



Opportunities for Making Wood Products from Small Diameter Trees in Colorado

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Abstract—Colorado's forests are at risk to forest health problems and catastrophic fire. Forest areas at high risk to catastrophic fire, commonly referred to as Red Zones, contain 2.4 million acres in the Colorado Front Range and 6.3 million acres Statewide. The increasing frequency, size, and intensity of recent forest fires have prompted large appropriations of Federal funds to reduce fire risk and improve fire protection. Experimental ecological restoration studies using thinning and prescribed fire have been conducted at several locations across the State during the past 5 years to determine if high-risk areas could be treated to improve forest health and reduce the potential for catastrophic fires. These studies established that 80 to 96 percent of the trees removed to improve ecological conditions were between 5 and 11.9 inches in diameter. Some trees 12 inches and larger in diameter had to be removed to properly apply ecological prescriptions and typically comprised 4 to 18 percent of the trees removed. The projects studied had profit margins of 1 percent (Pines Partnership), 6 percent (Mixed Conifer Project), a loss of \$78,000 (Chessman Reservoir-Trumbull Project), and required subsidies of \$779 per acre (Fox Run) and \$679 per acre (Air Force Academy).

A search for opportunities to use small diameter trees from these projects was conducted as part of an effort to improve the financial feasibility of forest restoration. A previous study, "Wood Use in Colorado at the Turn of the Century" (Lynch and Mackes 2001), describes in detail the various types and quantities of wood products used in the State and identifies where products came from. Using this study, the authors identified potential products that might be manufactured from small diameter trees removed in restoration thinning.

The potential opportunities for using wood are listed in two categories: (1) existing products, processes, and technology, and (2) new products, processes, and technology. Products are arranged within each category in order of increasing complexity of processing and technology. Estimates of the potential retail market value for each product are presented. Examples of existing product opportunities include Christmas trees, mine props, firewood, posts and poles, rough sawn lumber and timbers, and oriented strandboard. Examples of new products and processes include structural roundwood, biomass energy, and wood pulp. The report concludes that future restoration programs must be designed to provide a consistent supply of raw material to processors. It also recognizes that there is no single product that will utilize all small diameter trees from Red Zone areas. Instead, a stable, diverse wood industry appears to be the most desirable future.

Keywords: small diameter trees, wood products, forest restoration

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Introduction

Natural resource management agencies recognize that Colorado forests have serious forest health problems and significant potential for catastrophic forest fires. Forest areas at high risk to fire, commonly referred to as Red Zones, have been identified for the Front Range as well as Statewide. The Front Range Red Zone area is estimated to contain 2.4 million acres that must be treated to reduce the risk of catastrophic fire (USFS 1996). There are 6.3 million high-risk acres Statewide (CSFS 1998a), and estimates of high and moderate risk areas total 17.3 million acres. Census data from 1990 indicate 750,000 people and 300,000 dwellings are present in high-risk areas, figures that will undoubtedly be revised upward substantially when 2000 census data are available.

Catastrophic fire events such as the 1996 Buffalo Creek fire, the Hi Meadows, Bobcat Gulch, and Mesa Verde fires in 2000 focused attention on the need for restoration programs to reduce fire risk. Thinning and removing trees from critical forest areas and restoring normal ecological processes, such as low intensity fires, can mitigate high-risk areas. Following the 2000 fire season, appropriations of Federal funds increased dramatically for forest and watershed restoration as well as for increased fire protection. As these programs are implemented, the need to effectively dispose of small diameter trees and forest fuels will increase. The purpose of this paper is to discuss opportunities to utilize wood from small diameter trees.

Forest Restoration Studies

In experimental studies conducted between 1996 and 2002 (Lynch and others 1998, Lynch and Jones 1998, Lynch and others 2000, Lynch 2000) trees were

removed from several forest areas in Colorado to achieve ecological restoration objectives. These objectives were established to improve forest health and reduce the incidence of catastrophic fire by ecologists. In particular, objectives focused on making changes beneficial to forest structure, reducing fuel loading, improving plant diversity, reproducing trees, and reintroducing natural fire regimes. From these experimental studies, findings indicate that accomplishing forest restoration objectives requires mechanical removal of undesirable smaller trees, retention of larger trees and snags, and use of prescribed fire. This is essentially the opposite of traditional logging where large trees are removed and small trees are left. Results of these studies in relation to small diameter tree removals are summarized in table 1.

Material in the 3 to 4.9 inch diameter class was usually not merchantable. Trees in this size class were cut and left on the site for subsequent prescribed burning as specified in the ecological restoration prescription. The white fir-aspen unit at Gordon Creek was so densely populated with trees in this size class that a specific effort was made to count the stems cut to better describe costs. Trees less than 3 inches in diameter were often consumed in the prescribed fire that followed thinning. In the Air Force Academy Project smaller trees were chipped, removed from the site, and used for energy fuel tests.

From the table, a definition of what is meant by small diameter trees becomes clear. In all but two of the forest restoration units 80 to 96 percent of the trees removed were below 12 inches in diameter. Trees that were 12 inches and larger amounted to 4 to 18 percent of the trees removed. The exceptions are the Joyce unit (100 acres) of the Pines Partnership Project and the small sample unit in the Air Force Academy Project (10.7 acres). In these two cases, the forest being thinned consisted of more large trees. The same ecological

Table 1—Colorado forest restoration projects with trees removed from site.

