logs from the chipper directly into waiting chip vans. Because of the simple approach, no logs are sorted for other uses. **Table 2.9** lists the required pieces of equipment and their respective functions.

Table 2.9 – Mobile Chipping Operation Equipment Items

Equipment Item	Function(s)
Wheeled Log Loader	Unload log trucks. Feed logs from log deck to chipper.
Chipper	Convert logs into chips. Please note that this piece of equipment has a "built-in" log loader that is used to load logs into the chipper.
Screen	After chipping, this piece of equipment screens the pieces that are too large and too small, leaving only pieces with the desired size as the finished product.
Front-End Loader	Load finished chips into chip vans. Move bark and fines away from chipper to hog fuel storage pile. Load hog fuel into chip vans.

The estimated capital cost for the preceding items is $1.565 million, broken out as follows: $985,000 for the chipper; $180,000 for the front-end loader; $250,000 for the wheeled log loader, and $150,000 for the screen. Except for the chipper, all of the prices are for used equipment.

A mobile chipping operation requires the labor of three people. One to feed logs into the chipper, one to move by-products (bark and fines) away from the chipper, and a third to move logs from log decks to the chipper infeed operator.

2.8.5 Location Requirements

Given that the operation considered here is mobile, the site requirements are largely limited to having enough available space to deck logs, to allowing enough space for the equipment, and to allowing trucks to bring logs in and take pulp chips away. BECK estimates this translates into a site occupying 5 to 10 acres. The site also would need a means of weighing incoming log trucks.

2.9 SAWN LUMBER FROM SMALL DIAMETER LOGS

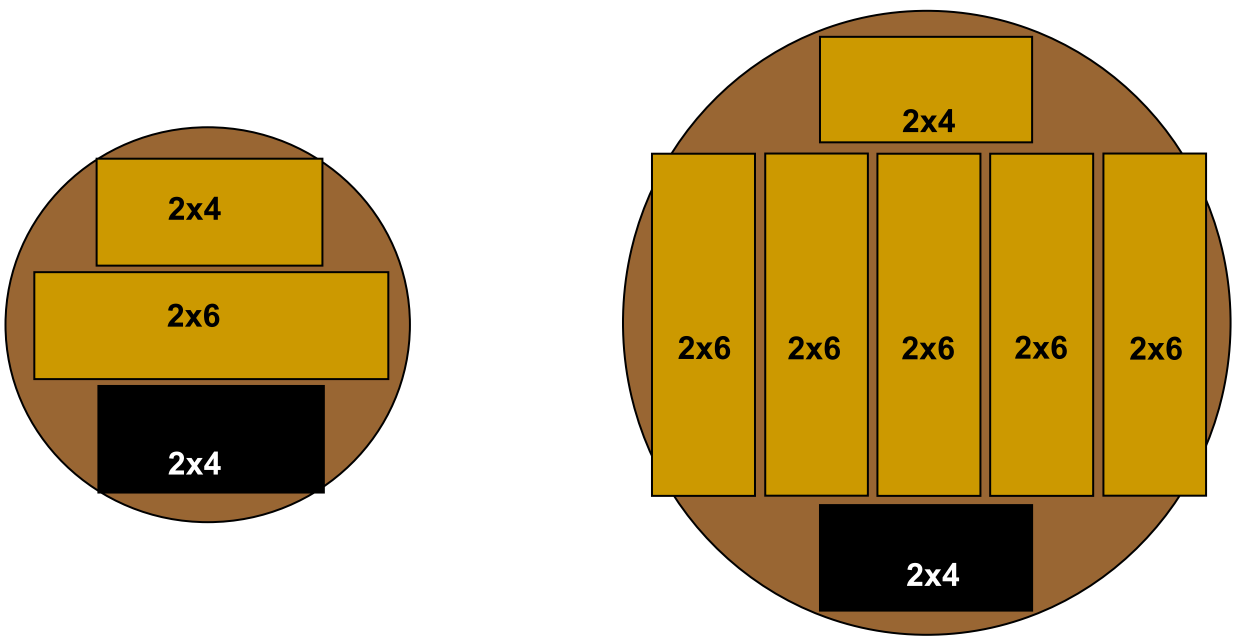
2.9.1 Technology Overview

The technology of sawmilling is mature and well proven. However, with respect to a small log sawmill, there continue to be incremental changes aimed at improving: 1) efficiency (log to lumber recovery); 2) productivity (increasing log processing speed); and 3) automation (upgrading/improving). Each of the following paragraphs describe these factors.

Recovery refers to the efficiency with which the cubic volume of the log is converted into lumber. Recovery at sawmills has improved perhaps most significantly because of the development of systems for scanning logs prior to sawing so that the sawing solution that will yield the highest combination of lumber volume and value can be produced. Complementing the scanning systems are log positioning systems that are capable of orienting the log relative to the saw in the position the scanning system has identified for achieving the optimal log to lumber breakdown.

To illustrate the importance of recovery consider the following. In small logs an error in recovery results in a much higher loss in lumber output volume relative to a similar error on a larger log. In **Figure 2.7**, assume the log on the left has a small end diameter of 6.5 inches, is 12 feet long, and will yield a sawing solution of two 2x4s and one 2x6 (28 board feet) if sawn optimally. However, if the log is not positioned relative to the saws correctly and one of the 2x4s cannot be recovered, then the log will only yield 20 board feet of lumber, and the sawing mistake causes a 29 percent volume reduction. In contrast, the log on the right has a small end diameter of 10” and is 12’ long and will yield 76 board feet of lumber if sawn optimally. If one of the 2x4 pieces of lumber cannot be recovered, the yield drops to 68 board feet –only an 11 percent reduction on lumber volume recovery.

Figure 3.7 – Importance of Sawing Accuracy in Small Logs



The scanning and log positioning systems just described are able to operate at very high speeds. Achieving high throughput rates is critically important for small log processing because many pieces must be handled to achieve a desired level of output. For example, consider two sawmills with each producing 60 million board feet per year when operating 8 hours per day (one shift). Mill A saws logs that average 10” small end diameter and are 12’ long. Mill B saws logs that average 6.5” small end diameter and are 12’ long. Mill A will yield about 76 board feet of dimension lumber per log and will have to cut about 6.6 logs every minute. Mill B will yield about 28 board feet of lumber per block and will have to cut about 17.8 blocks per minute. Thus, in order for both mills to achieve the same annual production over 2,000 hours, Mill B needs to run nearly three times as fast.

Automation is the third critical factor in small log sawmilling. Many of the historically labor intensive processes in a sawmill have been automated. For example, sorting lumber by grade/length on a green chain using labor has been replaced by automated bin sorters that recognize special markings on individual boards to drop the piece out at the appropriate bin. Another example is that lumber grading has been highly automated.

2.9.2 Raw Material Specifications

To develop a small log sawmill that would be able to produce softwood lumber cost competitively (i.e., be of sufficient scale to operate at relatively low per unit manufacturing cost), a mill would require 30 to 40 million board feet of logs per year when operating on a one ship basis and sawing only logs less than 12 inches in diameter (i.e., a 4.5" minimum small end diameter and a 12" maximum large end diameter) and a minimum length of 16 feet.

2.9.3 Market Characteristics

In general, lumber markets rise and fall with new home construction and repair/remodeling activity. This is especially true of structural lumber products, but it also applies to many types of specialty products. **Table 2.10** provides a summary of how softwood lumber production/demand has risen and fallen in North America over the last 10 year economic cycle.

Table 2.10 - Softwood Lumber Industry Production and Consumption 2006 to 2014 (WWPA)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
U.S. Lumber Production										
West	19,333	17,983	16,315	12,994	10,710	11,137	11,617	12,593	13,488	14,067
South	18,986	18,696	16,985	14,641	11,789	12,354	13,474	14,295	15,071	16,111
Other	2,138	2,047	1,858	1,542	1,255	1,311	1,414	949	1,392	1,471
Total U.S. Lumber Production	*40,457*	*38,726*	*35,158*	*29,177*	*23,754*	*24,802*	*26,505*	*27,837*	*29,951*	*31,649*
Imports to U.S. from Canada										
From British Columbia	12,231	11,859	9,814	6,781	5,075	5,252	4,797	5,336	5,916	6,199
From East of Rockies	9,274	8,290	6,858	4,840	3,228	3,781	4,051	4,192	4,999	5,939
Total imports from Canada	*21,505*	*20,149*	*16,672*	*11,621*	*8,303*	*9,033*	*8,848*	*9,528*	*10,915*	*12,138*
Imports to U.S. from Other Regions										
From Latin America	-	785	620	426	285	231	202	161	193	329
From Europe	-	1,603	880	487	177	105	147	87	146	142
Total Non-Canadian	-	*2,657*	*1,712*	*1,060*	*551*	*435*	*441*	*336*	*442*	*569*
Total Lumber Imports into U.S.	*21,505*	*22,806*	*18,384*	*12,681*	*8,854*	*9,468*	*9,289*	*9,864*	*11,357*	*12,707*
U.S. Exports of Lumber										
to Canada	248	250	254	295	268	395	350	377	383	371
to China	-	-	-	-	-	154	422	245	396	344
to Japan	51	51	67	101	115	161	175	164	181	129
to Mexico	224	209	196	207	182	197	235	282	288	296
to All Others	375	420	476	421	417	440	485	514	545	600
Total U.S. Lumber Exports	*898*	*930*	*993*	*1,024*	*982*	*1,347*	*1,667*	*1,582*	*1,793*	*1,740*
U.S. Softwood Lumber Consumption										
Shipments from U.S. Producers	40,553	38,596	34,712	29,153	24,001	24,700	26,503	27,734	29,940	31,619
Plus Imports	24,678	22,806	18,385	12,681	8,855	9,468	9,289	9,864	11,357	12,707
Minus Exports	(897)	(930)	(993)	(1,024)	(983)	(1,347)	(1,667)	(1,582)	(1,793)	(1,740)
Apparent Consumption	***64,334***	***60,472***	***52,104***	***40,810***	***31,873***	***32,821***	***34,125***	***36,016***	***39,504***	***42,586***

2.9.4 Production Characteristics

Sawmilling is a relatively complicated process. Incoming logs are typically purchased on a weight basis (for small diameter logs). The logs are then debarked and bucked to lumber lengths (e.g., 8 to 20 or more feet in two foot increments). The bucked log lengths then enter the sawmill where (for small log operations) they typically are processed from log into lumber and by-products in a "single pass". In other words, at a larger log sawmill, a single log will reciprocate numerous times through the single saw. Small log mills, in contrast, generally have multiple saws and chipping heads at the primary breakdown so that the log is converted into a combination of lumber, chips, and sawdust in a single pass.

Beyond the primary breakdown, a small log sawmill will be very similar to mills that process larger logs. In other words, there will be conveyors for moving the lumber through the process, bins for sorting lumber into like widths, lengths, grades, etc. Stackers for stacking lumber into units prior to drying in dry kilns. And a planer mill for finishing lumber to its final dimension.

An order of magnitude capital cost for developing a "greenfield" small log sawmill is $35 to $45 million dollars, and it would include bucking and debarking equipment, a sawmill, lumber dry kilns, and a planer.

Cost competitive dimension and stud mills in the Western U.S. will have per unit manufacturing costs of roughly $120 to $140 per thousand board feet of lumber produced. This includes all costs for handling, debarking and bucking logs in the log yard, sawmilling, drying, planing, and general and administrative expenses, including depreciation. In other words, all of the costs for manufacturing lumber except for the cost of purchasing the logs.

Another key production characteristic of small log sawmilling is that it produces significantly more mill residues than sawmills processing larger diameter logs. For example, using the sawmills from the previous comparison (Mill A processing logs that average 10" in small end diameter and Mill B processing logs that average 6.5" in small end diameter), if each sawmill produces 100 million board feet of lumber per year, the small log mill will produce an estimated 63,000 bone dry tons of chips compared to an estimated 29,000 bone dry tons of chips at the mill processing larger logs. This is because larger logs allow for a higher proportion of the log's cubic volume to be recovered as lumber.

2.9.5 Location Requirements

Small log sawmilling would require significantly more space than most of the other technologies considered in this report – perhaps a total of 20 to 40 acres, depending on the scale of the operation. In addition, like some of the other technologies considered, a sawmill is fairly power intensive, so the electrical service to the site must be robust. Also, small logs are typically purchased on a weight basis, so the site needs a truck scale. Small log sawmilling will involve lumber drying. Therefore, the site will need a boiler that will likely be fired by sawmill residues. Thus, siting would have to take into account any local air quality limitations that may be associated with the operation of a wood-fired boiler. Finally, lumber is often shipped long distances to end users. Therefore, a site with a rail siding would almost certainly be a requirement for this technology.

