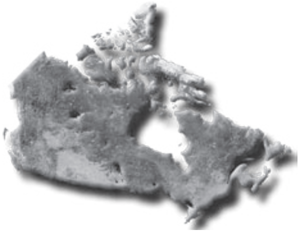

Current knowledge of characteristics and utilization of post-mountain pine beetle wood in solid wood products

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Mountain Pine Beetle Initiative
Working Paper 2005–8

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Abstract

British Columbia is in the midst of the largest outbreak of the mountain pine beetle ever recorded in western Canada. Mature lodgepole pine trees form the bulk of the trees under attack. The mountain pine beetle) carries several specific blue-stain fungi that decrease the wood moisture content and weaken the tree defence mechanisms, eventually leading to tree death. Blue stain develops quickly in the sapwood of dying trees. Blue stain carries over into products made from the stained logs, affecting what products can be made from the wood and profitably sold. Infested trees also dry and develop splits and checks as the drying stresses are relieved. The physical condition of the wood affects how it can be processed.

This paper discusses current knowledge of the properties of post-mountain pine beetle wood, and its use and marketing. It draws upon information from the literature and current research in Canada that pertains to properties of blue-stained and dead wood. Implications for use of post- mountain pine beetle wood for various products are discussed, significant data gaps are identified, and recommendations are made for research to bridge these gaps.

Key Words: *Dendroctonus ponderosae*; lodgepole pine; mountain pine beetle; *Pinus contorta*; wood processing; wood quality

Résumé

La plus importante infestation de dendroctone du pin ponderosa jamais observée dans l’Ouest canadien sévit actuellement en Colombie-Britannique. Les arbres attaqués sont principalement les pins tordus latifoliés mûrs. Le dendroctone du pin ponderosa transporte certains champignons responsables du bleuissement du bois, qui réduit son degré d’humidité et affaiblit les mécanismes de défense des arbres, entraînant finalement leur mort. Le bleuissement apparaît rapidement dans l’aubier des arbres mourants. Il se retrouve dans les produits fabriqués avec les billes bleuies et limite les produits qui peuvent être fabriqués avec ce bois et vendus avec profit. De plus, les arbres attaqués s’assèchent, et des gerces et des fentes apparaissent dans leur bois par suite du séchage. L’état physique du bois a des répercussions sur sa transformation.

Cet document expose les connaissances actuelles concernant les propriétés, l’utilisation et la mise sur le marché du bois visité par des dendroctones du pin. Il s’inspire des informations disponibles dans les documents publiés et des résultats des travaux de recherche menés au Canada sur les propriétés du bois bleui et du bois mort. Les conséquences pour l’utilisation du bois provenant d’arbres tués par les dendroctones du pin pour la fabrication de divers produits sont discutées, les lacunes importantes en matière de données sont identifiées et des recommandations sont formulées concernant les travaux de recherche à effectuer pour combler ces lacunes.

Mots clés : *Dendroctonus ponderosae*; pin tordu; dendroctone du pin; *Pinus contorta*; traitement du bois; qualité du bois

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Introduction

In western Canada, the main host of mountain pine beetle (*Dendroctonus ponderosae Hopkins*) is lodgepole pine (*Pinus Contorta* var*. latifolia*). Periodic mountain pine beetle outbreaks normally cause catastrophic levels of mortality. Mature lodgepole pine form the bulk of this mortality. For example, in the central interior of British Columbia in 2003, the beetle attacked an estimated 173.5 million cubic metres of mature lodgepole pine, a 60% increase over the 2002 estimate. The beetle also threatens much of the province's remaining one billion cubic meters of mature pine (COFI 2003). Dealing with the large volume of killed trees has altered harvest schedules. Annual allowable cuts in infested areas is increased for the medium term; this will eventually be followed by a sharp decrease in harvest volumes. This reduction presents significant economic challenges for regional forest dependent communities.

The mountain pine beetle carries specific blue-stain fungi, such as *Ophiostoma clavigerum and O. monitum*, and possibly also *O. minus* and *O. ips* (Kim et al. 2003; Lee et al. 2003). These fungi interrupt water translocation, lower wood moisture content and weaken tree-defence mechanisms. Effects of the fungi, along with damage to inner bark and phloem caused directly by the beetle, eventually lead to tree death (Unger 1993). Dealing with the large volume of infested trees has disrupted orderly harvesting plans in British Columbia's central forest regions.

Sawmills in mountain pine beetle-infested regions will increasingly be processing beetle-killed lodgepole pine timber. This salvaged timber will be affected by blue stain; this will limit the kind of products that can be made from the wood and profitably sold. Because infested trees also develop splits and checks as drying stresses are relieved, the physical condition of the wood is altered. This, in turn, has implications for how it is processed. In this paper, we review the state of knowledge on the post-mountain pine beetle wood properties for use in solid wood products.