Pines Partnership Project - San Juan National Forest (Dolores, Colorado)**Percent Removal by Diameter Class**

Unit	Acres	Species	3 to 4.9"	5 to 7.9"	8 to 11.9"	12" +	Tons/Acre
Unit 1	125	Ponderosa	No Data	50.1%	39.2%	10.7%	29.6
Unit 4	95	Ponderosa	No Data	48.4%	41.1%	10.5%	33.3
Unit 5B	108	Ponderosa	No Data	40.9%	51.8%	7.3%	35
Unit 5E	65	Ponderosa	No Data	44.3%	51.4%	4.2%	23.5
Joyce	100	Ponderosa	No Data	22.0%	26.0%	52.0%	21.7

Gordon Creek Project - San Juan National Forest (Pagosa Springs, Colorado)**Percent Removal by Diameter Class**

	Species	3 to 4.9"	5 to 7.9"	8 to 11.9"	12" +	Tons/Acre
75 Acre Unit	White fir	49.1%	15.1%	17.5%	18.3%	36.1
	Aspen	--	30.2%	69.8%	--	10.7

Fox Run Project - Black Forest (Colorado Springs, Colorado)

Acres	Species	Avg. Diameter	Total Cords	Tons/Acre
24	Ponderosa	7.9	162	18-20*

Cheesman Reservoir - Trumbull Project (Deckers, Colorado)**Percent Removal by Diameter Class**

Unit	Acres	Species	3 to 4.9"	5 to 7.9"	8 to 11.9"	12" +	Tons/Acre
Cheesman	83	Ponderosa	No Data	56.5%	31.8%	11.7%	14.5
Trumbull #5	42	Ponderosa	No Data	57.1%	32.9%	10.0%	9.9
Trumbull #6	33	Ponderosa	No Data	62.0%	28.4%	9.6%	14.8

Air Force Academy - near Colorado Springs, Colorado**A total 138 acres treated - following data from samples****Percent Removal by Diameter Class**

Unit	Acres	Species	3 to 4.9"	5 to 7.9"	8 to 11.9"	12" +	Tons/Acre
Sample 1	10.7	Ponderosa	15.5%	17.8%	29.0%	37.8%	**
Sample 2	11.2	Ponderosa	7.7%	38.6%	44.3%	9.3%	**
Sample 3	2.2	Ponderosa	23.6%	49.7%	22.7%	4.0%	**

* Estimated, not weighed

** Tons per Acre data is still being collected at the time of writing this report

prescription used in units 1, 4, 5B, and 5E of the Pines Partnership Project was also applied in the Joyce unit. In the Air Force Academy study a separate ecological prescription was written for the unit because the forest area was distinctly different from the other units thinned. The results from these units demonstrate that when ecological restoration prescriptions are applied to forest areas needing fuel reduction treatment, there usually will be some areas where larger trees must be removed. However, as the above data show, most trees removed will be less than 12 inches diameter at breast height. It is important to note that if 12 inch and larger trees had not been removed

from all units, ecological restoration would have been incomplete and improperly done. Therefore, restoration must focus on the ecological prescription and not on tree diameter.

Removing trees in restoration projects is expensive. The general rule is: the smaller the trees, the higher the costs of removal. This is evidenced by the financial results of these studies. The Pines Partnership Project netted less than 1 percent profit before taxes, the Gordon Creek project netted approximately 5 percent profit before taxes, the Fox Run Project required payment of \$779 per acre to accomplish the work, the Cheesman-Trumbull Project resulted in a \$78,000 loss

to the contractor, and the Air Force Academy Project required payment of \$679 per acre to the contractor.

Wood Product Studies

Wood products manufactured from the trees removed in forest restoration studies included oriented strandboard, rough sawn lumber and timbers, studs (2x4's), paneling, posts and poles, excelsior, pulpwood, and firewood. Wood chips and short logs were also used in research projects. Because the financial results of restoration projects revealed low profit or losses, studies were initiated to determine how to reduce costs and improve revenue from wood product opportunities.

The authors are conducting studies to investigate wood products that might potentially be manufactured from small diameter trees. The basis for these studies was the comprehensive survey, "Wood Use in Colorado at the Turn of this Century" (Lynch and Mackes 2001). This survey lists the various types of wood products used in Colorado, quantifies the amount of wood used, and identifies where the wood comes from. Colorado is considered a superb market for wood products of all types, and its citizens use tremendous quantities of wood in a wide variety of applications. However, nearly 90 to 100 percent of the wood used comes from other States and countries. This presents Colorado with an opportunity to utilize wood from its own forests to meet some of this demand while improving ecological conditions in Colorado forests.

Wood from small diameter trees, particularly ponderosa pine from the Colorado Front Range, has a number of material problems. These trees have numerous limbs, and as a result the wood has a high frequency of knots, often large. Trees have often grown in crowded conditions under stress. As a result, growth rings are dense and the wood may be quite hard. In addition, growth stresses create compression wood, often referred to as reaction wood, in these trees. When lumber is cut from the tree, it does not dry uniformly, and stresses within the board result in warping. The wood also may split, crack, or check during drying, further degrading the quality of lumber and timbers. These problems are not easily overcome and can result in considerable loss and waste. The lumber may not even be satisfactory for low quality uses such as pallets. Other tree species such as white fir and Douglas-fir have their own unusual set of material problems. Therefore, caution should be exercised in predicting that small trees will result in a windfall of wood for higher value uses. Considerable small diameter material

testing and product development will be necessary to create satisfactory products for use.