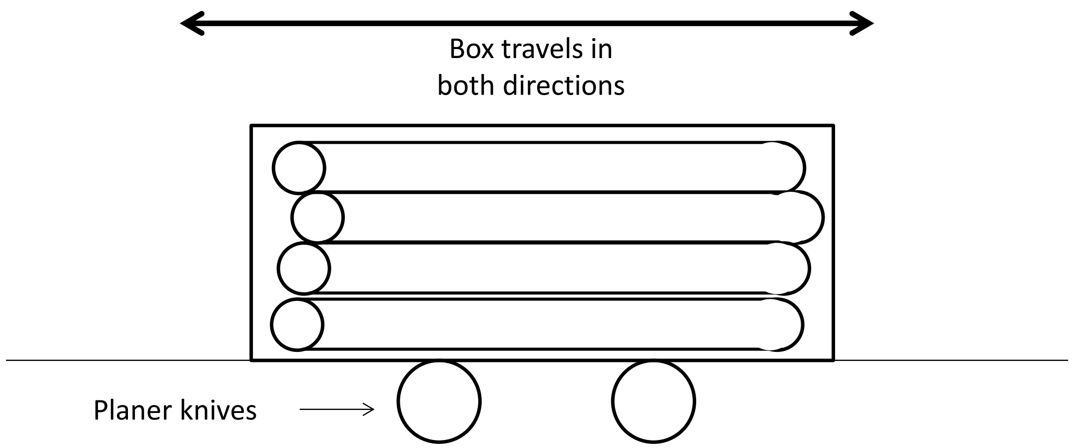
2.10 SHAVINGS (ANIMAL BEDDING)

2.10.1 Technology Overview

Shavings made from wood fiber are commonly used as bedding for animals, including horses, chickens, and small pets kept in cages. Historically, the shavings used for this purpose came from the by-products of sawmilling (i.e., when lumber is planed to its final dimension). The Great Recession, when sawmills were operating at historically low levels and producing limited amounts of shavings, spurred wider adoption of a technology for converting small diameter roundwood into shavings.

Small diameter logs are placed into bins that move back and forth over planer knives. As the logs move across the rotating knives, gravity presses the logs against the knives and shavings are produced. **Figure 2.8** illustrates the concept from a side view.

Figure 2.8 – Small Diameter Roundwood Shavings Planer (side view)



2.10.2 Raw Material Specifications

The raw material requirements for making wood shavings are not restrictive (i.e., a wide range of material sizes and species can be used). Common specifications for the feedstock are a minimum small end log diameter of 3 inches, a maximum diameter of 20 inches, and a minimum length of 8 feet. These specifications are very similar to "pulpwood" specifications at a whole tree chipping operation.

A shavings machine operation on a one-shift basis will consume about 25,000 green tons (12,500 BDT) of small diameter trees annually. This translates into the production of about 700,000 bags of shavings per year (3 cubic feet of compressed shavings per bag). Shavings operations typically pay about $25 to $35 per green ton for raw material delivered to the facility in roundwood form.

2.10.3 Market Characteristics

In the Western U.S. the largest market for wood shavings is bedding for horses. This type of bedding is sold in bags. A convention in the industry is to start with 9 cubic feet of shavings and compress it into a plastic bag with a volume of 3 cubic feet. When the end user of the shavings opens the bag, the shavings again expand to a volume of 9 cubic feet.

BECK is not aware of any published information about the size of the market for animal bedding from wood shavings. However, the population of horses can provide us with an indication of market size. **Table 2.11** shows the Western U.S. horse population by state in 2012. Assuming that 15 percent of those horses are bedded in a stable and that each of those horses uses one bag of shavings every other day, it translates into an annual usage of over 23.1 million bags of shavings per year. Assuming an expansion factor of 2.5 when going from solid wood to shavings, a total of 1.2 cubic feet of solid wood is contained in each bag. This, in turn, translates to about 33 pounds of wood per bag. Assuming a weight of 33 pounds per bag (at 10 percent moisture content), the estimated size of the bagged shavings in tons is about 380,000 tons per year.

Bagged shavings (3 compressed cubic feet/bag) sell for about $5 to $6 per bag at the retail level. At the shavings plant, bags typically sell for about $2.75 to $3.25 per bag depending on the operation and the distance to market.

Table 2.11 – Western U.S. Horse Population (2012)

State	Horse Population
AZ	92,394
CA	142,555
CO	110,360
ID	61,439
NM	50,723
NV	22,464
MT	97,921
OR	70,427
UT	58,979
WA	64,616
WY	72,461
Total	**844,339**

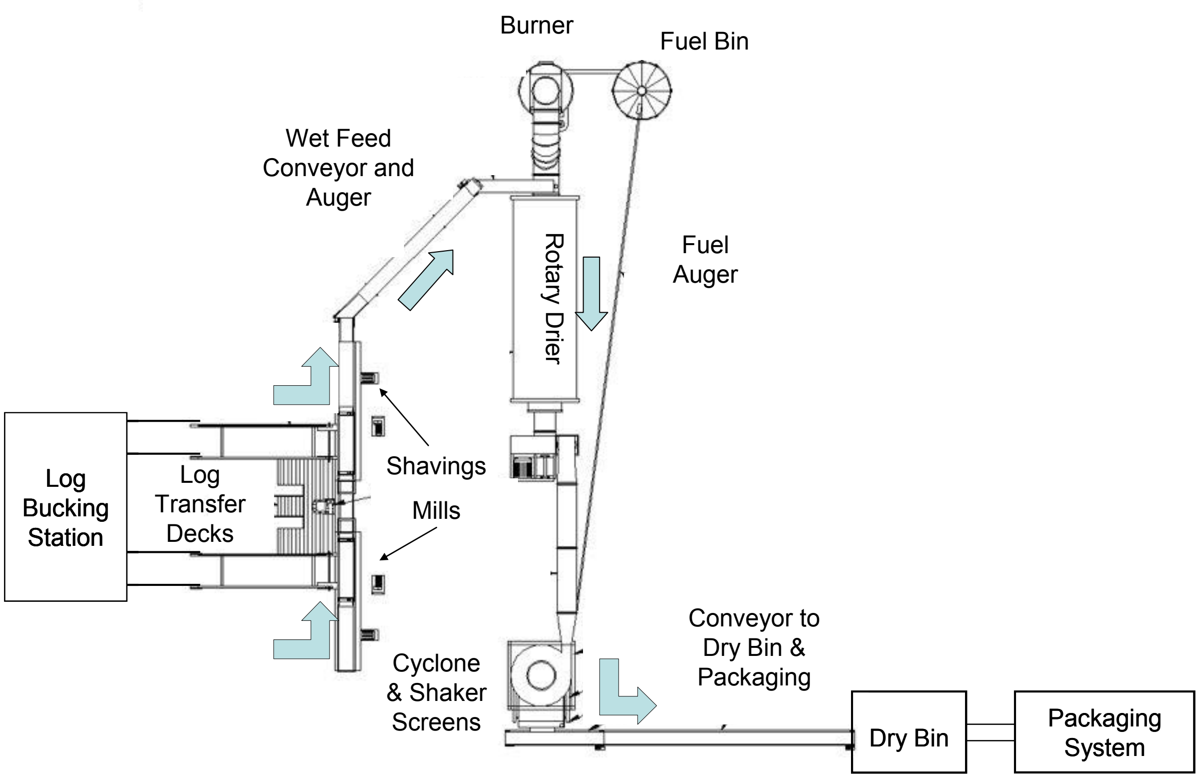
2.10.4 Production Characteristics

Manufacturing wood shavings from roundwood is a relatively simply process. The diagram shown in **Figure 2.9** is a typical shavings operation layout. The blue arrows show the flow of material. Starting at the left side of the diagram, a log bucking station cuts the logs to length (either 4’ lengths or 8’ lengths, depending on the type of shaving machine). If a biomass burner is used for drying the material, logs do not need to be debarked prior to conversion to shavings because much of the bark becomes the fines that are burned in the dryer.

The bucked logs are placed on log transfer decks, which move the logs to the shaving machine(s) **Figure 2.8** shows a simplified drawing of the two machines. Planer knives in the shavings machine convert the roundwood into shavings, which then fall out of the bottom of the machine and onto a conveyor and auger system that delivers the shavings to the dryer. The shavings pass through the dryer and exit at about 12 percent moisture content (by weight).

Next, a cyclone system transfers the dried shavings to one or more screens which sort the smaller and larger shavings pieces. The small pieces from the screener are sent back to the fuel bin to await being burned to provide heat for the dryer. Typically, about 12 to 15 percent (dry volume basis) of the original material ends up as burner fuel (most of which is bark). The larger portions exit the screener and are conveyed to a large dry bin. From the dry bin, the shavings are sent to a packaging machine where they are compressed and bagged. Filled bags are placed on pallets and then shrink-wrapped prior to shipment.

Figure 2.9 – Wood Shavings Manufacturing Process Layout Diagram



The following is a list of the capital equipment required for the operation of a stand-alone wood shavings plant:

- **Truck Scale –** raw material (logs) for the plant is purchased on a weight basis. Therefore, a truck scale is required to measure the volume of logs received on each truckload.
- **Forklift –** the forklift will perform multiple functions at the operation (e.g., feeding logs from the log storage area into the manufacturing process, unloading logs from trucks [in the case of trucks that do not have self-loaders], moving pallets of finished product into storage, loading outbound trucks with pallets of finished product). Special attachments for the forklift (log tongs and forks) are required to complete all of these functions.
- **Knuckleboom Loader/Cut-Off Saw –** this is a stationary piece of equipment that processes longer length logs into pieces of the appropriate length for the shavings mill.
- **Log Transfer Decks –** these are chain conveyors that are used to transport cut-to-length logs to the shavings mill.
- **Shavings Mill –** this is the equipment used to convert the logs into shavings.
- **Burner/Fuel Bin/Rotary Drum Dryer/Cyclone –** this set of equipment is used to dry the shavings to a low enough level of moisture so that the shavings can be packaged in bags without developing mold, mildew, fungus, etc. A number of different fuels can be used to heat the dryer, but we have assumed the dryer will burn the small material (fines) produced by the shavings process since this is the most cost efficient fuel.
- **Dry Bin –** this is simply a large bin for storing dried shavings prior to bagging.
- **Bagger –** this piece of equipment is an automated bagging system for compressing the wood shavings into a sealed bag that can more efficiently be stored and shipped than uncompressed bulk shavings.
- **Miscellaneous Conveyers** – many of the previously described pieces of equipment are connected with belt conveyors for transporting the material from station to station as it flows through the manufacturing process.

An order of magnitude capital cost estimate for the preceding list of equipment and a 100’ x 100’ building is $3.0 to $3.5 million.

A shavings operation such as the plant described here requires staffing of four hourly employees. One person is needed to operate the log bucking station. A second is needed to offload the bucked logs into the shavings machine(s). A third person is needed on the back end of the plant for operating the bagging machine and stacking finished bags onto pallets. A fourth person is needed to operate a loader for feeding logs to the operation and taking finished pallets of shavings away from the back end of the operation.

2.10.5 Location Requirements

The site for a shavings plant must be readily accessible by semi-tractor trailer typed trucks (i.e., wide entry/exit roads at the site and roads into and out of the site that are capable of supporting trucks weighing as much as 80,000 pounds. A shavings plant of the scale described here will use electrical power requiring service to the site of approximately 500 to 1,000 kilovolt amperes. The raw material procured for the plant would be purchased on a weight basis, which means the site would require a truck scale. In terms of size, a facility of the scale described here could be sited on a space of 5 to 10 acres.

2.11 RETURN TO FIBER VALUE ESTIMATES

Return To Log (RTL) or Return To Fiber (RTF) are forest industry terms used to describe the value the products produced from a conversion facility will yield after accounting for the cost of converting the material from its original form into a finished product. RTL refers to processes where the incoming feedstock is logs (or roundwood). RTF refers to processes where the incoming feedstock is wood fiber in the form of chips, sawdust, shavings, etc.

To illustrate, an RTL example for sawmills is calculated by:

1. Estimating the total revenue ($/MBF) that can be generated from sawing a log (i.e., value of the lumber, chips, sawdust, shavings and bark).
2. Subtracting the total cost ($/MBF) of converting the log into lumber and by-products from the total revenue.
3. The result is referred to as the RTL Value or the Allowable Delivered Log Cost.

In other words, the result of RTL and RTF calculations is the value generated by the log/fiber after accounting for the cost of converting it into a product.

For the purposes of this study, BECK has completed RTL/RTF analyses for the nine technologies considered in this study. Since the various technologies use different units of measure for the raw materials and finished products, BECK has converted all units to $ per bone dry ton basis. This allows for a direct comparison of the economics underlying each technology and the identification of the technologies capable of generating the greatest value.

It is important to note that the analysis has been conducted at a relatively high level and that a number of assumptions have been made about the scale (and operating costs) of the various technologies. Therefore, the results should not be viewed as precise cost and revenue estimates. Rather, the focus should be on the relative difference between the values generated by each conversion technology.

Table 2.12 shows the estimated values and key metrics associated with each technology. A list of the key assumptions associated with each technology is included in the sections following the table.

As shown, lumber manufacturing is by far the technology that creates the highest value. Then pulp chips, shavings, and post and pole manufacturing are in a second tier group that provides similar RTL/RTF values. Given the logging and transportation costs analyzed in **Section 2.1**, using small diameter roundwood as a feedstock for these businesses is feasible. There is a third tier group of technologies that includes briquettes, pellets, biomass CHP, and firewood that all create roughly equal value. However, unlike the other technologies just mentioned, using small diameter roundwood as a feedstock for these businesses is marginal unless the raw material is at the high end of the size class ranges identified in **Section 2.1**. Finally, fuel chips was by far the conversion technology providing the lowest return and using small diameter roundwood as a feedstock is not feasible.

With regard to lumber, the $97 per bone dry allowable log cost translates into a delivered log cost of $350 per MBF Scribner Eastside basis or about $48 per green ton. The analysis was based on the assumption that the sawmill could only process logs between 4.5” in diameter on the small end and up to 12” in diameter on the large end. The table also shows the amount of material each conversion facility was assumed to consume annually and an order of magnitude capital cost estimate for developing such a facility. For all technologies it was assumed that the owner/developer requires a 15 percent return (calculated on the entire capital expense, not just on the owner’s equity). That cost was added to the conversion cost estimate. A more detailed description of the assumptions used in the analysis is provided following the table.