Shelf-life of standing dead lodgepole pine

Because trees deteriorate continuously after death both recovery volumes and values decrease with the amount of time that dead trees are left standing (Lowery 1982; Sinclair et al. 1977). Moisture, oxygen and temperature are factors that determine rate and extent of physical and biological deterioration of wood (Giles 1985). Secondary beetles, woodborers and decay fungi often also develop within the stem. How quickly lodgepole pine trees in beetle-affected regions of British Columbia deteriorate is unknown and is likely site specific—associated with microclimate and soil-moisture content. A climate-based index for determining overall decay hazard in wood that is not in contact with the ground (Scheffer 1971) may be a useful predictor of the rate at which decay sets in the part of the stem that is away from the ground. This index is based on mean monthly temperature and precipitation. The Scheffer Index has been calculated for only a few communities within the beetle-affected area (Setliff 1986), but shows large variation across the range of the beetle in the province's interior.

Water or snow storage can be used to control log deterioration over time; however, Rogers (2002) suggests that the economics of storing large volumes of wood in water are not compelling, and that beetle-killed trees can economically be stored only as standing dead. Lumber-recovery studies in the literature demonstrate varying shelf-life results. Significant economic losses have been shown after as little as 1 to 3 years (Fahey et al. 1986). At the other extreme, lumber production using standing dead grey-attack lodgepole pine trees before the bark has sloughed off has been shown to be profitable (Dobie and Wright 1978). Current volume and grade recovery information needs to be developed for post-mountain pine beetle lodgepole pine to predict what would occur in modern spruce–pine–fir lumber (SPF) sawmills.

Harvesting and lumber processing

A secondary effect of blue-stain fungi on mountain pine beetle-killed wood is excessive dryness: this poses technical challenges to wood use. Reid (1961) reported that the range in moisture content in the outer sapwood of non-infested live lodgepole pine is normally about 85% to 165% of oven-dry weight, with a steep moisture gradient from the outer sapwood to about 30% in the heartwood. In trees that have been infested by mountain pine beetle for one year, sapwood moisture content can be as low as 16%. Seasoning checks develop as the standing dead trees dry below the fibre-saturation point (~ 30% moisture content), and grey-stage trees usually end up with one or more major checks running from bark to pith (Fahey et al. 1986).

The forest products industry has traditionally been reluctant to handle dry, grey-stage logs. Work (1978) gives three types of losses associated with handling dead trees such as lodgepole pine:

1) Fibre loss and reduced volume of product outturn;
2) Quality loss from blue stain and decay; and
3) Product loss from physical characteristics such as splits and checking.

The biggest value losses in dead logs are associated with handling. Dry, brittle trees are more susceptible to breakage—11% in four-year-dead trees versus 0% in live trees (Work 1978). The processes of falling, skidding, loading, hauling, decking and feeding mills involve handling the wood with large machinery. Each of these phases is associated with handling losses, ultimately resulting in shorter lumber lengths of lower quality. Additional expenditure on smooth roads and yards has been recommended to reduce breakage during transport (Mancini 1978). Secondary problems with handling dead wood include safety concerns and harvesting costs (Mancini 1978, Kohrt 1978). Toppled trees cause delays in skidding and lower chipping productivity with portable chippers.

Dry logs delivered to the sawmill also present difficulties in the processing stage. Debarkers tend to become less efficient when handling dry logs, because the dry fibre is easily damaged. These machines are adjusted so as to minimize fibre damage as well as remove as much bark as possible—a balance that is especially critical with dry logs (Mancini 1978). Frequent switching between live logs and dead ones is likely to be problematic. Sheets of bark peeling off dead logs can jam debarking equipment (Sinclair and Ifju 1977). Modification of debarkers is required, and log ponds or spray washing of logs have been recommended (Mancini 1978); because of environmental reasons pertaining to run-off water, modern sawmills are reluctant to use these.

Dry wood requires more energy to saw. Saws and chipper and planer blades blunt faster, in part because of dirt and stones lodged in wood checks. Checks and splits in logs open up and reduce board width and length. When checked lumber breaks during processing, pieces can jam sawmill and planer machinery, which leads to downtime and reduced productivity.

Log scanners and sawing-optimization systems currently in use do not take checking into account. Logs are normally processed through sawmills without regard to checks. Mancini (1978) reports more than triple the normal green percentage of economy studs and lower mill productivity (by nearly half, in pure deadwood). The end result is a lower lumber-recovery factor, with smaller board widths and shorter lengths than would be obtained if checks were not present. Current sawmill-optimization technology may be adaptable to maximize recovery from beetle-killed logs; however, recent data on lumber and grade recovery from post-beetle logs are not available.

As beetle-killed lumber is leaving the sawmill it may need additional sorting based on moisture content prior to kiln drying. Lumber from dead trees also results in a disproportionate amount of product re-inspections when received by customers (Wallace 1978). For exporters, re-inspections in the marketplace are expensive, and often result in settlements at lower value than the originally agreed-upon selling price.