A survey conducted by the Colorado State Forest Service (CSFS 1998b) shows that wood processing plants in Colorado are primarily small businesses, mostly family owned and operated. There have been exceptions, such as Louisiana-Pacific Corporation (their oriented strand board plant recently closed) and Koppers Corporation. While Koppers is part of a larger corporation, it actually has a rather small operation in Colorado and is mainly involved in treating wood to improve its durability. To stay viable, small businesses need a constant raw material supply at a reasonable price, assistance with research and development, and assistance with marketing. Unfortunately, consistent supplies of wood at reasonable prices have not been available in the past. Over the years, the wood supply from public lands has been steadily declining and has also been inconsistent. Pricing has not always been realistic considering the low quality of the trees and the high costs of removal. As a result, many firms have gone out of business or have been unable to invest in updated technology. Therefore, the State has been gradually losing industrial potential to utilize small diameter trees from the forests. Also, a vigorous program of forest thinning to solve health and fire problems may be confronted by the limited ability of existing firms to utilize trees that need to be removed from Red Zone areas.

Potential Opportunities in Existing Markets

In this section, suggestions of possible volumes, values, and opportunities to use small diameter trees in existing markets are presented based on previous study of wood use in Colorado (Lynch and Mackes 2001). This list starts with opportunities to utilize wood in simple products using existing facilities and technology. It then moves to new product opportunities that require increasingly complex processing and new technology investments.

Christmas Trees

Douglas-fir, white fir, subalpine fir, and lodgepole pine are the most desirable Christmas trees in Colorado forests. To utilize them, the trees only need to be cut and marketed. No further processing is needed for fresh, wild trees. Many forest areas with potential for catastrophic fires have these species present in the understory. These trees create a fuel

ladder for fires to move up into the crowns of larger trees. In other areas, these species create dense stands with closed canopies that are prone to devastating crown fires.

The potential exists to meet virtually all of Colorado's demand (495,000 trees in 1998) for Christmas trees and improve forest health at the same time. However, not all Christmas trees in the forests are "perfect." Such trees have not been tended or sheared as occurs on commercial Christmas tree farms. Therefore, efforts must be made to assist small businesses with marketing and to increase public awareness that using such "imperfect," but "organic," trees is actually environmentally beneficial. This market had an estimated total retail value of \$11.6 million in 1999.

Mine Props

Mine props are quite possibly the simplest roundwood product. A small log that is 6 inches in diameter on the small end, from 5 to 11 feet in length, relatively straight, limbed, unpeeled, and dry can make a mine prop. Lodgepole pine, ponderosa pine, Douglas-fir, and Englemann spruce are preferred. Aspen and true firs are used but are least preferred. Conservatively, an additional 75,000 mine props could be thinned from Colorado forests each year to improve forest health and reduce intense fires. For example, if every tree in a forest area were just the right size for a mine prop, an estimated 1,500 acres could be thinned each year. Unfortunately, trees in a forest are seldom that uniform in size and shape. Thus, mine props are but one of several products that might be realized from a thinning program. The principal barriers to the use of mine props from Colorado forests are inappropriate stumpage rates charged by agencies, unrealistic contract requirements, and the lack of a consistent thinning program to date. This market had an estimated total retail value of \$710,000 in 1999.

Firewood

Firewood production requires cutting a tree into segments, splitting the segments, and allowing these to dry. Virtually every tree species in Colorado is acceptable for firewood use. However, Englemann spruce may be the least desirable because of its tendency to pop and throw sparks while burning, although among some campers this natural fireworks display may be considered entertaining. The firewood market is currently fragmented geographically, and communication among buyers and sellers is not well developed. Currently, some people have firewood to sell but no buyers, while others want to buy firewood but can't

find a seller. This could be resolved by establishing a type of "virtual firewood sort yard" on an Internet Web site where commercial buyers and sellers could list firewood supply and demand. It could also provide a list of firewood vendors for private individuals to contact. There is a potential to provide up to 3,200 cords of small bundle firewood annually from Colorado that is now imported from other States and countries. That potential retail market value of this firewood is approximately \$1.2 million at current market prices. In addition, bulk firewood could also be provided in place of imported wood. When fossil fuel prices rise for home heating, it is anticipated that the firewood market will again become attractive to many homeowners. Such demand may also improve opportunities to reduce wood residues from manufacturing or municipal tree wastes. Information is not available to estimate the market value of bulk firewood that could replace imported firewood or satisfy current unmet demand.

Posts and Poles

Fence posts need to be cut to length, peeled, dried, and treated with chemicals to resist decay. Rocky Mountain juniper has been used for native fence posts without peeling or treating for more than 100 years. The preferred species for manufactured posts and poles are lodgepole pine (90 percent of the market), ponderosa pine, and Douglas-fir. Aspen is sometimes used in decorative applications. It takes a fairly uniform, straight log with minimal taper to make an acceptable post or pole. Over 300,000 posts were used in 1999 for agricultural fencing, and approximately 60 percent of these came from out of state. Some smaller diameter material can be sorted for other roundwood uses. Markets exist for stair and deck banisters and balustrades, latillas, tepee poles, decorative posts, tourist and gift items, and rustic furniture. These markets are often localized and limited in size. Research and marketing assistance could improve opportunities for the use of less desirable species in the post and pole market. An estimated 100,000 posts that are imported annually could be replaced by posts processed in State with a retail market value of approximately \$600,000 based on current market prices.

House Logs

House logs are cut to length, peeled, and notched before use. Custom log homebuilders prefer long, large logs. Natural house logs need to be 10 inches or more in diameter, straight, and fairly uniform in size with little taper. In some cases logs may also be milled to achieve uniformity or a desired shape. However,

several building techniques are used to accommodate variation in log shape and length.