Table 2.12 – Estimated Return to Fiber/Log Values for Nine Technologies

	Lumber	Pulp Chips	Shavings	Post and Pole	Briquettes	Pellets	Biomass (CHP)	Firewood	Fuel Chips
Sales Value f.o.b. plant, ($/BDT)	206	76	178	195	167	160	107	95	25
Conversion Cost Inc. dep. and owner return @ 15% ($/BDT)	109	19	126	144	126	122	72	60	19
RTF Value ($/BDT)	**97**	**56**	**52**	**51**	**41**	**38**	**35**	**35**	**6**
BDT/Year (BDT)	137,000	84,000	10,200	5,000	9,900	47,000	121,000	9,400	84,000
Cap EX ($ millions)	40	2.5	2.5	1.5	2.0	10	54	0.5	2.0

2.11.1 Description of Key Assumptions Used in the RTL/RTF Analysis

Lumber – the sawmill modeled in the analysis would produce 70 million board feet of lumber annually from logs measuring 4.5” in diameter on the small end and no larger than 12” in diameter on the large end. The capital cost for such an operation would be between $35 and $45 million. On an MBF log scale basis, the mill would consume about 37.8 million board feet Scribner Eastside log scale. The assumed log-to-lumber recover was 1.85. On a volumetric basis, the assumed lumber recovery was 42 percent of the cubic volume recovered as lumber with the balance being a combination of sawdust, chips, shavings, and bark. The average sales realization for the mill was assumed to be $404 per MBF of lumber and includes the value of mill residual sales. This value is comparable to what mills in the Inland West region have experienced in the first quarter of 2015. The conversion cost, including depreciation was assumed to be $132 per MBF (lumber scale).

Pulp Chips – the pulp chip analysis assumes a mobile chipping operation located in Eastern Oregon about 250 to 300 miles from pulp mills on the Lower Columbia River (e.g., Longview, WA) that require a certain percentage of pine (whitewood) in their feedstock. Since pine is not readily available west of the Cascades, there is generally some material flowing from Eastern Oregon (where pine is more prevalent) to the pulp mills on the Lower Columbia River. The f.o.b. mill sales value of the chips (and by-products such as bark and fines) was assumed to be about $76 per bone dry ton. This is a value from several ago when sawmills were producing less lumber and as a result fewer mill residual chips. This in turn caused the price of chips to increase in the Pacific Northwest. This value was used because it was a price observed during a time when chipping operations in Eastern Oregon were active. Today, when the cost of shipping chips to the Longview region is added to the $76 per BDT price, the delivered cost is significantly higher than current chip market values. Thus, caution should be used when considering a whole log chipping business in Eastern Oregon because the high cost chips from the region are generally the first supply sources cut-off from further deliveries when chip supply becomes more plentiful. The combined cost of chipping and owner's return was assumed to be $19 per bone dry ton.

Shavings – the operation modeled in this study would consume a little over 10,000 bone dry tons of roundwood raw material per year. The business would use "whole log shaving machines" to convert the roundwood into shavings, which would then be bagged and sold as animal bedding. The plant was assumed to have the capacity to produce about 700,000 bags per year, with each bag holding 3 cubic feet of compressed shavings. When the bag is opened the shavings expand to occupy 9 cubic feet. The average sales value per bag was assumed to be $2.50 (f.o.b. the plant). It was assumed that the volumetric recovery in going from roundwood to shavings was about 85 percent. Most of the downfall would be bark, which would be burned to dry the shavings in a rotary drum drier. The operation was assumed to run on a one shift basis. The economics of producing shavings would be improved if the operation was operated on a two shift basis, and at the same time: the raw material costs were not significantly increased and there was a large enough nearby market to absorb the extra production.

Post and Pole – the operation modeled in this study would consume a little over 5,000 bone dry tons per year and have a capital cost of about $1.5 million. The operation would work on a one shift basis, 250 days per year and produce about 1,300 eight foot long posts per day ranging in small end diameter size from 3 to 6 inches. The average sales value of the posts was assumed to be $2.81 per post f.o.b. the plant.

Briquettes – the operation modeled in this study would consume nearly 11,700 bone dry tons of raw material per year and produce about 11,000 tons of briquettes per year at 10 percent moisture content. Briquettes were assumed to sell for $150 per ton f.o.b. the plant. It was also assumed that about 15 percent of the incoming feedstock would be screened from the process as either bark or fines and that this material would be burned to dry the feedstock to the appropriate moisture content for briquette manufacturing. The operation was assumed to run on a 3 shift basis, 5 days per week or 6,000 hours per year. The production capacity of the briquetting machine was assumed to be 2.0 tons per hour, and the plant was assumed to operate at 90 percent uptime. Power was assumed to cost $0.07 per Kilowatt hour.

Pellets – the pellet plant modeled in the study would produce about 50,000 tons of pellets per year and would consume a little over 55,000 bone dry tons of raw material annually. The difference between those two volumes is a combination of moisture content (pellets are sold at about 7 percent moisture) and about 15 percent of the incoming feedstock being used as fuel for drying the feedstock to the required moisture content. The plant was assumed to run 24 hours per day, 7 days per week and that the uptime would average over 90 percent, which translates into about 8,400 hours of uptime per year. This further translates into an average production rate of nearly 6 tons of finished pellets per hour. The cost of power was assumed to be $0.07 per kilowatt hour.

Biomass CHP - biomass power return-to-fiber values are based on an 18 MW plant selling its power at $70/MWH in year one and escalating at 2 percent per year for 20 years, selling low pressure steam in year one at $4.63/thousand pounds on sales of 15,000 pounds per hour and escalating at 3 percent per year for 20 years. Annual fuel consumption was estimated to be 121,125 BDT, with an average delivered fuel cost of $30.55/BDT in year one and escalating at 3 percent annually for 20 years. A capital cost of $54.4 million was estimated.

Firewood – the firewood operation modeled in the study was assumed to produce 9,000 cords of firewood per year, which translates into about 9,500 bone dry tons of raw material required annually. Each cord was assumed to contain 80 cubic feet of solid wood and 48 cubic feet of air space. The sales value was assumed to be $100 per cord f.o.b. the plant.

Fuel Chips – the assumptions associated with the Fuel Chip business were basically identical to the pulp chip business, with the exception being that the value of the fuel produced from the operation was assumed to be $25 per bone dry ton (f.o.b. the plant). That value reflects the current market values for biomass fuel.

CHAPTER 3 – INTEGRATED PROCESSING FACILITY

The objective of this section of the report is to evaluate the suitability of co-locating several of the forest products conversion technologies described in this report at an integrated biomass processing facility. As was demonstrated in the accompanying small diameter supply assessment by Mason Bruce & Girard, significant volumes of small diameter material are available in the region. In addition, technologies exist for profitably convert this small diameter material into finished products.

Although the conversion technologies were all considered independent of each other in the preceding sections, in this report section, the focus will switch to analyzing (at a high level) the concept of developing an integrated biomass processing facility where two (or more) conversion technologies are located at a single facility. Since the potential number of combinations utilizing nine technologies is huge, the initial focus is on identifying technology combinations that naturally complement each other in terms of feedstock usage, process heating needs, and other opportunities for efficiencies that reduce administrative and operating costs. The second part of this report section analyzes the high level economics of several of the most logical and economically favorable technology combinations.

3.1 IDENTIFYING OPPORTUNITIES FOR EFFICIENCY

Table 3.1 is a matrix describing the basic characteristics of the technologies considered in this study. The key point concerning the information in the table is that it can be used to categorize the technologies into two main groups – "anchor" technologies and "secondary" technologies.

Technically, all of the technologies considered can utilize small diameter roundwood as the feedstock. However, as identified in the RTL/RTF analysis in **Section 2.11**, some can more cost effectively utilize small diameter roundwood as a feedstock. These technologies can be thought of as anchor technologies at an integrated small diameter processing facility because their economic structure is such that they could operate viably as a stand-alone facility. These technologies have all been labeled "yes" in the category "Uses Small Diameter Trees" in **Table 3.1**.

The others cannot operate viably as a stand-alone facility when small diameter roundwood is the feedstock. These technologies have all been labeled "no" in the category "Uses Small Diameter Trees" in **Table 3.1**. However, if by-products from another operation are the feedstock for these technologies, the economics would be improved because those by-products tend to be a lower cost raw material. This is due to those by-products potentially having very limited market value, yet by virtue of being a by-product of another conversion process, they have already been collected in a centralized location and are often already in a physical form (i.e., small pieces) conducive for utilization by one of the technologies considered in this report.

In a situation where there are few nearby consumers of mill by-products, (e.g., no paper mills, no particleboard/MDF mills, and limited markets for landscape material and hog fuel), the cost of by-products as a feedstock is largely determined by how far they need to be transported. In an integrated facility scenario, the by-products would essentially have zero transportation cost, although there may be a very small cost associated with operating and maintaining a pneumatic or conveying system to move the by-products from one place on an integrated site to another processing center.

Table 3.1 – Small Diameter Conversion Technology Informational Matrix

Technology	Portable	Gas or Electric Power	Uses Small Diameter Trees	Produces By Products	Uses By-products	Thermal Host	Storage for raw material	Dry Storage needed for finished product
Lumber	No	Electric	Yes	Yes	No	Yes	Yes	Yes
Pulp Chips	Yes	Both	Yes	Yes	No	No	Yes	No
Shavings	No	Electric	Yes	Yes	No	Yes	Yes	Yes
Post and Pole	No	Electric	Yes	Yes	No	No	Yes	No
Briquettes	No	Electric	No	No	Yes	Yes	Yes	Yes
Pellets	No	Electric	No	No	Yes	Yes	Yes	Yes
Biomass CHP	No	Electric	No	No	Yes	No	Yes	No
Firewood	Yes	Both	Yes	Yes	No	Yes	Yes	Yes
Fuel Chips	Yes	Both	No	Yes	Yes	No	Yes	No

Table 3.2 shows a categorization of the technologies that, in BECK's judgment, would best serve as anchor technologies and those that would best serve as secondary technologies. As described in the previous section, the grouping is formed largely on the basis of whether the technologies can cost-effectively utilize small diameter material as a stand-alone facility.

Table 3.2 – Categorization of Technologies into "Anchor" and "Secondary" Groupings

Anchor Technologies	Secondary Technologies
Lumber	Briquettes
Shavings	Pellets
Post and Pole	Biomass CHP
Pulp Chips	Fuel Chips
Firewood	

3.2 HIGH LEVEL ANALYSIS OF SELECTED COMBINATIONS

This section of the report provides a high level analysis of the benefits arising from co-locating selected business combinations.

3.2.1 Sawmill and Pellet Plant

The combination of a sawmill and pellet plant is a likely candidate for co-location since the shavings and sawdust produced by the sawmill can readily be used for the production of pellets. The analysis assumes plants of the same capacity as modeled in Section 3.11, the Return-to-Fiber analysis.

In BECK's most recent Western Dimension Sawmill Benchmarking Study covering Calendar Year 2013, the average f.o.b. mill value for sawdust was $18 per bone dry ton and $31 per bone dry ton for shavings. Assuming the pellet plant and sawmill were under the same ownership, the value returned to the sawdust and shavings would increase to the RTF shown under the pellet plant in Table 3.12. This would be an increase of $20 per bone dry ton for sawdust and $7 per bone dry ton for shavings. BECK estimates that a sawmill producing 70 million board feet of lumber per year will produce about 7,300 bone dry tons of sawdust and 7,600 bone dry tons of shavings annually. Thus, the development of a pellet plant would result in an increase in annual revenue from sawmill residual sales of $199,200 per year (7,300 x 20) plus (7,600 x 7).

Note, however, that the pellet plant modeled in Section 3.11 required 55,000 bone dry tons of feedstock per year. This means that an additional 40,000 bone dry tons of feedstock would be needed from other sources to supply the plant. BECK estimates that a sawmill producing 70 million board feet of lumber annually would produce about 32,000 bone dry tons of chips annually. Thus, even adding the chips to the supply for the pellet plant would not fully meet the annual raw material requirement.

Another consideration in the use of chips as pellet feedstock is that the average f.o.b. mill value of chips during the 2013 Western Dimension Sawmill Benchmarking Study was $55 per bone dry ton. Thus, assuming the sawmill could at least realize the industry average chip sales price, it would be a losing proposition for the sawmill to divert its chips to the pellet plant, since the estimated maximum price the pellet plant can afford to pay for raw material is only $38/bone dry ton. Yet another consideration is that using chips as a feedstock complicates the pellet manufacturing process since the chips need to be hammermilled to reduce them to a size appropriate for pelletizing.

Of course, another option would be to develop a pellet plant scaled to the size of the sawmill's output of sawdust and shavings. That, however, would be a significantly smaller plant with lower economy of scale, which, in turn, would lower the RTF value delivered by the plant. Analyzing the many different scenarios arising from a sawmill and pellet plant combination are beyond the scope of this study.

3.2.2 Sawmill and Cogeneration Plant

As described in the previous section, a sawmill producing 70 million board feet of lumber annually would produce an estimated 32,000 BDT of chips, 7,200 BDT of sawdust, 7,600 BDT of shavings. In addition, the sawmill would produce an estimated 11,900 BDT of bark for a total of 58,700 BDT of by-products annually. The 18 MW biomass plant modeled in Section 3.11 requires 121,000 BDT of fuel annually. Thus, the sawmill would only be capable of providing roughly half the cogeneration plant's annual supply. Additional fuel may be available from other nearby forest products conversion facilities and from logging slash.