Appearance grades and value-added wood products

Within days of successful attack by mountain pine beetle, pigment usually begins to develop in the fungi. This produces the blue colour of blue-stained wood (Safranyik et al. 1974). By the time identification of attack can be detected from crown characteristics, more than 50% of the cubic volume or nearly 100% of the sapwood is stained (Harvey 1979). Blue stain affects the sapwood and is the most visible characteristic of beetle-damaged wood.

Attempts have been made to market blue-stained wood products as an appearance- or “character-” grade product after large bark beetle outbreaks in the United States. Blue-stained mountain pine beetle pine was reportedly sold in Colorado for exterior siding and fencing, interior paneling, furniture and other products under names such as “Primitive Pine” and “Blue Mountain Pine” (Howe 1978). Currently, no products are marketed under such names, indicating lack of market success. At about the same time, similar seems to have been limited, as no commercial producers supplied blue-stained products (Levi 1978). The current attack in British Columbia has also spawned similar marketing attempts such as “Denim Pine®” and “Blue Pine” products. However, markets for blue-stained appearance products seem to be very limited niche markets with little chance of moving large volumes of wood.

Available research on consumer reaction to blue-stained wood in appearance-grade products is sparse. Fell (2002) conducted a consumer-preference test of various wood species for appearance-grade end uses and included blue-stained lodgepole pine. Heavily blue-stained lodgepole pine wood was highly noticeable by survey respondents and largely disliked for all appearance end-uses. Consumers overwhelmingly chose other non-stained wood of any species over heavily blue-stained pine. This explicitly demonstrates consumers' willingness to discriminate between wood products on the basis of the blue stain. A small proportion of participants found blue-stained wood "interesting"—perhaps indicative of a niche market. Still, a small amount of lightly blue-stained wood could possibly be included in some appearance grades, as respondents noticed lightly blue-stained wood less than natural lodgepole pine colour variation between heartwood and sapwood .

Grading rules for appearance products also restrict blue-stained products from higher grades. For example, in "B and better—1 and 2 Clear" select white pine boards, blue stain is limited to "light in an occasional piece over not more than 10% of the face" (National Lumber Grades Authority 2003). Japanese lumber purchasers limit the amount of blue stain in their structural products. They often negotiate a special "J-grade", primarily of the highest-grade timber. This grade is usually very restrictive towards blue-stain content and is therefore both an appearance and structural grade.

Although most of the rationale for not choosing blue-stained wood is likely aesthetic, some motivations are based on incorrect perceptions. For instance, the Japanese Forestry and Forest Product Research Institute indicates that Japanese customers question the soundness of the wood, because they associate blue stain with the first stages of decay. Although this may be the case in regard to other fungal staining, this is not the case with respect to mountain pine beetle blue stain. Further, the Japanese translation of "mountain pine beetle" is similar to that of the Japanese Sawyer Beetle (*Monochamus alternatus*)*.* This is regrettable given that the *Monochamus* genus is the primary vector for the pinewood nematodes that have caused major losses in pine timber in Japan and China (Dwinell 1997; USDA 2002). Although these perceptions are inaccurate, they create major barriers to entry into markets outside North America.

Clearly the marketing and sale of a large quantity of blue-stained wood for appearance-grade value-added products will require major promotion. As in the past, many consumers may confuse blue stain with mould, thereby reducing demand for the product. Although not regarded as a defect in most construction-grade solid wood, an excess of stain makes marketing of the wood more difficult. Regardless of whether the end use of blue-stain wood is structural or visual, appearance problems associated either with misconceptions or with aesthetic displeasure will reduce demand.

Strength of structural products

Most SPF lumber is sold for structural use. Blue stain is not regarded as a defect in most structural softwood lumber-grading rules. For structural lumber, firm blue-stained wood is permitted in all grades; only in the "Select Structural" grade is amount of stained sapwood limited. Although the assumption of the forest products industry is that firm blue-stained wood is as sound as non-stained wood, until recently, there were no test data available to demonstrate this belief.

The effects of blue-stain fungi on wood strength are highly dependent on wood and fungus types. Certain blue-stain fungi of tropical and hardwood species cause decay that degrades wood strength (e.g., *Botrydiplodia theobromae,* Encinas and Daniel 1995; *Ceratocystis fagacearum*, Sachs et al. 1970; scheffer 1973). According to the literature, the effect of blue-stain fungi on temperate pine species is unclear. However, reduced impact bending strength, a measure of a wood's toughness, has been reported (Wilcox 1978). Some work has found no discernable strength-reduction effect without severe staining; other work found a 30% loss in impact bending strength (Scheffer 1940: Findlay and Pettifor 1937; Chapman and Scheffer 1940). A study on southern pine beetle-killed timber indicated a reduction of 30% to 40% in toughness, of 11% in stiffness or modulus of elasticity, and of 19% in breaking strength or modulus of rupture (McLain and Ifju 1982). None of this work tested lodgpole pine affected by fungi specifically associated with mountain pine beetle. However, Forintek Canada Corporation (Forintek 2003; Byrne 2003) recently completed a project designed to provide information on the strength properties of mountain pine beetle-killed lodgepole pine. Lum (2003) compared mechanical properties of lodgepole pine sapwood containing beetle-transmitted blue stain with those of non-stained sapwood harvested from the same region. No significant difference in density between the two types of wood was found. When standard test methods were used, blue-stained and non-stained woods were found to have comparable clear wood-bending strength (modulus of rupture) and stiffness. A 5% lower mean toughness was found in stained specimens, but this was only marginally significant. The small difference in toughness associated with blue-stained mountain pine beetle wood clear specimens would likely be masked in full-size pieces of lumber by the differences in mechanical properties of the heartwood and sapwood, and strength-reducing growth characteristics such as large knots. It is also important to note that the 5% loss in toughness that was detected is much lower than the levels reported in scientific literature for other blue-stain fungus–wood species combinations.