Approximately 4.05 million lineal feet of logs were used in Colorado log homes in 1998. Most logs were imported from out of State, and many came in kits or in previously manufactured log home packages. For example, log home packages are currently imported from as far away as Finland.

Engelmann spruce and lodgepole pine are the most preferred and commonly used Colorado tree species for log homes. However, ponderosa pine and Douglas-fir are also used by some builders.

Small diameter material has been used in the past to construct log dwellings in Colorado. Such material, however, may have defects that render it unsuitable for house logs. Machining or milling small diameter logs can produce attractive, uniform-sized material for log home construction. In addition, there are forest areas where removals of larger house logs could benefit forests by increasing defensible space or improving forest health, particularly in areas infested with bark beetles. A thinning program that is flexible enough to take advantage of such areas could also improve the overall economic outlook for forest restoration by including higher value house log material to offset costs associated with low value small material. The 1998 retail value of the house log market in Colorado was \$37.5 million.

Utility Poles or Pilings

Utility poles and pilings must be cut to length, peeled, dried, and treated with chemicals to resist decay. Trees must be straight, fairly uniform in size with a minimum of taper, and meet length requirements. In Colorado, lodgepole pine is the preferred species. The necessary facilities to treat such long logs exist only in Denver. In addition, logs that are acceptable for utility poles or pilings are also of the size and length that make them attractive for higher value house logs.

Since all utility poles are imported, the size of the potential market for Colorado is really dependent on the supply offered. The total retail value of the Colorado market was \$16.9 million in 1998.

Biomass Chips

The tops and limbs, and unmerchantable small trees resulting from thinning, must be disposed of in some manner. One historic method of disposal of this material, commonly referred to as slash, has been to conduct a prescribed burn. In many cases, however, the existing amount of fuels in the forest plus the addition

of slash may create prescribed fire conditions that could damage a forest severely. Therefore, other methods such as chipping, shredding, or grinding may be needed to reduce fuel loading. Depending on chip size and shape, several potential uses are:

Landscape Mulch — All tree species and even some shrub species can be used for landscape mulch. To create this product, the treetops and limbs are chipped, shredded, or ground mechanically into particle sizes and shapes that fit desired landscaping uses. Usually long strip-like chips that will intertwine and resist blowing by the wind are most popular. A number of small businesses within Colorado currently convert municipal tree wastes into landscape mulch. However, an estimated 80,000 cubic yards of cedar and redwood landscape mulch are still imported each year with an estimated retail value of \$2.8 million at current market prices. Much of this imported mulch could be replaced with urban tree waste material from Colorado if market preferences for cedar and redwood mulch could be overcome and if current landfill tipping fees were to become more realistic. Landfill tipping fees are often too low, resulting in burial of potential mulch material rather than utilization.

Mulching is also a particularly good way to dispose of limbs and small, deformed trees from forest thinnings. However, mulch is a relatively low value product and very cost sensitive to harvesting, loading, and hauling material from the forest. Therefore, in most cases, small material that is only suitable for mulch must be regarded as a liability and will require subsidies to remove it.

Compost — Nitrogenous wastes are often difficult to dispose of and may threaten water supplies. However, when combined with carbon, microorganisms can break down such wastes into a useful soil amendment and water-conserving material known as compost. Currently, there is strong demand for compost in agricultural applications as well as residential lawn and garden uses in Colorado. Several projects using wood chips and various nitrogenous wastes for composting have been conducted in Colorado. Where the right combinations of wood residues and nitrogen sources are available, composting is an effective and profitable way to use wood residues. At this time, it is not possible to estimate the opportunity for using small diameter material from the forest in composting. However, composting is growing for a number of reasons and has the potential to be a significant user of wood biomass. A new study is pending that will explore a new dimension of composting and identify key costs as well as the type of chips that are most suitable for use.

Rough Sawn Lumber and Timbers

All Colorado tree species are used for rough sawn lumber, although some species have characteristics and properties that make them more desirable. The tree must be cut into even length logs (usually 8, 10, 12, 14, and 16 feet) plus a 3 to 6 inch trim allowance and then sawn into boards and/or timbers. Debarking the tree before sawing may improve the potential range of products from the tree and reduces wear on saw blades. In Colorado, rough lumber and timbers are typically air-dried. Small diameter trees may contain compression or reaction wood that can cause twist, sweep, crook, cupping, and splitting of lumber and timbers. Care must be taken in sawing and drying to reduce such losses. Potential products and market volumes used are presented in figure 1. The retail values of each of the products shown in the figure can be obtained from “Wood Use in Colorado at the Turn of the Century” (Lynch and Mackes 2001). However, for purposes of this report, the total retail value of the above products was estimated to be \$53 million in 2000. Residues from the processing of the rough lumber and timber products may be used for:

- Decorative landscaping bark from ponderosa pine or Douglas-fir (ring debarking is preferred to produce desirable bark chunks).
- Large animal bedding (dry peelings and sawdust).

- Small animal bedding (dry sawdust).
- Compost (green sawdust added to a nitrogen source along with water).
- Slabs for cabin siding, fencing, firewood, or, if peeled, made into shavings for animal bedding.