With regard to the economics of the cogeneration plant, the analysis in Section 3.11 revealed that the estimated RTF value for an 18 MW plant is $35 per bone dry ton. Thus, the only way development of this scenario makes sense is for the sawmill to have no options for selling any of its by-products at a value greater than $35 per bone dry ton and that the average delivered value of fuel from other sources (e.g., logging slash and other mill by-products) is equal to or less than $35 per bone dry ton.

Again, a smaller cogeneration plant scaled to the output of the sawmill could be considered. A rough rule of thumb is that every megawatt of cogeneration capacity requires 8,000 bone dry tons of fuel. Thus, a sawmill of the size considered in the analysis (70 million board feet) could support (with only its own by-products as fuel) a cogeneration plant of approximately 7 MW. However, the same reduced economy of scale applies to this concept, as it requires roughly the same labor to operate a 7 MW plant as it does an 18 MW plant.

3.2.3 Shavings, Post and Pole, Firewood, and Cogeneration

Generally, a biomass CHP facility must be larger than 5 MW to be economically feasible. There are, however, exceptions for which special circumstances make smaller scale plants feasible. Examples of such circumstances include:

- Very low biomass fuel costs
- Federal, State, or Local incentives that either greatly reduce capital cost, set an above market value for renewable power, or create special tax benefits that might attract private investors

Such circumstances, however, are rare. Therefore, for this section BECK has assumed that the minimum size for a viable CHP plant is 5 MW, which translates into an annual biomass fuel requirement of roughly 40,000 bone dry tons. Given that fuel requirement, the remainder of this section provides an analysis of the amount of biomass fuel that three co-located businesses could provide to the plant and the amount of process steam they would consume.

The co-located businesses considered in the analysis include a roundwood to wood shavings plant, post and pole plant, and firewood plant all operating on the same site. As described in Section 3.11, a typical shavings plant would consume 10,200 BDT of raw material annually, a post and pole plant would consume 5,000 BDT annually, and a firewood operation 9,400 BDT annually.

For the shavings plant, between 15 to 20 percent of the incoming volume would be a combination of bark and fines (pieces too small to be used as shavings). This means there would be approximately 1,800 BDT of by-products annually that could be used as biomass fuel for a co-located 5 MW cogeneration plant. In addition, about 15 percent of the post and pole plant's raw material would be a combination of bark and peelings, which translates into about 750 bone dry tons per year of by-products that could be used as fuel. For the firewood operation, an estimated 5 to 10 percent of the volume would be a combination of downfall, trim-ends, bark, etc. Thus, approximately 700 bone dry tons of biomass would be available from the firewood operation annually.

Therefore, the combined amount of by-products available from the three operations is estimated to be about 3,250 BDT. That amount is about 8 percent (3,250/40,000) of the fuel volume that would be required annually. This means that nearly 37,000 bone dry tons of fuel would have to come from other sources in order to be able to develop a cogeneration plant of sufficient scale as to be economically viable.

3.3 DISCUSSION

In each of the three preceding scenarios, the same point was illustrated – the scale of the "anchor" facility was not closely matched to the requirements of the co-located facility. This is one of the key issues that must be evaluated early on in the consideration of any assessment of co-located businesses. Does the fiber balance among the various businesses (i.e., incoming raw material versus fiber out as finished product versus by-products versus demand from co-located businesses) all roughly equal out? If not, then material from outside sources must be available or, vice-versa – there must be other markets available for the portion of the by-products that would not be consumed by co-located businesses.

As was illustrated in the examples, each type of business has feasibility constraints related to scale. Therefore, increasing or decreasing the scale of one of the businesses to match to requirements of a co-located business is not possible. The bottom line is that great care in planning must be taken early on in such a project to assure the businesses are compatible in terms of scale.

CHAPTER 4 – APPENDIX 1

Non-sawtimber Supply Assessment for Eastern Oregon

Region 6

Prepared by:

Mason, Bruce & Girard, Inc.
9/30/2015

Prepared for:

The Beck Group
9/30/2015

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Executive Summary

This report characterizes non-sawtimber harvests from National Forests in Eastern Oregon. Our objectives were to quantify overall harvest levels, describe the composition of non-sawtimber volume in terms of size class and species, and identify differences in non-sawtimber between regular and stewardship sales. We examined several data sources—USFS presale cruise data, sale appraisals, and interviews—to assess non-sawtimber harvests from the National Forests of Eastern Oregon.

Annual harvest levels of non-sawtimber volume were 260,225 tons per year over the interval 2007-2011. We calculated overall harvest volume during the earlier interval from the USFS FACTS database. Interviews with harvest contractors suggest USFS sale cruises can underestimate non-sawtimber by more than 30%.

Non-sawtimber with small end diameter (SED) less than 6" constituted 73% to 84% of the inventory for most species. Material less than 8" SED made up 95% to 99% of the non-sawtimber fraction. Larger piece sizes of more than 8" SED contributed 5% of the total for ponderosa pine and 16% of white fir non-sawtimber.

Regular USFS timber sales generated higher non-sawtimber harvests overall from 2007-2011 than did stewardship sales, with 170,605 tons per year from regular sales versus 89,619 tons per year from stewardship sales. Stewardship sales had higher non-sawtimber harvest rates per area with 7.3 tons per acre compared to 4.5 tons per acre from regular sales. Stewardship sales accounted for 20.2% of the total harvest, but 34.4% of the non-sawtimber volume.

Interviews with Eastern Oregon harvest contractors confirmed that the value of non-sawtimber offsets handling and transport costs. Contractors reported that USFS sale cruises typically underestimate overall volume by approximately 30%, and further underestimate the proportion of the non-sawtimber relative to sawtimber by as much as 40% on some sales.

This report confirms substantial harvest of non-sawtimber volume from Eastern Oregon USFS sales, and emphasizes the need to identify higher value markets for this material.

1. BACKGROUND

The Oregon Department of Forestry (ODF) is searching for opportunities to improve markets for non-sawtimber in Eastern Oregon. Most of the timberland in Eastern Oregon is managed by the USDA Forest Service (USFS), and that agency engages in substantial forest restoration efforts.

Non-sawtimber is defined as smaller diameter logs from tree tops, small trees from pre-commercial thinning or USFS restoration treatments, and larger unsound timber not suitable for manufacture into solid wood products. Demand for smaller diameter timber that might flow from USFS forest restoration activities comes from pulp mills, energy producers, firewood, fence poles, and other lower-value uses. Where extraction costs and transportation costs exceed value, non-sawtimber may simply be burned on site.

New or alternative technologies for processing small non-sawtimber require an annual volume supply ranging from a few hundred tons for a firewood manufacturer to as much as 700,000 tons for a new OSB mill. The feasibility of non-sawtimber processing in Eastern Oregon will depend on the availability and characteristics of the raw material.

2. OBJECTIVES

This report is a companion to a larger study that reviews the opportunities for different types of facilities that could utilize small wood in Eastern Oregon. The purpose of this report is to:

- Describe the nature of the material sold as non-sawtimber by the USFS in terms of species composition and size class distribution.
- Determine how much non-sawtimber is harvested from the USFS timber sale program.
- Characterize the differences between regular USFS timber sales and the stewardship contracts with respect to the fraction of non-sawtimber volume.

3. METHODS

We relied on a number of different data sets for this report. In this section we describe the information available. In the following section we focus on the results of our investigation.

3.1. Region

The study area encompasses USFS Region 6 national forests in Eastern Oregon: Deschutes, Fremont-Winema, Malheur, Ochoco, Rogue-Siskiyou, Umatilla, and Wallowa-Whitman (Figure 1). The Rogue-Siskiyou NF was included in an effort to maintain consistency with a previous study about USFS forest restoration in Eastern Oregon (1). We acquired data at the sale level from the Ochoco (Paulina and Lookout Mountain districts), Umatilla (Pomeroy, Heppner, and Walla Walla districts), and Wallowa-Whitman (La Grande district) National Forests (Figure 2).

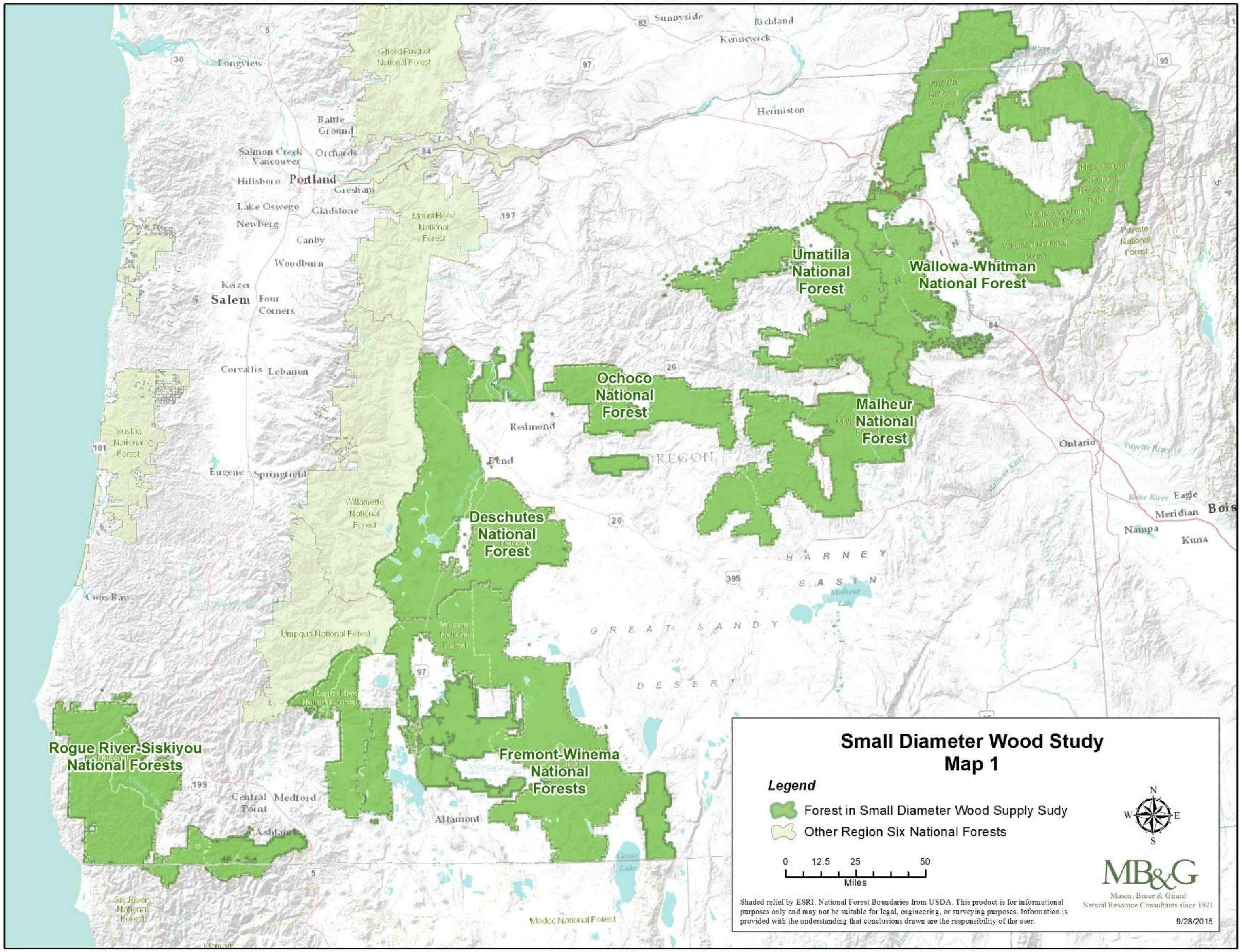

Figure 1. The study area includes seven national forests in USFS Region 6.

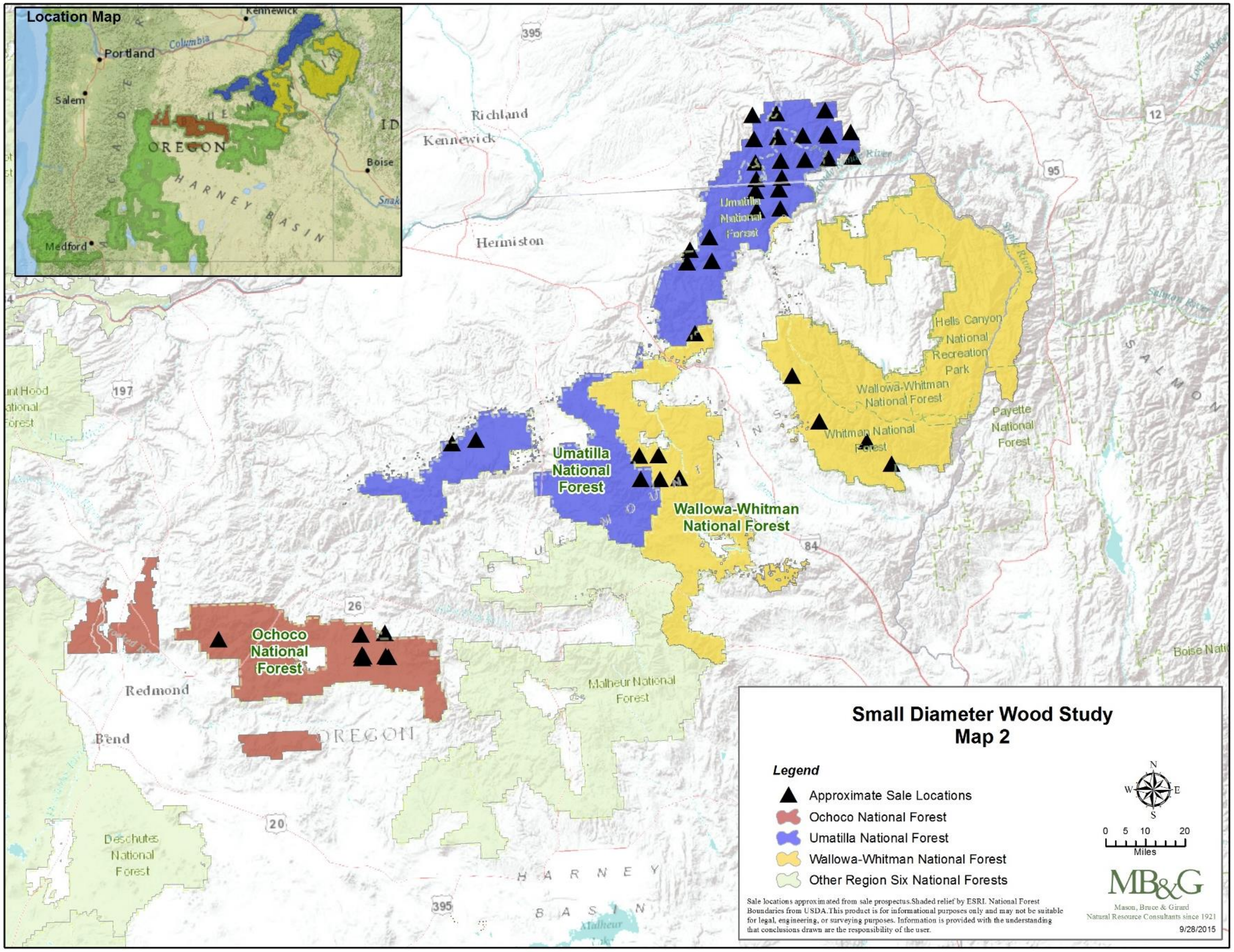

Figure 2. Individual sales in Ochoco, Umatilla, and Wallowa-Whitman national forests. Sales in Washington were excluded from detailed analysis.