Member parts of engineered wood products are glued or mechanically fastened together, and some are highly stressed in tension, so blue-stain wood tension-loading capabilities are important. Lum (2003) performed a metal-plate-connected "tension splice" test to examine the holding ability of fasteners on blue-stained wood compared to unstained wood. The tension splice is a critical joint found in virtually all metal-plate-connected wood trusses. The truss grip capacity of stained wood was 6% higher and statistically significant; the mean slip at ultimate load was 4% higher, but not significant. When based on the load at a connector plate slip of 0.016 inches (0.4 mm) relative to the wood member, the blue-stained sample also had a 6% higher capacity than the non-stained sample. Although the improvement rates found are unlikely to be economically exploitable by industry, they do show blue stain does not weaken the wood.

The overall conclusion is that the beetle-transmitted blue stain does affect mechanical properties of lumber. However, these tests were done on material that was probably cut from recently dead trees (green- or red-stage attack). As the trees proceed towards grey-stage attack and if dead trees are left standing, it is possible that incipient decay will set in and strength properties be affected.

Dimensional stability of wood in service

McFarling and Byrne (2003) studied the dimensional stability of blue-stained mountain pine beetle wood and observed initially that it tended to have different checking patterns than non-stained sapwood does. Pieces of blue-stained and unstained 2 x 4-in. lodgepole pine lumber were studied by repeatedly subjecting them to wetting–drying cycles. Amount of bow, crook, cupping, twist, and checking was measured after each cycle. Blue-stained wood exhibited both more dimensional stability and greater permeability. In blue-stained wood, stresses appeared to be relieved by many micro-checks rather than by fewer large checks. Field tests of preservative-treated decking were installed to observe wood dimensional stability over extended wet and dry cycles. The tests found little difference between the checking of stained and unstained wood, and no discernible movement was detected due to secure fastening of deck boards.

Gluing and finishing of wood in value-added uses

Lodgepole pine is a wood species well suited to value-added uses requiring gluing and finishing such as structural glue-laminated beams and furniture. Increased permeability noted in dimensional-stability tests indicates possible irregular absorption or over-absorption of finishes and glues (Levi 1981). To determine possible effects of higher permeability, Williams and Mucha (2003) examined finishing characteristics of edge-glued panels with alternating stained and non-stained laminates.

Finishes were chosen to either enhance the character of the wood or to diminish the contrast between stained and non-stained portions of wood. The increased permeability of blue-stained wood did not affect the evenness or adherence of any of the finishes tested. However, finishes containing blue, red, and charcoal tints in the stain, toner, or glaze coatings tended to better mask blue stain. Edge-laminated panels were used to test strength and durability of glue lines when structural (phenol resorcinol formaldehyde) or non-structural (polyvinyl acetate) adhesives were used. Presence of blue-stained lodgepole pine at glue joints made no difference to shear strength and durability of joints with either adhesive. All joints exceeded American Society for Testing and Materials standard test requirements. Clearly, presence of blue stain in lodgepole pine need not hinder furniture production provided a natural finish to highlight blue-stain contrast, or a dark finish to mask it, is acceptable to the consumer.

Kiln drying of lumber

Drying of beetle-killed wood provides special challenges for the lumber industry. This is because beetle-killed lodgepole pine typically has a moisture content, on average, of 20% to 30% of oven-dry weight one year after attack—well below normal levels for live-cut lodgepole pine timber (Reid 1961, Tegethoff et al. 1977, Lieu et al. 1979, Lowery and Hearst 1978). Koch (1996) summed up the problem when he wrote, “dead beetle killed lodgepole pine … if mixed with green timber and dried on a standard kiln schedule will be degraded from overdrying”. Kiln-drying schedules for beetle-killed lodgepole developed by Nielson and MacKay (1986) show explicitly the longer drying times required compared to a standard schedule developed by MacKay and Oliveira for live-cut wood (1989).