Sawn, Kiln Dried, Planed, and/or Graded Lumber

Most Colorado tree species can be used for sawn, kiln dried, planed and/or graded lumber to some degree, but true firs, blue spruce, and aspen are less desirable for structural purposes. As noted in the rough sawing discussion, small diameter trees may contain relatively high frequencies of knots, reaction wood, and other defects that may reduce structural properties resulting in losses or down grading. A mill with kilns, planers, and grading operations is located at Montrose, CO. Other mills that air-dry and plane lumber are located in several places across the State. However, few if any of these mills have grading stamps. Potential products and volumes are presented in figure 2. While it is unlikely that the harvest from Colorado forests could meet this level of demand, the total retail market value for the above products is estimated at \$591 million in 2000. However, any dried, planed, and graded lumber from Colorado could be used to offset imports. In addition, dried and planed lumber may be used in

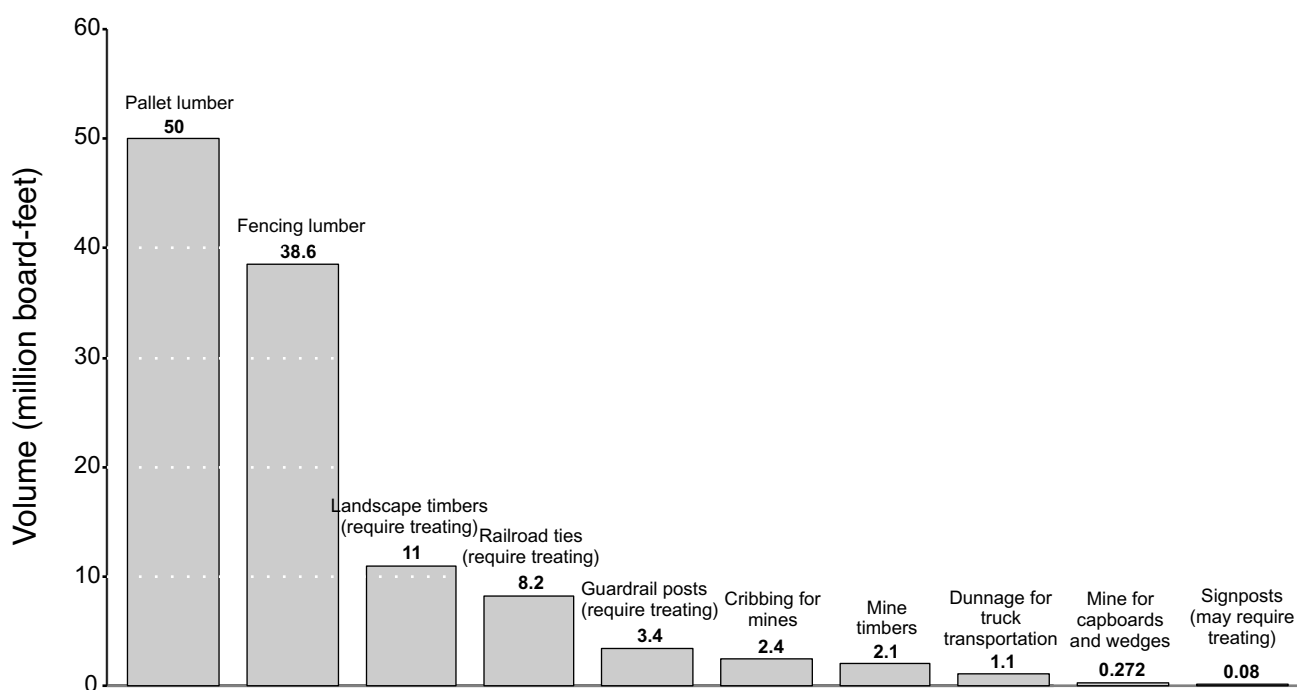


Figure 1—Annual Colorado consumption (2000) of rough sawn lumber and timber products.