3.2. Sale summary

To better understand the composition of non-sawtimber volume, we obtained detailed data for 18 timber sales – six each from the Ochoco, Umatilla and Wallowa-Whitman National Forests. Specifically, we reviewed the pre-sale cruise, sale prospectus, timber sale appraisal and bid results (Form 2400-17), and sale volume summary for individual harvest units (Appendix A).

The pre-sale cruise data were not consistent between forests. The Ochoco NF cruise summary provided the most detail; from that we extracted log diameter distributions (see §3.3). For all three forests, we summarized sale parameters including area, sawtimber at the species level, aggregated non-sawtimber, and non-sawtimber to sawtimber ratios (Table 1, Appendix A).

Table 1. Timber sale area, volume, and volume per area for six sales (four regular, two stewardship) each at the Ochoco, Umatilla, and Wallowa-Whitman National Forests.

Forest	Sale area (ac)			Volume			Volume / acre	
	Total	Regular	Steward	Saw (Mbf)	Nonsaw (ton)	ton:Mbf	Saw (Mbf)	Nonsaw (ton)
Ochoco	5,900	4,930	970	21,224	17,860	0.84	3.60	3.03
Umatilla	5,083	1,664	3,419	33,961	101,262	2.98	6.68	19.92
Wall.-Whit.	7,275	1,462	5,813	48,652	86,051	1.77	6.69	11.83

3.3. Diameter distribution

We summarized sawtimber and non-sawtimber volume by sale, and where possible by species. Log diameter class data were readily extracted from a subset of the sales from the Ochoco NF; we summarized diameter distributions by species for this set of sales. Conversion factors between CCF and tons were unavailable for some sales, so we opted to present sawtimber and non-sawtimber volume on a CCF scale by species for each sale.

3.4. Non-sawtimber harvest levels

Harvest levels for non-sawtimber derived from the Forest Service ACtivity Tracking System (FACTS) and Timber Information Manager (TIM) application (Ref. 7), and from interviews conducted with harvest contractors and timber processors in Region 6. Sales spanned contract periods across a four-year interval between 2007 and 2011. Forests in this region include the Deschutes, Fremont Winema, Malheur, Ochoco, Umatilla, Wallowa-Whitman, and Rogue-Siskiyou NFs. In total, the data represent timber sales on 200,257 acres, of which regular sales covered 151,230 acres and stewardship sales 48,027 acres. We calculated total volume of sawtimber (Mbf), poles (Mbf), non-sawtimber (tons), and fuelwood (cords) for each forest, also presenting value, volume per acre, value per acre, and value per volume unit. Separately, we present this set of values on an average annual basis (Appendix B).

3.5. Harvest contractor and processor interviews

MB&G interviewed harvest contractors and timber processors affiliated with the 18 timber sales for which we obtained pre-sale cruise data, and called the USFS timber contract administrators at the district level. We asked each entity a standard set of questions, allowing for impromptu additions when more information was offered:

Contractors or processors:

1. Were your non-sawtimber harvest volumes for these sales (or others that you might wish to share) equivalent to the USFS pre-sale cruise, and to the sale appraisal?
2. Did you remove biomass from the harvest site, and if so, what products were merchandized from that volume?
3. Do you have any records related to diameter class distributions by product or species?
4. Do you have records related to product types or merchandizing for biomass material?

Contract administrators:

1. Did contractor reports indicate that removed volumes were comparable to the pre-sale cruise, or whether there was independent variability in over- or under-run?
2. Did contractors indicate in written or spoken communication, or via volume reports, the end uses of any non-sawtimber volume?

We received responses to these questions from several contractors and processors. Contract administrators from USFS offices have not yet responded to our inquiries.

3.6. Conventions and conversions

Henceforth, abbreviations DF indicate Douglas-fir, LP lodgepole pine, PP ponderosa pine, WF white fir, and WL Western larch. MB&G received sale volumes in units of Mbf for the three national forests, but we received a full set of unit conversion factors at the sale level only for the Ochoco NF. Where available, we converted from units of Mbf to units of tons using factors specified for each sale. For Umatilla and Wallowa-Whitman sales for which we had no conversion factors, we calculated non-sawtimber tonnage using the acreage-weighted average of sale level conversion factors. To convert between Mbf and CCF we multiplied by 2.05; we multiplied CCF units by 3.084 to convert between CCF and tons. For the Umatilla and Wallowa-Whitman forests, we typically had conversion factors to translate between Mbf and CCF, which we applied at the sale level. Conversion factors were usually unavailable between CCF and tons, so for USFS FACTS data, we applied a composite conversion factor of 2.19 tons/CCF, reflecting the species level specific gravity for green wood (Ref. 8) weighted by the species composition of sales at the Ochoco, Umatilla, and Wallowa-Whitman forests.

4. RESULTS

In this section, we explain our findings relative to the three main study objectives.

4.1. What is the diameter distribution of the volume sold as non-sawtimber?

For the three forests that provided detailed data on 18 sales, the non-sawtimber volume is defined as: (a) the portion of the log between the 6" merchantable sawtimber top and a 3" or 4" top; and (b) un-merchantable cull logs with no small end diameter limit. Only the Ochoco NF provided cruise data appropriate for creating a more detailed picture of the diameter distribution of non-sawtimber logs.

Figure 3. Distributions of small end diameter for saw (grey) and non-sawtimber (blue) volume at the species level for the Hulk, Jack, and LSP sales in the Ochoco National Forest.

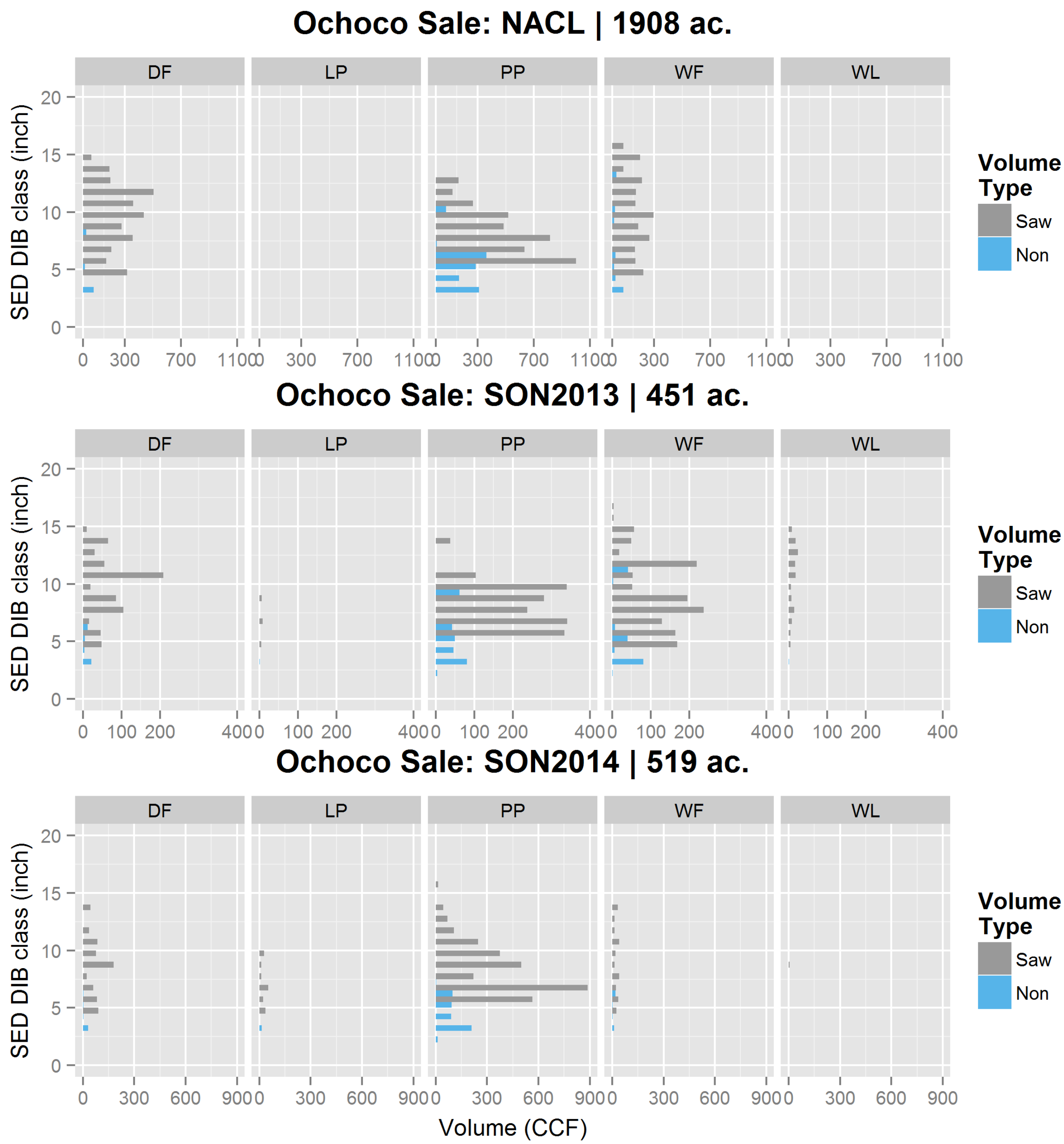

Figure 4. Distributions of small end diameter for saw (grey) and nonsaw (blue) volume at the species level for the NaCl sale (regular), and two stewardship sales, GA Son 2013 and GA Son 2014.

Presale cruise data from all three forests indicated that non-sawtimber volume came from logs between a 3” and 4” top and a merchantable top of 6”. On the six Ochoco sales, we received more detailed data from the presale cruise, which confirmed that the non-sawtimber volume was concentrated in diameter classes less than 6” small end diameter (SED), as shown in Figure 3 and Figure 4. Approximately 75% of the volume identified as non-sawtimber was in logs less than 6” SED and nearly all was in logs less than 8” SED. The exception was WF where logs greater than 8” SED accounted for 15.8% of the volume. We find this consistent with the observation that larger WF logs carry more defect than other species. The diameter distribution for all species as a weighted average of volume shows a shift toward more volume in >8” SED classes due to the higher net volume of WF and PP in these classes.

Table 2. Non-sawtimber diameter distributions by species for volume per acre and percent of non-sawtimber harvest. Data aggregated across sales at the Ochoco National Forest. The average of non-sawtimber percent volume across species (Wt. Avg.) is weighted by volume (CCF/acre) within the diameter class.