Apart from difficulties resulting from differing moisture contents in healthy and beetle-killed lodgepole pine, a number of issues must be resolved before kiln-drying properties of mountain pine beetle lodgepole pine can be understood. The higher permeability and microchecking of beetle-killed lodgepole pine (McFarling and Byrne 2003) may effect kiln-drying characteristics. Customized optimum schedules for very dry wood that ensure the lumber achieves the minimum 56° C for 0.5-hour core-wood heating necessary for heat-treatment phytosanitary certification may need to be developed. Answers to these questions should maximize the value of kiln-dried, beetle-killed timber.

Veneer and plywood manufacture

Various researchers have looked at processing beetle-, fire- and storm-damaged wood for veneer and plywood, (Nielson 1985; Nielson and Wright 1984; Giles 1985; Reiter 1985; Walser 1985; Unligil and Shields 1979; Peralta et al. 1993; Snellgrove and Ernst 1983; Walters and Weldon 1982; Woodson 1985). A general observation from the veneer studies was that the most serious problems experienced while processing beetle-killed timber are reduced veneer yield and reduction in full-sheet recovery. Walters and Weldon (1982) found beetle-killed southern pine trees at 90 to 180 days after kill produced 9% less veneer volume, fewer full sheets and a higher percentage of random-width veneer. Snellgrove and Ernst (1983) found a 30% reduction in volume recovery and a higher percentage of random-width veneer in lodgepole pine that had been dead for three years prior to harvesting. The increase in random width veneer volumes can be expected to negatively affect mill operating margins. Recent statistics reported in the trade publication, *Random Lengths*, indicated a price spread of approximately $60 per cubic metre between full sheets and random-width veneer in 2001. A study of beetle-killed spruce carried out at a Prince George plywood plant found that the greatest loss of value came from dry wood and checking (Reiter 1985). Most of the blue stain was lost in roundup. Losses due to more spinouts during peeling of low-moisture content logs were also anticipated.

Wang and Dai (2004) completed a project that examined veneer-peeling issues for beetle-killed lodgepole pine. The objective was to attempt to maximize veneer value from this resource. Because of increased permeability and dryness, post-beetle salvage logs can be thawed more easily in winter and dried faster than normal logs. These characteristics present an opportunity to reduce costs by using different log conditioning, veneer peeling, and drying parameters. Laboratory tests, pilot plant, and mill trials were conducted to quantify the impact of using post-mountain pine beetle logs for veneer manufacture, and to determine optimum manufacturing strategies for conditioning, peeling, and drying. Wang and Dai (2004) found that:

1) Proper log conditioning is key to improve veneer recovery from beetle-killed logs;
2) Lathe settings also have a pronounced effect on veneer quality and veneer recovery; and
3) Compared to the control (green veneer), green veneer from mountain pine beetle wood has lower moisture content and smaller moisture content variation.

In general, veneer from mountain pine beetle-killed wood can be clipped more narrowly, with an equivalent of 1% increase in recovery because of smaller width shrinkage, and be sorted more accurately, requiring only two green sorts: heart and light sap. Beetle-wood veneer can be dried faster, with a reduction in drying time by about 35% for the light sap veneer. Despite a 1% increase in recovery from veneer clipping and a 27% increase in productivity from veneer drying, the recovery of mountain pine beetle logs was overall about 8% lower than that of control logs. This lower value represents the higher percentage of narrower random sheets, waste from peeling, and increased manual handling and composing. It was noticed that the blue-stain colour of beetle-wood veneer interfered with camera vision grading systems. Since mountain pine beetle-killed wood is drastically different from other species in terms of moisture content and subsequent processing characteristics, it is recommended that this wood be sorted in the log yard and handled differently than normal green wood.

Composite wood-based panelboard production

Current trends and related literature provide insights into the feasibility of converting beetle-killed wood into composite wood panel products such as medium density fibreboard (MDF) and oriented strandboard (OSB) but more research is needed. Lodgepole pine has long been identified as having all the desirable characteristics for composite wood product production (Maloney 1981). Additionally, British Columbia and Alberta producers already make use of lodgepole pine residues from lumber production for MDF, and producers in the southern U.S. make use of other pine species for OSB production. In terms of MDF and OSB capacity, there is reason to believe beetle-killed lodgepole could be used if some adjustments are made in the manufacturing process. The question is whether the characteristics of blue-stained mountain pine beetle lodgepole pine are of appropriate quality to produce these products economically.

If the fibre were suitable, physical potential exists to make use of some of the beetle-affected volumes—probably less so with MDF than with OSB. There are two MDF mills in western Canada, with a total capacity of about 260 MSF 3/4". Potential levels of volume utilization are difficult to determine, as MDF mills rely on residues. Existing plants rely on local residues because they are expensive to transport. Although moisture loss is a detriment to strandboard, it could be a boon to fibreboard products: as dead timber dries, it becomes lighter, which reduces transportation costs, and requires less drying time, which can save production costs. Koch (1996) notes that although lodgepole pine is not a primary source for fibreboard (i.e. MDF), it is a suitable fibre source. He goes on to write, “one plant in Whitecourt, Alberta uses significant quantities of lodgepole pine”, and that after a beetle outbreak in the late 1980s to 1990s, “plants [MDF] in eastern Oregon used high percentages of lodgepole pine salvaged from extensive bark beetle-killed stands” (Koch 1996).