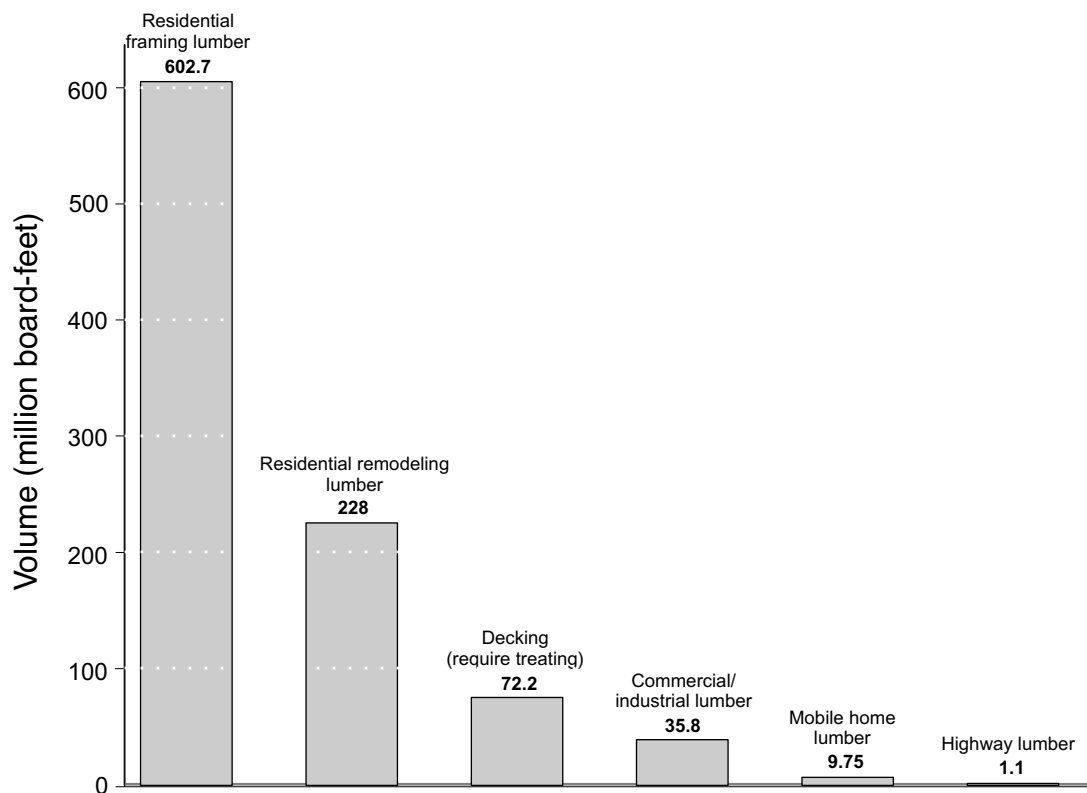


Figure 2—Annual Colorado consumption (2000) of sawn, kiln dried, planed, and/or graded lumber products.

softwood flooring, molding, paneling, finger-jointed products, and edge-glued panels. Some mills also create planed log siding and specialty products. No volume or value estimates for these products are currently available.

Shavings and Sawdust for Animal Bedding

Dry shavings and sawdust from nearly all tree species are used in these markets. However, only aspen is currently used for laboratory animal bedding. Studies done by Mackes and others (2000) suggest that white fir shavings may also be desirable for laboratory animal bedding. Figure 3 shows the animal bedding products and volumes currently consumed annually in Colorado. The total retail value of these products was estimated to be \$10.1 million in 1999.

Oriented Strandboard (OSB)

Aspen, true firs, lodgepole pine, and ponderosa pine are used to make oriented strandboard. OSB is an important structural panel and preferred in many applications over plywood. In this process, trees are cut into logs that are peeled, processed to the appropriate length

and waferized. The wafers are coated with a resin and oriented directionally into a thick mat. Heat and pressure are applied to compress the mat into a board with a predetermined thickness. Boards are trimmed to a 4 foot width by an 8 foot length. This is an excellent way to utilize small diameter trees of any shape or condition. An OSB plant in Olathe, CO, that was operated by Louisiana-Pacific Corporation recently closed due to lack of wood supply and a depressed market. This plant had the capacity to meet 21 percent of the market if all of its production had remained within the State. However, the location of this plant made utilization of small diameter material from the Front Range more expensive. If an OSB plant were constructed at a central location along the Front Range, it could provide an excellent outlet for trees from thinning projects ongoing in the region. The market in Colorado appears to be easily able to support one to two plants. Marketing efforts encouraging construction firms to buy Colorado wood products would help. Current uses of OSB are outlined in figure 4. Annual consumption volume estimates given in figure 4 are on a 3/8-inch basis, and the retail value of these products was estimated at \$231.5 million in 2000.

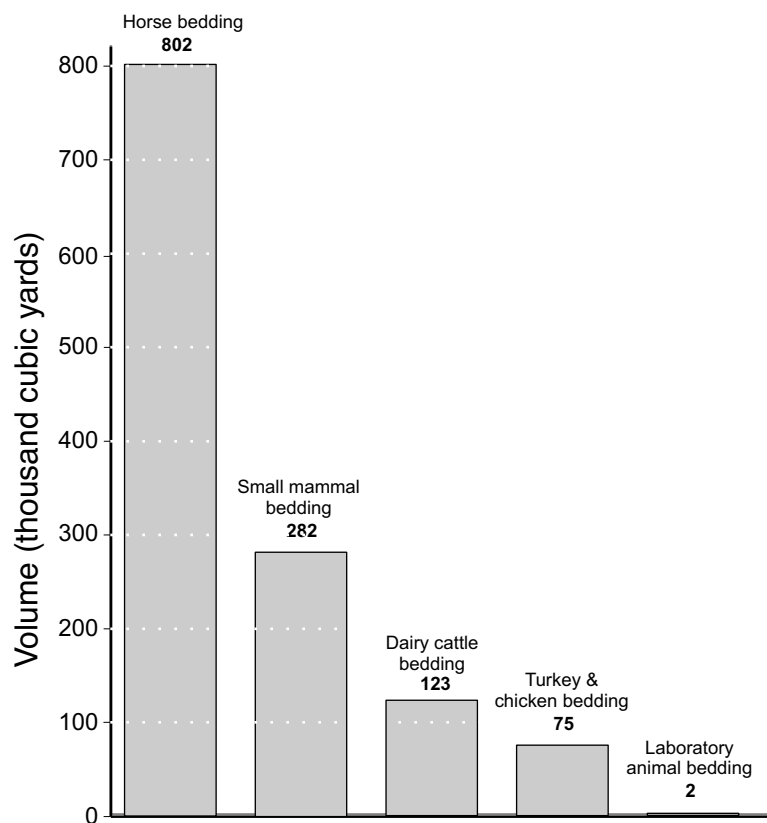


Figure 3—Annual Colorado consumption (2000) of shavings and sawdust products utilized for animal bedding.