SED DIB	CCF / acre					% of non-sawtimber					
(")	DF	LP	PP	WF	WL	DF	LP	PP	WF	WL	Wt. Avg.
2	0.0006	0.0000	0.0053	0.0018	0.0003	0.5%	0.0%	0.8%	0.7%	2.1%	0.75%
3	0.0684	0.0254	0.2158	0.1212	0.0064	62.5%	56.4%	34.0%	48.0%	38.1%	41.3%
4	0.0059	0.0056	0.0950	0.0148	0.0055	5.4%	12.4%	15.0%	5.9%	32.3%	12.0%
5	0.0174	0.0045	0.1721	0.0483	0.0003	15.9%	10.1%	27.1%	19.1%	1.7%	22.9%
6	0.0142	0.0090	0.0988	0.0264	0.0042	13.0%	20.0%	15.6%	10.5%	24.9%	14.4%
7	0.0010	0.0000	0.0158	0.0000	0.0001	0.9%	0.0%	2.5%	0.0%	0.4%	1.59%
8	0.0020	0.0005	0.0000	0.0010	0.0000	1.8%	1.1%	0.0%	0.4%	0.0%	0.33%
9	0.0000	0.0000	0.0235	0.0021	0.0001	0.0%	0.0%	3.7%	0.8%	0.5%	2.43%
10	0.0000	0.0000	0.0065	0.0040	0.0000	0.0%	0.0%	1.0%	1.6%	0.0%	0.99%
11	0.0000	0.0000	0.0013	0.0171	0.0000	0.0%	0.0%	0.2%	6.8%	0.0%	1.74%
12	0.0000	0.0000	0.0000	0.0076	0.0000	0.0%	0.0%	0.0%	3.0%	0.0%	0.72%
13	0.0000	0.0000	0.0000	0.0027	0.0000	0.0%	0.0%	0.0%	1.1%	0.0%	0.25%
14	0.0000	0.0000	0.0000	0.0020	0.0000	0.0%	0.0%	0.0%	0.8%	0.0%	0.19%
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16	0.0000	0.0000	0.0000	0.0034	0.0000	0.0%	0.0%	0.0%	1.4%	0.0%	0.33%
<6	**0.0922**	**0.0356**	**0.4881**	**0.1860**	**0.0125**	**84.3%**	**78.9%**	**77.0%**	**73.7%**	**74.1%**	**77.0%**
<8	**0.1074**	**0.0446**	**0.6027**	**0.2125**	**0.0168**	**98.2%**	**98.9%**	**95.1%**	**84.2%**	**99.5%**	**93.0%**
>8	**0.0020**	**0.0005**	**0.0312**	**0.0399**	**0.0001**	**1.8%**	**1.1%**	**4.9%**	**15.8%**	**0.5%**	**7.0%**

4.2. Non-sawtimber harvest levels

1.4.2 How much non-sawtimber is harvested annually?

Non-sawtimber harvests from national forests in Eastern Oregon amounted to 260,225 tons per year, with 89,619 tons from stewardship sales and 170,605 tons from regular sales between 2007 and 2011. Harvests of non-sawtimber volume per area were lower from regular sales (4.5 tons/acre), or 21% of the regular total, than from stewardship sales (7.3 tons/acre), or 35% of the stewardship sale total (Table 3).

From the Forest Service ACtivity Tracking System (FACTS) and Timber Information Manager (TIM) application, we calculated total harvest of all timber fractions between 2007 and 2011. Some USFS timber sales are sold "lump-sum" meaning that they are not scaled. In that case, differences between the volume sold and the volume actually harvested and removed are not accounted for in this database. Note that our interviews suggest that non-sawtimber volume is often underestimated in the USFS cruise. Table 3 shows the cumulative harvest between 2007 and 2011 converted into tons for each product type and sale type. Variations are shown in Appendix C. Non-sawtimber harvest totaled 170,605 tons per year from regular sales and 89,619 tons per year from stewardship sales. Overall non-sawtimber harvest rate was 5.2 tons/acre.

Table 3. Harvest converted to standard units of tons for all product classes from Eastern Oregon Region 6 National Forest land during the period between 2007 and 2011. Volume of sawtimber and poles (originally Mbf) were converted to non-sawtimber equivalent units (tons), by a multiplication of Mbf * 2.05 to get to yield CCF, then a multiplication of CCF * 2.1935 to get yield tons. This conversion factor was calculated from species-level specific gravity data (Ref. 8), and is substantially lower than the USFS ton/CCF values, typically greater than 3. We cannot consider implications of USFS conversion disparities without additional data. For fuelwood, originally in cords, equivalent units of tons calculated by multiplying Cords * 2.675 (tons/Cord) to arrive at units of tons (Ref. 9).

Forest	Fraction	Units	Volume	Volume/ Year	Value	Volume/ Acre	Value/ Acre	Value/ Volume
Regular	Sawtimber	Tons	2,626,752	656,688	$39,815,144	17.37	$263.28	$15.16
	Poles		184	46	$1,337	0.00	$0.01	$7.26
	Non-Saw		**682,422**	**170,605**	**$236,935**	**4.51**	**$1.57**	**$0.35**
	Fuelwood		3,069	767	$20,501	0.02	$0.14	$6.68
	Subtotal:		3,312,428	828,107	$40,073,917	21.90	$264.99	$12.10
Stewardship	Sawtimber	Tons	480,479	120,120	$7,983,765	9.80	$162.84	$16.62
	Poles		0	0	$0	0.00	$0.00	$0.00
	Non-Saw		**358,477**	**89,619**	**$11,158,198**	**7.31**	**$227.59**	**$31.13**
	Fuelwood		80	20	$300	0.00	$0.01	$3.74
	Subtotal:		839,036	209,759	$19,142,262	17.11	$390.44	$22.81
Combined	Sawtimber	Tons	3,107,232	776,808	$47,798,909	15.52	$238.69	$15.38
	Poles		184	46	$1,337	0.00	$0.01	$7.26
	Non-Saw		**1,040,899**	**260,225**	**$11,395,132**	**5.20**	**$56.90**	**$10.95**
	Fuelwood		3,150	787	$20,801	0.02	$0.10	$6.60
	Total:		4,151,464	1,037,866	$59,216,179	20.73	$295.70	$14.26

2.4.2 What is the species composition on non-sawtimber?

Species composition of sawtimber averaged 25% DF, 6% LP, 21% PP, 46% WF, and 2% WL (Table 4) across 18 representative timber sales from three National Forests. Non-sawtimber species composition should reflect that of sawtimber.

Based on our review of the 18 sales, we found that the non-sawtimber advertised for sale consists primarily of the topwood from trees that produce sawtimber volume. Consequently, non-sawtimber should be similar in species composition to sawtimber. There are exceptions, particularly for PP and WF. In sales at Ochoco NF, we found some amount of non-sawtimber volume contributed by larger trees, perhaps due to slashing and or cull trees (§4.1, Table 2). Assuming that this is the general case, we would expect PP and WF to be over-represented in the non-sawtimber fraction of a larger population of sales.

Table 4. Harvest levels from individual sales at Ochoco, Umatilla, and WW, including species composition, volume, and percentage by species. Species composition data were unavailable for two sales. Sawtimber tonnage converted from CCF using USFS conversion factors for each sale or forest. Note that these conversion factors are typically greater than 3 tons / CCF. *This higher conversion factor does not affect estimates of percentage species composition, but sawtimber tons should be interpreted with caution.*

Forest	Sale		DF*		LP†		PP‡		WF		WL		Saw	Nonsaw	Total
	Contract	Type	Ton	%	Ton	%	Ton	%	Ton	%	Ton	%			
OCH	66230	Reg	3,171	20%	0	0%	11,950	75%	733	5%	0	0%	15,854	2,289	18,144
	66131	Reg	9,197	23%	3,833	10%	1,851	5%	22,695	58%	1,565	4%	39,140	4,643	43,783
	66115	Reg	6,991	28%	1,422	6%	2,699	11%	13,456	54%	392	2%	24,959	2,879	27,838
	66214	Reg	9,522	33%	1	0%	12,385	43%	6,787	24%	2	0%	28,696	4,687	33,383
	66164	Stw	2,168	18%	63	1%	5,253	43%	4,246	35%	417	3%	12,147	1,593	13,740
	66255	Stw	2,209	17%	494	4%	9,213	72%	855	7%	24	0%	12,795	1,769	14,321
UMA	71306	Stw	0	---	0.0	---	0	---	0	---	0.0	---	0	6,975	6,975
	71322	Stw	154	7%	33.7	2%	0	0%	1,531	74%	349.5	17%	2,068	11,307	13,375
	71272	Reg	8,709	23%	0.0	0%	0	0%	28,883	77%	0.0	0%	37,592	6,196	43,788
	71355	Reg	15,940	41%	0.0	0%	0	0%	23,046	59%	0.0	0%	38,986	35,503	74,489
	71256	Reg	6,567	13%	0.0	0%	0	0%	44,337	87%	0.0	0%	50,904	35,669	86,572
	71397	Reg	10,823	15%	0.0	0%	9,233	13%	50,040	71%	0.0	0%	70,096	5,613	75,709
WW	331088	Stw	2,039	8%	6,417	25%	609	2%	16,529	65%	0	0%	25,594	32,349	57,943
	331070	Reg	43,045	49%	0	0%	21,752	25%	23,054	26%	0	0%	87,852	670	88,522
	330916	Stw	3,402	33%	5,779	57%	0	0%	977	10%	0	0%	10,158	14,823	24,981
	331195	Reg	0	---	0	---	0	---	0	---	0	---	---	---	35,113
	331120	Reg	16,113	15%	0	0%	14,841	14%	78,394	72%	0	0%	109,348	1,683	111,031
	331179	Reg	32,079	57%	0	0%	17,538	31%	6,727	12%	0	0%	56,344	1,413	57,757
Ac. Weighted Avg:			**12,785**	**25%**	**887**	**6%**	**7,697**	**21%**	**21,344**	**46%**	**169**	**2%**	**42,882**	**8,483**	**53,124**

* Includes < 4% AF | † Includes < 7% ES | ‡ Includes < 8% PC

4.3. How to stewardship and regular sales differ?

Stewardship sales cover fewer acres and have lower per-acre harvest levels (see §1.4.2). Non-sawtimber makes up 35% of stewardship sale volume, but only 16% of regular sales. From regular sales, non-sawtimber accounted for 0.6% of the overall value, compared to 58.3% from stewardship sales (Table 3). From a small sample of 18 sales, the proportion of non-sawtimber harvest volume was highly variable on stewardship sales, and more consistent on regular sales (Table 5). The overall percent of non-sawtimber volume was also higher on stewardship sales. Note that these comparisons are made on the basis of USFS conversion factors, see **Table 4**.

Table 5. Relative proportions of volume as fraction of total harvest on a per ton basis.

Forest	Nonsaw proportion		Saw proportion	
	Regular	Steward	Regular	Steward
Ochoco	11.9%	12.0%	88.1%	88.9%
Umatilla	27.6%	92.3%	72.4%	7.7%
Wall.-Whit.	1.6%	57.6%	98.4%	42.4%

Table 3 shows a substantial difference in non-sawtimber value between regular and stewardship sales. These values represent averages over a wide geographic area and several years, so some of the difference is due to variability in markets for non-sawtimber, sale location and sale composition. Also at play, however, are internal USFS appraisal procedures that must adjust initial appraised rates to ensure that each sale component returns a positive net value to the Treasury. For example, if the non-sawtimber component is appraised with a negative value, then positive values from sawtimber are reallocated to bring all components above zero value. This occurs more often on regular sales where the non-sawtimber tends to be more incidental to the sawtimber objectives. In these cases, non-sawtimber logging costs are higher because per acre volumes are lower, causing a larger disparity between sawtimber and non-sawtimber value.

On the basis of overall harvest (tons), regular sales exceeded stewardship sales by more than five-fold for sawtimber, but only two-fold for non-sawtimber (Figure 5). Considered in terms of harvest volume per acre, stewardship sales had more non-sawtimber volume and a relative increase in sawtimber (Figure 5).

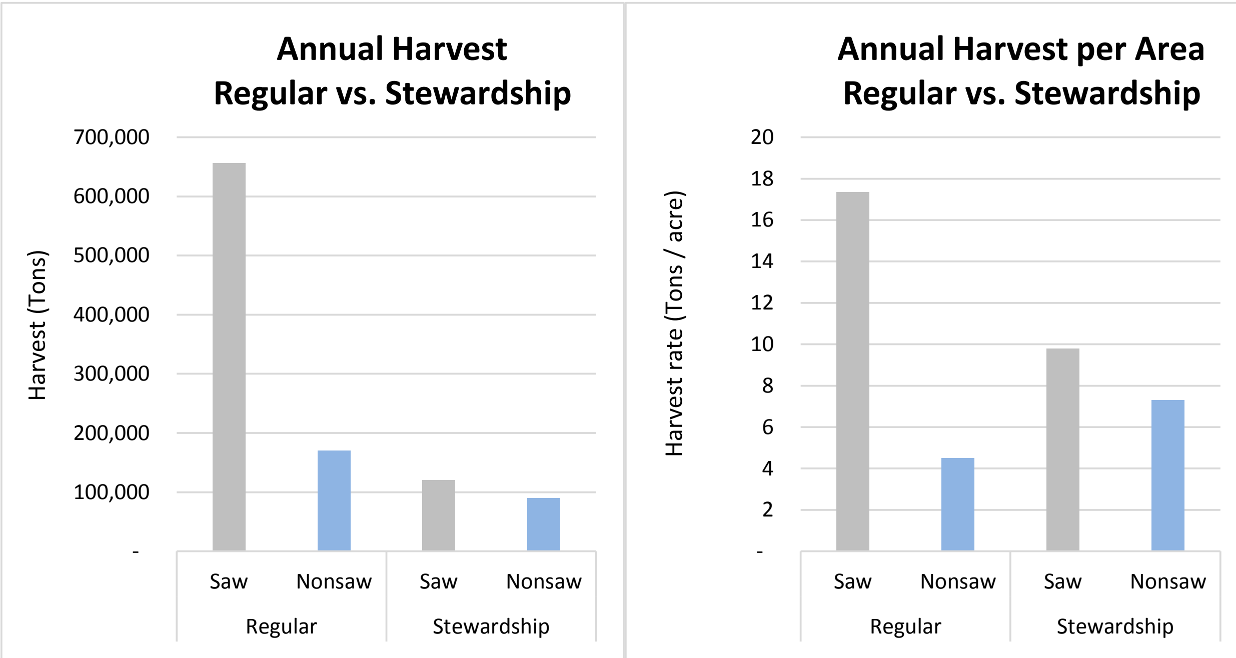

Figure 5. Regular versus stewardship sawtimber and non-sawtimber volume and harvest rate.