As discussed above, a small amount of lodgepole pine finds its way into OSB, but the preferred wood species in Canada is aspen, which is cheap and widely available. Preliminary work at Forintek indicates that the quality of OSB panels derived from 100% mountain pine beetle-killed wood, whether standing dead for 2 or for 20 years, would not be acceptable in the marketplace due to greatly reduced water-resistance properties and dimensional stability. These panels, made using the current aspen panel manufacturing conditions, were not able to meet the Canadian Standards Association (CSA) panelboard standard for OSB thickness swell after a 24-hour water soak, or for modulus of rupture retention after the accelerated-aging test. Only when adhesive loading was increased dramatically did OSB panels made of 100% mountain pine beetle wood meet CSA standards; however, adhesive loading is uneconomical.

This experience contrasts with older literature on panel production that needs to be reinterpreted in light of modern product standards, product application requirements, manufacturing economics and industry practices. Thirty years ago, Maloney et al. (1976) conducted a study on making composite panel products from standing dead white pine and dead lodgepole pine in the U.S. They concluded that the dead material of both white pine and lodgepole pine could be used effectively in making particleboard, MDF and flakeboard (a precursor to OSB). Their experimental data have great reference value. For example, they showed that lodgepole pine composite panels have relatively poor linear expansion, exceeding commercial standards, except in flakeboard. This would, therefore, raise serious concerns today in the manufacture of particleboard or high-density fibreboard for flooring—applications that are very important for these two products now, but were not 30 years ago. In the flakeboard experiments with dead lodgepole pine, high thickness swell and water absorption was observed. This is similar to recent findings at Forintek, and warrants concern in the context of modern product requirements: although boards made by Maloney et al. met the standards of the time (circa 1976), they would not meet market standards today, which are more demanding.

Koch (1996), in summarizing other authors studying beetle-killed lodgepole, found that “quite acceptable structural flakeboard could be made from the species, whether trees were live or dead at time of harvest” (Koch 1996, Heebink 1974, Ramaker and Lehmann 1976, Price and Lehmann 1978). In his study of comparative economics of manufacturing composition boards from dead timber, Maloney (1981) concluded that equipment modifications for composite-board plants using the dead tree resource would not be major when compared to plants operating conventionally. Furnish preparation using cutting knives would probably be subjected to more wear and maintenance when cutting the dead trees into furnish. Extra screening capacity would also be necessary as more fines are generated, resulting in lower rates of timber-volume utilization. This is due to deterioration of the wood and, in the case of OSB, moisture loss. To be an acceptable product, OSB requires quality strands and the smallest amount of fines, because fines consume excess amounts of resin binder and contribute little to mechanical properties. This is significant, as logs dried to an average 50% moisture content produced nearly double the fines relative to green logs (Knudson and Chen 2001). Beetle-killed lodgepole pines can be at 20% moisture content one year after attack (Reid 1961). In addition to these findings, the Forintek preliminary study showed that at least 30% more adhesive would be needed to produce commercially acceptable OSB panel products from dead lodgepole pine. It is estimated that even a 10% increase in resin use to manufacture OSB from mountain pine beetle-killed pine would be uneconomical, because it would increase costs by approximately $1.7 million per plant per year.

Overall, using beetle-killed lodgepole pine poses potential problems for panel production. Panel products made from beetle-killed lodgepole will contain blue stain and, coupled with lower timber recovery and utilization rates, will face lower demand with relatively higher production costs.

There is also uncertainty around the potential of creating additional markets for panel products from British Columbia. Questions remain that need to be resolved in order to understand the role panel products can play, such as: does increased permeability of blue-stained lodgepole pine (McFarling and Byrne 2003) provide and opportunity to mitigate lower moisture levels? Does blue stain inhibit properties of adhesives and strength of panel products? How long is beetle-killed timber suitable for making various panel products?

Preservative treatment

Some of the literature indicates that blue-stained wood may be less resistant to decay fungi than non-stained wood (Findlay 1939; Scheffer 1940) This is largely due to increased permeability that allows for greater water penetration. Increased permeability of other (non-mountain pine beetle) blue-stained wood has been demonstrated (Scheffer 1969) and therefore might be anticipated in products made from beetle-affected stands. Preservative-treated wood products are thus an obvious candidate end use for post-beetle wood; some studies on this have been documented in the literature.