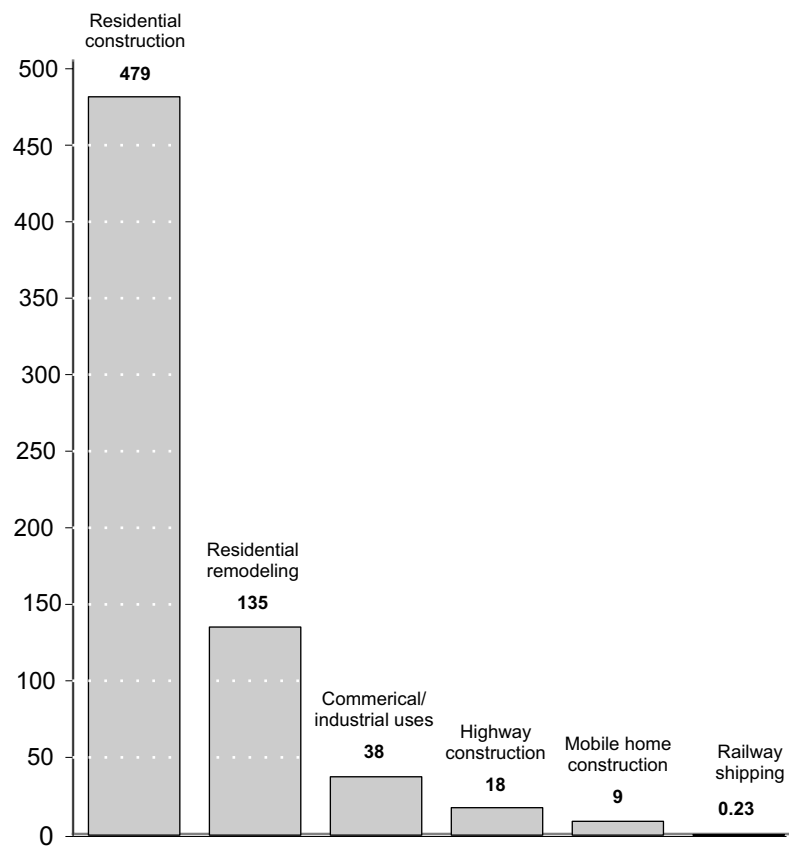


Figure 4—Annual Colorado consumption (2000) of oriented strandboard.

Potential Opportunities for New Products, Processing, and Technology

New wood products could be made from small diameter trees if new processing facilities were built or new technologies were introduced to the State. The following is a list of the most likely possibilities.

Roundwood for Structural Applications

Wolfe and Moseley (2000) conducted tests using small diameter roundwood for value-added structural applications where building codes permit their use. The natural look of roundwood is well suited for rustic structures, and diameters of 6 inches or greater reduce flammability. Peeled posts and poles can be put together using special connectors to form the framing for structures such as barns, sheds, picnic shelters, kiosks, and other outdoor shelters. Strength testing and the applicability of this construction technique using Colorado tree species will have to be researched. If this use proved to be applicable, it could provide value-added support to existing post and pole businesses. To date, it has not been possible to estimate the volume and value potential for the barn, shed, and outdoor shelter market.

The Interior West Center at Colorado State University has a research project under way that is utilizing short length, small diameter logs in attractive log home construction. This project is attempting to update a time-honored building method known as “piece-on-piece” construction. To date, higher quality ponderosa pine logs have performed surprisingly well as construction material in this project.

Another project in Arizona is successfully using small diameter logs in traditional hogan construction for the Navajo Nation (Indigenous Community Enterprises 2002).

Wood Pellets

The potential for wood pellet production has been researched extensively (NEOS 1993). Wood pellets provide comfortable heat and are a low air pollution alternative to burning firewood. Currently 100 percent of all wood pellets used in Colorado are imported. Current average annual consumption is estimated at 60,000 tons and had a value of \$8.8 million in 1999. If energy prices continue to increase, consumption may rise dramatically. The sticking points for wood pellet manufacture are a consistent supply of wood wastes

from higher value product manufacturing, in quantities sufficient to meet pellet plant economies of scale. Existing facilities that have potential to produce pellets, such as lumber mills, are having trouble obtaining a consistent supply of raw material that would allow them to invest in pelletization technology to deal with potential residues. Assistance in the form of low cost loans or other incentives could encourage further investment in this technology.

Biomass Energy

Trees efficiently convert solar energy into wood fiber and thus provide a natural, renewable energy source. Wood residues left over from manufacturing processes are also potential sources of energy for Colorado. Wood chips may be used directly in combustion processes, as a supplement to other energy materials such as coal, or processed into a derivative product such as ethanol. There are distinct air quality benefits associated with burning wood in place of, or as a supplement to, coal. Wood is lower in sulfur content than hydrocarbon fuels and therefore can reduce emissions such as sulfur dioxide. However, the use of wood has been restricted because wood is lower in BTU content than other fuels, has higher moisture content, and generally costs more to use.

Research projects are currently under way at Colorado State University to evaluate the feasibility of using chipped material from the forest as an energy fuel. These studies involve co-firing wood chips with coal at a cement plant and an electric power plant in Colorado. Because of the relatively low cost of coal, reducing chipping and removal costs will be necessary to economically burn wood at this time. Developing new wood chip based fuels such as pellets or briquettes may improve the economics and resolve handling problems associated with chipped wood. If we can find ways to increase BTU levels, reduce moisture content, and lower costs, wood chips and/or residues could become an important energy fuel. At the present time, wood chip costs are being subsidized in these studies. The principal removal costs are chipping, loading, and hauling. However, when wood residues are removed from the forest in conjunction with higher value products, costs are reduced and the feasibility for the use of chips is improved.

There is reason to be cautiously optimistic that wood chips from the forest can become an energy fuel in Colorado. It appears that the future for this will depend upon several factors. These include the market price levels for traditional energy sources such as coal, reduction of wood chip moisture content, additions to

increase wood chip BTU's, improvements in harvesting and transporting wood chips, the design of forest restoration projects to distribute costs over higher value products, and the availability of government subsidies for renewable energy.