5. HARVEST CONTRACTOR INTERVIEWS

We reached out to timber harvest contractors and timber processing groups involved with the 18 individual timber sales from the Ochoco, Umatilla, and Wallowa-Whitman NFs for which we had detailed cruise data (§3.2). Two logging contractors declined to respond, three were unavailable via any contact method, one responded in full, and three contractors agreed to respond but did not. Four timber processing groups were contacted, and all agreed to supply some amount of information regarding the composition and use of non-sawtimber volume.

Responses by contractors are best summarized in text format, as their contributions departed from our standard question set (§3.5). The timber sale purchaser that responded to our interview request has worked in the Ochoco and Umatilla National Forests, including both stewardship and regular sales. From both sale types, they cite a 100% non-sawtimber removal rate with SED for non-sawtimber between 3" to 8" and negligible volume from larger diameter classes. On typical sales, their harvest subcontractors report at least a 20% classification error in USFS cruise data, underestimating non-sawtimber volume and overestimating sawtimber.

Two timber processors either do not keep any records of non-sawtimber volume at the sale level, or do not do so consistently and could therefore not respond to questions about the nature of this material. In both cases, these processors milled strictly saw timber and relied on logging subcontractors to deal with non-sawtimber material in any way possible. One processor confirmed that some logging contractors burned non-sawtimber material on site, while other contractors removed non-sawtimber for chip markets, when these were favorable.

The other two processors who responded to our inquiry milled a combination of sawtimber and non-sawtimber material, producing lumber, chips, and lower-value products. One of these processors cited a consistent 30% overrun on USFS pre-sale cruise data for sawtimber, and indicated a similar impression for non-sawtimber volume, although suggested that on some sales the non-sawtimber fraction could be underestimated in the presale cruise to a substantially higher degree. The other processor corroborated the 30% overrun on sawtimber, but suggested a wider range of 30% to 50% overrun on non-sawtimber volume. The wide range of underestimates for non-timber volume applied in particular to stewardship sales. As an example, this processor cited a sale in which approximately 29 MMbf non-sawtimber material was removed from an area with a pre-sale cruise volume of 18 MMbf—an overrun of 37.9%.

None of the processors or contractors indicated that they routinely scale or otherwise track the diameter distributions of non-sawtimber volume, although one processor suggested that the USFS cruise data accurately captured the range of diameters, though not the total volume. All four processors confirmed that the value of non-sawtimber typically equaled its removal cost, so that the benefit in removing this timber was principally to achieve a higher standard of forest management rather than to gain value from the market.

6. IMPLICATIONS

Our study calculates supplies of non-sawtimber harvested in Eastern Oregon between 2007 and 2011, and characterizes the composition of this material from sales between 2012 and 2014. To draw some general conclusions, we make the assumptions that past harvest rates continue, and in **Table 6**, we combine the annual harvest data with diameter class distributions drawn from our sample of 18 sales—admittedly a low sample size. **Table 6** shows that we expect about 199,618 tons per year of non-sawtimber with SED less than 6”. Most of the non-sawtimber volume (234,530 tons per year) includes log sizes of SED less than 8”; a small fraction (25,695 tons per year) comprises larger log sizes. Although we presented an assessment of species composition for three national forests, we hesitate to extrapolate those conclusions across all of the forests in Region 6 due to significant differences in species mix across the Eastside national forests.

Table 6. Diameter distribution and species composition applied to 2007-2011 harvest of non-sawtimber volume.

Sale type	Size class	Tons / year 2007-2011
All	SED < 6"	199,618
	SED < 8"	234,530
	SED > 8"	25,695
	Total:	260,225
Regular	SED < 6"	130,871
	SED < 8"	153,760
	SED > 8"	16,846
	Total:	170,605
Stewardship	SED < 6"	68,747
	SED < 8"	80,770
	SED > 8"	8,849
	Total:	89,619

Table 6 may understate the amount of sawtimber available. Our contractor interviews suggest that actual harvest might be 30% above the advertised sold volume on USFS timber sales. If this figure is correct, actual non-sawtimber harvests could be closer to 338,000 tons per year. In conclusion, this study confirms significant non-sawtimber harvest from national forests in Eastern Oregon, suggesting an opportunity for higher value markets for this material.

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8. APPENDIX

8.1. Appendix A: Background data on 18 sample sales

Detailed pre-sale cruise data, including sold volume classified by sawtimber and non-sawtimber, as well as species composition, were available from 18 sales in three national forests (Table 7). These sales were selected by a combination of acreage and sold volume. Overall, stewardship sales were 15% of the number of total sales, but one of our objectives was to characterized volume from stewardship sales in particular, so they are overrepresented in the present dataset. Total harvests have not yielded all of the sold volume in this time interval, but these figures are through 12/31/2014, and the interval extends through 2016 (**Table 7**).

Table 7. Sales with 2400-17 forms and presale cruise data.

Forest	Sale	Contract	Bid	Term	Area (ac.)
Ochoco	LSP SBA	66115	9/17/2012	3/31/2016	923
	Jask SBA	66131	8/12/2013	3/31/2017	1,452
	GA Son 2013	66164	9/19/2013	12/31/2017	451
	NaCl	66214	4/28/2014	3/31/2018	1,908
	Hulk	66230	7/28/2014	3/31/2018	647
	GA Son 2014	66255	9/24/2014	12/31/2017	519
				Subtotal:	**5,900**
Umatilla	Southpark	71256	12/4/2012	3/31/2018	923
	Howler	71272	3/5/2013	3/31/2017	691
	2013 POM Bio STW	71306	8/26/2013	3/31/2015	1,000
	CRSC Eastalder STW	71322	9/17/2013	3/31/2017	664
	Northpark	71355	4/1/2014	3/31/2019	1,008
	Tofu	71397	7/8/2014	3/31/2018	797
				Subtotal:	**5,083**
Wallowa-Whitman	Peep STW	330916	9/15/2011	10/31/2014	702
	Empire	331070	7/18/2013	3/31/2017	2,038
	Cove II STW	331088	8/15/2013	10/31/2016	760
	Skull	331120	9/26/2013	3/31/2018	1,713
	Trail	331179	6/19/2014	10/31/2017	1,060
	Sandbox	331195	9/18/2014	11/30/2017	914
				Subtotal:	**7,187**

Table 8. Volume sold by species and product class (saw versus nonsaw) for individual timber sales contracts, 2007 – 2014, at the Ochoco National Forest.

Sale	DF	LP	PP	WF	WL	Saw	Nonsaw	Total
CCF								
Hulk	1,028	0	3,875	238	0	5,141	742	5,883
Jack SBA	2,982	1,243	600	7,358	507	12,691	1,505	14,196
LSP SBA	2,267	461	875	4,363	127	8,093	933	9,026
NaCl	3,087	0	4,016	2,200	1	9,304	1,520	10,824
GA Son 2013	691	20	1,674	1,353	133	3,871	514	4,385
GA Son 2014	729	163	3,040	282	8	4,222	552	4,774
Mbf								
Hulk	512	0	1,904	114	0	2,530	459	2,988
Jack SBA	1,492	628	287	3,581	254	6,242	694	6,936
LSP SBA	1,127	233	423	2,195	64	4,042	504	4,547
NaCl	1,503	0	1,901	1,075	0	4,479	709	5,187
GA Son 2013	345	10	802	650	67	1,873	238	2,111
GA Son 2014	361	80	1,474	139	4	2,058	249	2,307
Ton								
Hulk	3,171	0	11,950	733	0	15,854	2,289	18,144
Jack SBA	9,197	3,833	1,851	22,695	1,565	39,140	4,643	43,783
LSP SBA	6,991	1,422	2,699	13,456	392	24,959	2,879	27,838
NaCl	9,522	1	12,385	6,787	2	28,696	4,687	33,383
GA Son 2013	2,168	63	5,253	4,246	417	12,147	1,593	13,740
GA Son 2014	2,209	494	9,213	855	24	12,795	1,769	14,321

Table 9. Volume sold by species and product class (saw versus nonsaw) for individual timber sales contracts, 2007 – 2014, at the Umatilla National Forest.

Sale	DF	LP	PP	WF	WL	Saw	Nonsaw	Total
				CCF				
Bio Stwd.	0	0.0	0	0	0.0	0	2,235	2,235
CRSC Stwd.	49	10.8	0	491	112.2	664	3,629	4,293
Howler	2,793	0.0	0	9,263	0.0	12,056	1,987	14,043
North Park	5,112	0.0	0	7,391	0.0	12,503	11,386	23,889
South Park	2,106	0.0	0	14,219	0.0	16,325	11,439	27,764
Tofu	3,471	0.0	2,961	16,048	0.0	22,480	1,800	24,280
				Mbf				
Bio Stwd.	0	0.0	0	0	0.0	0	1,163	1,163
CRSC Stwd.	25	5.4	0	246	56.1	332	1,815	2,146
Howler	1,474	0.0	0	4,953	0.0	6,427	1,016	7,443
North Park	2,634	0.0	0	3,708	0.0	6,342	5,821	12,163
South Park	1,099	0.0	0	7,457	0.0	8,556	5,765	14,321
Tofu	1,890	0.0	1,521	8,893	0.0	12,304	910	13,214
				Ton				
Bio Stwd.	0	0.0	0	0	0.0	0	6,975	6,975
CRSC Stwd.	154	33.7	0	1,531	349.5	2,068	11,307	13,375
Howler	8,709	0.0	0	28,883	0.0	37,592	6,196	43,788
North Park	15,940	0.0	0	23,046	0.0	38,986	35,503	74,489
South Park	6,567	0.0	0	44,337	0.0	50,904	35,669	86,572
Tofu	10,823	0.0	9,233	50,040	0.0	70,096	5,613	75,709

Table 10. Volume sold by species and product class (saw versus nonsaw) for individual timber sales contracts, 2007 – 2014, at the Wallowa-Whitman National Forest.

Sale	AF	DF	ES	LP	PC	PP	WF	Saw	Nonsaw	Total
CCF										
Cove	26	632	151	1,918	0	196	5,330	8,253	10,431	18,685
Empire	0	13,881	0	0	0	7,014	7,434	28,329	216	28,545
Peep	0	1,097	0	1,864	0	0	315	3,276	4,780	8,056
Sandbox	0	0	0	0	0	0	0	0	0	11,323
Skull	0	5,196	0	0	0	4,786	25,279	35,261	543	35,804
Trail	0	10,344	0	0	434	5,222	2,169	18,169	456	18,625
Mbf										
Cove	12.9	316	75.6	960.8	0.0	98	2,670	4,134	5,226	9,360
Empire	0.0	7,168	0.0	0.0	0.0	3,581	3,830	14,579	111	14,690
Peep	0.0	585	0.0	958.2	0.0	0	168	1,711	2,503	4,214
Sandbox	0.0	0	0.0	0.0	0.0	0	0	0	0	5,848
Skull	0.0	2,700	0.0	0.0	0.0	2,453	13,820	18,973	287	19,260
Trail	0.0	5,296	0.0	0.0	218.1	2,669	1,071	9,255	233	9,488
Ton										
Cove	80	1,959	468	5,949	0	609	16,529	25,594	32,349	57,943
Empire	0	43,045	0	0	0	21,752	23,054	87,852	670	88,522
Peep	0	3,402	0	5,779	0	0	977	10,158	14,823	24,981
Sandbox	0	0	0	0	0	0	0	0	0	35,113
Skull	0	16,113	0	0	0	14,841	78,394	109,348	1,683	111,031
Trail	0	32,079	0	0	1,345	16,193	6,727	56,344	1,413	57,757

Table 11. Volume sold per acre by species and product class at the Ochoco National Forest.

Sale	DF	LP	PP	WF	WL	Saw	Nonsaw	Total
CCF / ac								
Hulk	1.6	0.0	6.0	0.4	0.0	7.9	1.1	9.1
Jack SBA	2.1	0.9	0.4	5.1	0.3	8.7	1.0	9.8
LSP SBA	2.5	0.5	0.9	4.7	0.1	8.8	1.0	9.8
NaCl	1.6	0.0	2.1	1.2	0.0	4.9	0.8	5.7
GA Son 2013	1.5	0.0	3.7	3.0	0.3	8.6	1.1	9.7
GA Son 2014	1.4	0.3	5.9	0.5	0.0	8.1	1.1	9.2
Ac. Wt. Avg.	1.8	0.3	2.4	2.7	0.1	7.3	1.0	8.3
Mbf / ac								
Hulk	0.8	0.0	2.9	0.2	0.0	3.9	0.7	4.6
Jack SBA	1.0	0.4	0.2	2.5	0.2	4.3	0.5	4.8
LSP SBA	1.2	0.3	0.5	2.4	0.1	4.4	0.5	4.9
NaCl	0.8	0.0	1.0	0.6	0.0	2.3	0.4	2.7
GA Son 2013	0.8	0.0	1.8	1.4	0.1	4.2	0.5	4.7
GA Son 2014	0.7	0.2	2.8	0.3	0.0	4.0	0.5	4.4
Ac. Wt. Avg.	0.9	0.2	1.2	1.3	0.1	3.6	0.5	4.1
Ton / ac								
Hulk	4.9	0.0	18.5	1.1	0.0	24.5	3.5	28.0
Jack SBA	6.3	2.6	1.3	15.6	1.1	27.0	3.2	30.2
LSP SBA	7.6	1.5	2.9	14.6	0.4	27.0	3.1	30.2
NaCl	5.0	0.0	6.5	3.6	0.0	15.0	2.5	17.5
GA Son 2013	4.8	0.1	11.6	9.4	0.9	26.9	3.5	30.5
GA Son 2014	4.3	1.0	17.8	1.6	0.0	24.7	3.4	27.6
Ac. Wt. Avg.	5.6	1.0	7.3	8.3	0.4	22.6	3.0	25.6

Table 12. Volume sold per acre by species and product class at the Umatilla National Forest.