Dead lodgepole pine has been recognized as suitable for preservative-treated products such as fence posts and utility poles (Lowery and Hast 1979). Tegethoff et al. (1977) suggest that decayed parts of dead pines could be trimmed prior to making poles, but recommend that beetle-killed trees suitable for poles should be harvested soon after death to avoid incipient decay. Lowery and Hast (1979) found that pressure treatment of posts and poles from dead lodgepole pine resulted in retentions exceeding minimum specification requirements. McFarling and Byrne (2003) quantified uptake of liquid during soaking or pressure treatment of both blue-stained (from mountain pine beetle-killed trees) and non-stained lodgepole pine lumber. Increased permeability of blue-stained sapwood was confirmed by data showing enhanced chromated copper arsenate uptake and penetration. These authors suggest that the mechanism for increased permeability is probably the opening up of ray parenchyma cells by blue-stain fungi, and the microchecking that could be observed on some lumber samples. One implication of stained sapwood treating more readily than non-stained wood is that stained wood might be liable to be over-treated when processed in mixed batches with non-stained wood. CSA standards require treatment of both heartwood and sapwood; consequently, improved sapwood permeability may be of limited advantage to producers, or may even result in higher costs due to excess uptake.

Other wood products that use preservatives include decking and treated framing lumber (Vlosky and Gaston 2004). Manufacturers in the southern U.S. treat some framing lumber (which may include imports from Canada) with disodium octaborate; a blue dye is added to the otherwise clear treatment solution to enable the treated wood to be differentiated from non-treated wood. This blue dye could mask blue stain in lumber harvested from infested stands, while the borate would impart durability. Wood for exterior decking is treated with copper-containing preservatives. The green colour of the treated wood also masks the blue stain, creating durable products that avoid marketing problems associated with blue stain.

Log-home manufacturing

Standing dead lodgepole pine trees are dry, seasoned, plentiful and relatively cheap; as such, they can make ideal material from which to manufacture log homes (Peckinpaugh 1978, Hamilton 2001). Making log homes with dead trees has been done for many decades in the northern U.S. Most logs are shaped with a planer, turned on a lathe, or sawn on two sides. Log homes are built at the buyer’s site or are pre-built at a construction plant. Poor-quality logs are not used for log homes: a basic level of quality is required. Peckinpaugh (1978) provides the following quality parameters for log-home logs: they should be free from rot, have no spiral checks, have no check larger than 0.635 cm., be at least 17.78 cm. in diameter, be at least 4.88 metres long, be straight, have no crook, have minimal sweep, and taper less than 7.62 cm. in 12.2 metres. Douglas-fir is the species most frequently used by British Columbia log-home manufacturers, although cedar, spruce and pine are also used to a significant degree (Thony 2004, Wilson et al. 2001). Beetle-killed trees that meet house-log specifications may have potential use in the log-home manufacturing sector. Some recent use as such has been documented (Stirling 2002, Thony 2004). The log-home industry consumes only a small proportion of the province's total harvest, however, which makes it unlikely to absorb much of the current outbreak volume.

Fuel pellet, wood energy and firewood production

Burning wood for energy has been proposed as a possible use for some volumes of beetle-killed lodgepole pine. Although domestic stoves, furnaces and fireplaces could make use of some logs, more compelling options involve industrial production of fuel pellets, electricity and heat. Large, commercial-scale wood-pelletization plants already in operation in the beetle-infestation area consume large volumes of residual fibre from other processing facilities. For example, one plant produces 200,000 tonnes of pellets per year, making use of approximately 1.22 times that volume in wood residual feedstock (CFDA 2005, B.C. Hydro 2004, Damen and Faaij 2003). As well, there are multiple co-generation plants and at least one plant producing direct electricity in British Columbia. Stennes et al. (conference presentation 2004) estimate these plants produce 600 to 650 MW per year of provincial woody biomass power capacity, using more than 3 million bone-dry tonnes of wood residues. Although these projects are certainly compelling examples, there are a number of issues to be considered before accepting the feasibility of using beetle-killed pine for energy purposes.

Potential for bioenergy from beetle wood in the form of pellets or energy depends heavily on costs for production, not technical feasibility. Most literature points to feedstock costs as a critical factor in economic feasibility of biomass-energy production. In British Columbia, current bioenergy depends on residual wood fibre delivered at little or no cost to production facilities. However, if direct salvaged beetle-killed lodgepole pine were used to procure wood fibre, costs of energy and pellets production could potentially double or triple. Also, given the extensive nature of the beetle-infestation area, costs associated with trying to harvest and transport wood fibre to new centralized bioenergy facilities could be daunting. Related costs include fixed-capital costs for bioenergy facilities, which tend to be exceptionally high in the cases of co-generation and electricity plants. Generally, bioenergy facilities need a low-cost feedstock, such as wood residuals, in order to be feasible and also often need a long-term fibre supply in order to pay off facility capital costs.

With regard to wood-fibre supply, both direct energy conversion and pelletization face a similar problem: potential long-term fibre-supply shortage. Current estimates show that in 15 years, British Columbia may face drop of almost 12 million m^3 in annual allowable cut from current beetle-induced uplift cut volumes (Pedersen 2004). Volumes of unused residual wood from pre-uplift levels remain available (B.C. Hydro 2004, Stennes et al. conference presentation 2004); additional capacity at existing pelletization plants (CFDA 2005), coupled with current proposed projects, will likely use these volumes. This is significant, as annual allowable cut reductions in 15 years will ultimately translate into a reduction of residual volumes below pre-increase levels. The result would be, assuming constant current costs, any new bioenergy projects for beetle-killed wood likely need to be able to pay off their fixed capital costs before the reduction.