Composite Products

The mixing of wood fiber with plastic for extrusion into composite products is an intriguing process and a viable possibility for utilizing recycled plastic and wood residues. This process could combine two existing waste streams into the creation of a usable product. Some research will be necessary to determine the types of waste materials that can be used effectively. Based on findings to date, commercial composite processing equipment is not currently operating within Colorado. However, the technology of extrusion is not unique and has been used to produce other products. Whether this technology can use wood removed directly from the forest is yet to be determined.

Composite decking material made of recycled plastic and wood fiber is an example of a product that could compete effectively in markets. Composite lumber use is increasing and constitutes about 5 percent of the decking market. In Colorado, the current retail value of this market is estimated at approximately \$2.37 million annually.

Cement-Wood Products

Cement is a product made in considerable quantities by plants along the Colorado Front Range. Products made with cement and wood hold potential for a number of uses. This is another product area that merits further investigation. Estimate of annual consumption (volume and value) have not been determined for cement-wood products use in the State.

Pine Excelsior

In the Pines Partnership Project (Lynch and others 2000) some ponderosa pine was used to create pine excelsior as an experiment to develop a new erosion control product. Excelsior is made by debarking a log, allowing it to dry, cutting the log into segments, and then shaving long thin strips of wood from the segment. The long thin strips then can be used for packing material, erosion control pads, and several other products. Aspen is the preferred species for excelsior. While the pine excelsior experiment conducted in southwestern Colorado was not successful for erosion control because of concerns about the reaction of seed germination to pine terpenes, it did raise interesting

possibilities for other new products. Further testing and analysis should be done to explore possibilities of utilizing pine and white fir for excelsior products. The potential for this market is not known.

Wood Pulp

Using clean wood chips from the forest for wood pulp is another potential outlet for small diameter material. Thermo-mechanical pulp plants have low water demands and low pollution levels. In addition, combining wood pulp with recycled newsprint pulp offers an opportunity to meet the demand for some of Colorado's paper products. Newsprint from Colorado currently goes into landfills or is recycled. Recycling involves shipping newsprint long distances to processing plants in other States.

In the thermo-mechanical pulping process, trees are cut in the forest, debarked, and chipped. Clean chips are delivered to the mill in truck trailers and processed into pulp at the plant using high levels of heat. Either inked or de-inked recycled newsprint pulp can be added at this point in the process, depending on the final product desired. Pollution does occur in the process but is relatively low compared to traditional methods of pulping wood. Paper recycling also introduces pollution. Using 2000 population figures supplied by the U.S. Census Bureau, Colorado citizens use an estimated 875,000 tons of paper with a value of \$672 million and 722,000 tons of paperboard with a value of \$349 million each year. Recycling rates of 70 percent in some counties indicate the volume of recycled material available and suggest that large amounts of paper and paperboard are still entering landfills.

Thermo-mechanical pulp plants are expensive to build. Recent estimates of \$700 to \$750 million are realistic. In addition, power generation would probably need to accompany such a plant at a cost of somewhere near \$250 million. A pulp plant would need to be sited in a location accessible to areas in critical need of thinning along the Colorado Front Range, an area noted for high land prices. In addition, no one will build a plant unless they can be guaranteed a consistent supply of wood chips to amortize the cost of the plant and make a profit. This would mean long-term contracts for wood from State and National Forest lands. In spite of potential barriers, this opportunity deserves additional study given the huge problem of wood utilization from anticipated forest restoration thinning and the demand for paper products in Colorado.

At this time, another alternative appears to be developing. A thermo-mechanical pulp plant has been

seriously discussed for construction in New Mexico. It is at least 3 years away from operation. However, chips from southern Colorado and the Front Range might be shipped by rail to this plant for processing. Again, costs of harvesting and processing chips plus transportation become critical to the feasibility of using this plant as an outlet for small diameter wood.

Other Opportunities

Since the publication of “Wood Use at the Turn of the Century,” potential markets for small diameter wood products continue to be discovered. For example, contact was made with a business installing concrete tile roofs that needed 1-inch x 2-inch rough sawn lumber strips. These strips are placed on the roof before the tiles are laid and can be made of relatively low quality lumber. Currently all of the material being used is shipped in from out of state. Concrete tile roofs are gaining market share because of fireproofing, hail resistance, and roof esthetics. Therefore, this market for rough lumber is expected to increase.

Also, short strips of low quality veneer are used in packaging bricks for shipment. These strips are used above the holes in brick packs to stabilize the lifting of the packs by forklifts. One company uses over a million of these strips annually. They are all imported from Texas.

Certainly not all the potential uses for small diameter trees have been discovered yet. Wood is such a versatile material and it is almost certain that other uses will arise. The work presented here will hopefully stimulate others to develop new product ideas that will further efforts to restore Colorado forests to good health.

Conclusion

Markets for all types of wood products clearly exist. There are substantial opportunities to use small diameter wood in many existing markets and there are interesting opportunities for new products, processing, and technology as well. No one ideal use or one

“silver bullet” solution exists for the problem of small diameter wood utilization. In fact, a stable, diverse wood products industry is the most desirable future for dealing with this problem. Also, it is unlikely that all the possibilities for utilizing small diameter wood were presented here. If a thinning program is initiated and agencies encourage businesses and communities to participate, innovative and creative people will find many other ways to use wood to meet society’s needs.

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