Sale	DF	LP	PP	WF	WL	Saw	Nonsaw	Total
CCF / ac								
Bio Stwd.	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2
CRSC Stwd.	0.1	0.0	0.0	0.7	0.2	1.0	5.5	6.5
Howler	4.0	0.0	0.0	13.4	0.0	17.4	2.9	20.3
North Park	5.1	0.0	0.0	7.3	0.0	12.4	11.3	23.7
South Park	2.3	0.0	0.0	15.4	0.0	17.7	12.4	30.1
Tofu	4.4	0.0	3.7	20.1	0.0	28.2	2.3	30.5
Ac. Wt. Avg.	2.7	0.0	0.6	9.3	0.0	12.6	6.4	19.0
Mbf / ac								
Bio Stwd.	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2
CRSC Stwd.	0.0	0.0	0.0	0.4	0.1	0.5	2.7	3.2
Howler	2.1	0.0	0.0	7.2	0.0	9.3	1.5	10.8
North Park	2.6	0.0	0.0	3.7	0.0	6.3	5.8	12.1
South Park	1.2	0.0	0.0	8.1	0.0	9.3	6.2	15.5
Tofu	2.4	0.0	1.9	11.2	0.0	15.4	1.1	16.6
Ac. Wt. Avg.	1.4	0.0	0.3	5.0	0.0	6.7	3.2	9.9
Ton / ac								
Bio Stwd.	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0
CRSC Stwd.	0.2	0.1	0.0	2.3	0.5	3.1	17.0	20.1
Howler	12.6	0.0	0.0	41.8	0.0	54.4	9.0	63.4
North Park	15.8	0.0	0.0	22.9	0.0	38.7	35.2	73.9
South Park	7.1	0.0	0.0	48.0	0.0	55.2	38.6	93.8
Tofu	13.6	0.0	11.6	62.8	0.0	87.9	7.0	95.0
Ac. Wt. Avg.	8.3	0.0	1.8	29.1	0.1	39.3	19.9	59.2

Table 13. Volume sold per acre by species and product class at the Wallowa-Whitman National Forest.

Sale	AF	DF	ES	LP	PC	PP	WF	Saw	Nonsaw	Total
CCF / ac										
Cove	0.03	0.8	0.2	2.5	0.0	0.3	7.0	10.9	13.7	24.6
Empire	0.0	6.8	0.0	0.0	0.0	3.4	3.6	13.9	0.1	14.0
Peep	0.0	1.6	0.0	2.7	0.0	0.0	0.4	4.7	6.8	11.5
Sandbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Skull	0.0	3.0	0.0	0.0	0.0	2.8	14.8	20.6	0.3	20.9
Trail	0.0	9.0	0.0	0.0	0.4	4.5	1.9	15.8	0.4	16.2
Ac. Wt. Avg.	0.0	4.3	0.0	0.5	0.1	2.4	5.6	12.8	2.3	15.1
Mbf / ac										
Cove	0.02	0.4	0.1	1.3	0.0	0.1	3.5	5.4	6.9	12.3
Empire	0.0	3.5	0.0	0.0	0.0	1.8	1.9	7.2	0.1	7.2
Peep	0.0	0.8	0.0	1.4	0.0	0.0	0.2	2.4	3.6	6.0
Sandbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Skull	0.0	1.6	0.0	0.0	0.0	1.4	8.1	11.1	0.2	11.2
Trail	0.0	4.6	0.0	0.0	0.2	2.3	0.9	8.1	0.2	8.3
Ac. Wt. Avg.	0.0	2.2	0.0	0.3	0.0	1.2	3.0	6.7	1.1	7.8
Ton / ac										
Cove	0.11	2.6	0.6	7.8	0.0	0.8	21.7	33.7	42.6	76.2
Empire	0.0	21.1	0.0	0.0	0.0	10.7	11.3	43.1	0.3	43.4
Peep	0.0	4.8	0.0	8.2	0.0	0.0	1.4	14.5	21.1	35.6
Sandbox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Skull	0.0	9.4	0.0	0.0	0.0	8.7	45.8	63.8	1.0	64.8
Trail	0.0	27.9	0.0	0.0	1.2	14.1	5.9	49.1	1.2	50.3
Ac. Wt. Avg.	0.0	13.3	0.1	1.6	0.2	7.3	17.3	39.8	7.0	46.8

8.2. Appendix B: Background data from the FACTS and TIMS databases

Table 14. Cumulative harvest of sawtimber, poles, nonsaw timber, and fuelwood from Eastern Oregon Region 6 National Forest land, 2007 – 2011.

Forest	Fraction	Units	Volume	Value	Volume/ Acre	Value/ Acre	Value/ Volume
Regular	Sawtimber	MBF	584,154	$39,815,144	3.86	$263.28	$68.16
	Poles	MBF	41	$1,337	0.00	$0.01	$32.67
	Non-Saw	**Tons**	**682,422**	**$236,935**	**4.51**	**$1.57**	**$0.35**
	Fuelwood	Cords	1,147	$20,501	0.01	$0.14	$17.87
Stewardship	Sawtimber	MBF	106,852	$7,983,765	2.18	$162.84	$74.72
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	**Tons**	**358,477**	**$11,158,198**	**7.31**	**$227.59**	**$31.13**
	Fuelwood	Cords	30	$300	0.00	$0.01	$10.00
Combined	Sawtimber	MBF	691,006	$47,798,909	3.45	$238.69	$69.17
	Poles	MBF	41	$1,337	0.00	$0.01	$32.67
	Non-Saw	**Tons**	**1,040,899**	**$11,395,132**	**5.20**	**$56.90**	**$10.95**
	Fuelwood	Cords	1,177	$20,801	0.01	$0.10	$17.67

Table 15. Average annual harvest of sawtimber, poles, nonsaw timber, and fuelwood from Eastern Oregon Region 6 National Forest land during the period between 2007 and 2011. All cumulative values were divided by the four years in the harvest period, but volume per acre should be carefully interpreted because a given acre would have been harvested only once. We present (Table 3) cumulative values in the text to clarify harvest per area.

Forest	Fraction	Units	Volume	Value	Volume/ Acre	Value/ Acre	Value/ Volume
Regular	Sawtimber	MBF	146,039	$9,953,786	0.97	$65.82	$17.04
	Poles	MBF	10	$334	0.00	$0.00	$8.17
	Non-Saw	**Tons**	**170,605**	**$59,234**	**1.13**	**$0.39**	**$0.09**
	Fuelwood	Cords	287	$5,125	0.00	$0.03	$4.47
Stewardship	Sawtimber	MBF	26,713	$1,995,941	0.54	$40.71	$18.68
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	**Tons**	**89,619**	**$2,789,549**	**1.83**	**$56.90**	**$7.78**
	Fuelwood	Cords	8	$75	0.00	$0.00	$2.50
Combined	Sawtimber	MBF	172,752	$11,949,727	0.86	$59.67	$17.29
	Poles	MBF	10	$334	0.00	$0.00	$8.17
	Non-Saw	**Tons**	**260,225**	**$2,848,783**	**1.30**	**$14.23**	**$2.74**
	Fuelwood	Cords	294	$5,200	0.00	$0.03	$4.42

Table 16. Cumulative harvest from USFS regular timber sales, 2007 – 2011, for individual forests.

Forest	Fraction	Units	Volume	Value	Volume/ Acre	Value/ Acre	Value/ Volume
Deschutes	Sawtimber	MBF	97,946	$5,731,789	2.66	$155.92	$58.52
	Poles	MBF	41	$1,337	0.00	$0.04	$32.67
	Non-Saw	Tons	202,925	$102,833	5.52	$2.80	$0.51
	Fuelwood	Cords	1,131	$19,283	0.03	$0.52	$17.05
Fremont Winema	Sawtimber	MBF	167,900	$11,859,957	5.09	$359.58	$70.64
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	235,129	$38,517	7.13	$1.17	$0.16
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Malheur	Sawtimber	MBF	101,502	$3,712,110	3.14	$114.85	$36.57
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	118,617	$10,731	3.67	$0.33	$0.09
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Ochoco	Sawtimber	MBF	51,574	$1,556,551.65	3.16	$95.46	$30.18
	Poles	MBF	-	$0.00	-	$0.00	$0.00
	Non-Saw	Tons	17,492	$2,098.73	1.07	$0.13	$0.12
	Fuelwood	Cords	-	$0.00	-	$0.00	$0.00
Umatilla	Sawtimber	MBF	30,529	$1,635,982	2.80	$150.28	$53.59
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	49,846	$73,769	4.58	$6.78	$1.48
	Fuelwood	Cords	16	$1,218	0.00	$0.11	$74.19
Wallowa Whitman	Sawtimber	MBF	44,514	$1,774,795	2.99	$119.31	$39.87
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	58,404	$8,986	3.93	$0.60	$0.15
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Rogue-Siskiyou	Sawtimber	MBF	90,190	$13,543,960	12.71	$1,908.41	$150.17
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	8	$1	0.00	$0.00	$0.08
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Total	Sawtimber	MBF	584,154	$39,815,144	3.86	$263.28	$68.16
	Poles	MBF	41	$1,337	0.00	$0.01	$32.67
	Non-Saw	**Tons**	**682,422**	**$236,935**	**4.51**	**$1.57**	**$0.35**
	Fuelwood	Cords	1,147	$20,501	0.01	$0.14	$17.87

Table 17. Cumulative harvest from USFS stewardship timber sales, 2007 – 2011, for individual forests.

Forest	Fraction	Units	Volume	Value	Volume/ Acre	Value/ Acre	Value/ Volume
Deschutes	Sawtimber	MBF	6,932	$663,771	1.47	$141.05	$95.75
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	37,744	$6,409	8.02	$1.36	$0.17
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Fremont Winema	Sawtimber	MBF	69,935	$2,413,562	3.75	$129.48	$34.51
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	6,042	$378	0.32	$0.02	$0.06
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Malheur	Sawtimber	MBF	13,991	$3,099,156	1.50	$331.92	$221.52
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	41,710	$1,454,951	4.47	$155.83	$34.88
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Ochoco	Sawtimber	MBF	1,529	$36,512.79	0.57	$13.62	$23.88
	Poles	MBF	-	$0.00	-	$0.00	$0.00
	Non-Saw	Tons	7,410	$622.50	2.76	$0.23	$0.08
	Fuelwood	Cords	30	$300.00	0.01	$0.11	$10.00
Umatilla	Sawtimber	MBF	2,276	$563,614	0.25	$60.77	$247.63
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	221,865	$9,125,921	23.92	$983.93	$41.13
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Wallowa Whitman	Sawtimber	MBF	12,155	$1,207,082	2.78	$275.97	$99.31
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	34,559	$565,656	7.90	$129.32	$16.37
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Rogue-Siskiyou	Sawtimber	MBF	34	$66	2.44	$4.69	$1.92
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	9,148	$4,261	653.40	$304.36	$0.47
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Total	Sawtimber	MBF	106,852	$7,983,765	2.18	$162.84	$74.72
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	**Tons**	**358,477**	**$11,158,198**	**7.31**	**$227.59**	**$31.13**
	Fuelwood	Cords	30	$300	0.00	$0.01	$10.00

Table 18. Cumulative harvest from USFS stewardship and regular timber sales combined, 2007 – 2011, for individual forests.

Forest	National Forest	Units	Volume	Value	Volume/ Acre	Value/ Acre	Value/ Volume
Deschutes	Sawtimber	MBF	104,878	$6,395,560	4.14	$296.96	$154.27
	Poles	MBF	41	$1,337	0.00	$0.04	$32.67
	Non-Saw	Tons	240,669	$109,241	13.54	$4.16	$0.68
	Fuelwood	Cords	1,131	$19,283	0.03	$0.52	$17.05
Fremont Winema	Sawtimber	MBF	237,836	$14,273,519	8.84	$489.05	$105.15
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	241,171	$38,894	7.45	$1.19	$0.23
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Malheur	Sawtimber	MBF	115,492	$6,811,266	4.64	$446.77	$258.09
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	160,328	$1,465,682	8.14	$156.16	$34.97
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Ochoco	Sawtimber	MBF	53,103	$1,593,064.44	3.73	$109.09	$54.06
	Poles	MBF	-	$0.00	-	$0.00	$0.00
	Non-Saw	Tons	24,901	$2,721.23	3.84	$0.36	$0.20
	Fuelwood	Cords	30	$300.00	0.01	$0.11	$10.00
Umatilla	Sawtimber	MBF	32,805	$2,199,596	3.05	$211.05	$301.22
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	271,711	$9,199,690	28.50	$990.70	$42.61
	Fuelwood	Cords	16	$1,218	0.00	$0.11	$74.19
Wallowa Whitman	Sawtimber	MBF	56,669	$2,981,878	5.77	$395.28	$139.18
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	92,963	$574,642	11.83	$129.93	$16.52
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Rogue-Siskiyou	Sawtimber	MBF	90,224	$13,544,025	15.15	$1,913.09	$152.09
	Poles	MBF	-	$0	-	$0.00	$0.00
	Non-Saw	Tons	9,156	$4,262	653.40	$304.36	$0.54
	Fuelwood	Cords	-	$0	-	$0.00	$0.00
Total	Sawtimber	MBF	691,006	$47,798,909	3.45	$238.69	$69.17
	Poles	MBF	41	$1,337	0.00	$0.01	$32.67
	Non-Saw	**Tons**	**1,040,899**	**$11,395,132**	**5.20**	**$56.90**	**$10.95**
	Fuelwood	Cords	1,177	$20,801	0.01	$0.10	$17.67