Although there are cost and supply concerns, there are also benefits specific to bio-energy products. Fuel pellets offer several benefits over wood chips and other forms of combustible wood material: they are a stable product and have significant advantages in terms of transportation, storage and handling. Processing also reduces phytosanitary concerns associated with the output of “green” wood products. As transport costs of biofuels do not depend on type of product but primarily upon product bulk and moisture content, lower transportation and storage costs are achieved through compacting of wood fibre (Suurs 2002). As well, as energy from wood ultimately replaces other energy sources and produces fewer carbon emissions, Canada’s Kyoto Protocol commitments could provide a source of carbon credit benefits. Wood-energy options may even be feasible without construction of additional facilities as, with limited modifications, 10% biomass can be co-fired in existing coal plants (Stennes et al. 2004).

Examples of economically feasible wood-energy use exist in British Columbia, but more work needs to be done before additional capacity is installed. Costs associated with accessing the beetle-killed fibre supply, and issues regarding long-term annual allowable cut levels of the supply complicate options. Although benefits associated with any carbon credits, lower transportation storage costs may mitigate overall product costs, it is not evident these would be sufficient to make new production facilities economically feasible. As such, use of additional wood fibre residuals may be limited to existing facilities for the time being. On the whole, questions concerning salvage and transportation costs, carbon credit benefits, feasibility of co-firing and the shelf life of beetle-killed wood and biofuel need to be resolved.

Summary and research needs

Challenges associated with manufacturing solid wood products from beetle-affected timber stands exist through all phases of production, including harvesting, transportation, log storage, processing, and end-product marketing. However, timber stands left in the wake of the current mountain pine beetle outbreak represent a significant economic resource; economic uses of this resource need to be carefully considered. A key issue is the amount of time, or shelf life, that is associated with capturing economic values, and how this may vary between locations. Upon reviewing the literature, it is clear much of the available research information is based on research conducted 20 or more years ago. There is need to update the research base to reflect current processing techniques, current equipment technology, and markets, and to explore research questions that remain unanswered.

With respect to research, high-priority needs include:

- Assessment of the deterioration of post-mountain pine beetle stands as a source of solid wood products, and how this varies across site and stand types;
- Measurement of the impacts of processing grey-stage logs on value and volume recovery;
- Examination of mechanical properties of grey-attacked wood over time as it goes into mill production;
- Determination of drying properties of blue stained wood versus non-stained wood;
- Examination of post-mountain pine beetle veneer on panel lay-up and hot pressing, product grade, panel stiffness and bonding strength; and
- Measurement of chemical characteristics of post-mountain pine beetle wood and impacts on bondability and wetability in panelboards.

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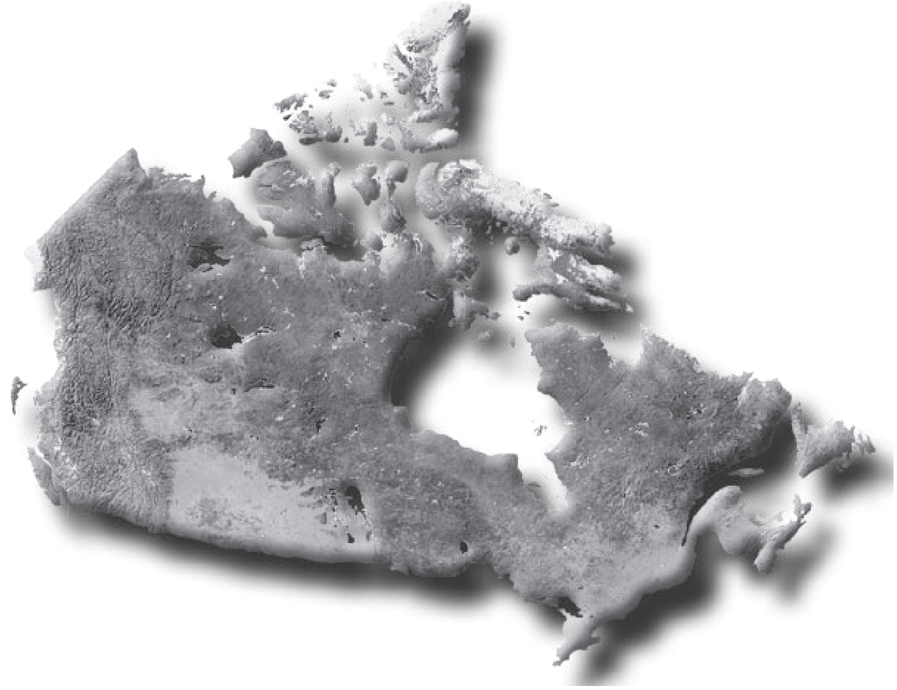

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