Extracting Greater Value from the B.C. Alpine Fir Wood Resource

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Summary

Alpine fir (*Abies lasiocarpa*, (Hook.) Nutt.) is one of four species classified together by BC lumber manufacturers as Spruce-Pine-Fir (SPF), the other species being white spruce (*Picea glauca* (Moench) Voss), Engelmann spruce (*Picea Engelmannii* Parry) and lodgepole pine (*Pinus contorta* Doug]. Of the four species, alpine fir is considered the least desirable because of its relatively low wood density, high moisture content, occurrence of high moisture pockets and lower drying rate compared to the other species. The predominant utilization practice in B.C. has been to process the four SPF species together for dimension lumber, with the residuals used for pulp and paper.

The availability of alpine fir is projected to increase significantly, and in some regions as high as 30% of the SPF mix. Therefore, the B.C. production of alpine fir lumber can conceivably increase to 1.5 to 2 billion board feet per annum within a relatively short period of time (i.e. 5 to 10 years). This project was carried out to investigate opportunities to extract the maximum value from the B.C. alpine fir resource by exploiting the attributes of alpine fir wood fibre and breaking down alpine fir logs to recover the highest value fibre for higher-margin products.

The project was carried out in four separate, inter-related studies:

- Industrial Computed Tomography (CT) Scanning of Logs
- Characterization of Basic Properties
- Suitability for Veneer Products
- Suitability for Specialty Lumber Products
  - Sawing and Grading of 5/4 inch Lumber
  - Drying of 5/4 inch Lumber.

Results from this study indicated that alpine fir has:

- Excellent dimensional stability in the edge grain (vertical grain) direction,
- Good recovery for 5/4 inch (32 mm) thick lumber,
- Limited clear grade lumber,
- Satisfactory performance for plywood and laminated veneer lumber (LVL) products, and
- More checking in the veneer than observed for other wood species.

A disadvantage of alpine fir is that it is not a durable wood, but an advantage is that it may prove treatable with new preservative technologies. We recommend further work to build on the knowledge developed in this project and address the durability issue of alpine fir by looking at the following three margin-added product applications where durability and dimensional stability are important:

- Exterior Cladding (treated and/or coated vertical grain lumber or laminated board for siding and fascia)
- Decking (treated vertical grain lumber)
- Permanent Wood Foundation (treated plywood, LVL and lumber).
Acknowledgements

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- CT Scanning: Sencer Alkan and Gabor Szathmary for their lead roles, along with Gerry Middleton, Dave Munro, Rowan Eberle and Peter Lister of Forintek for carrying out the CT scanning of the trees.

- Basic Properties: Doris Lougheed of Canfor Research for her lead role, and the two co-op students, Fiona Christensen (University of Victoria) and Brian Wong (UBC) for carrying out the thousands of basic property measurements.

- Veneer Products: Peter Ens and Ken Chan of Forintek for their lead roles and Gordon Chow for his assistance in carrying out the veneer peeling, drying, grading, plywood and LVL manufacturing and testing.

- Lumber Manufacturing: Laszlo Orbay for his lead role, along with Anthony Barbosa of Forintek and Igor Zaturecky and Isaac Chiu of Canfor Research for cutting, edging and grading the lumber.

- Lumber Drying: Luiz Oliveira and Dal Wright of Forintek for drying the lumber.
# Table of Contents

Summary .......................................................................................................................................................... i

Acknowledgements .......................................................................................................................................... ii

List of Figures .................................................................................................................................................. iv

1 Objective ....................................................................................................................................................... 1

2 Introduction .................................................................................................................................................. 1

3 Staff ............................................................................................................................................................. 2

4 Materials and Methods ............................................................................................................................. 3

4.1 Materials — Alpine Fir Trees .................................................................................................................. 3

4.2 Methods ................................................................................................................................................... 3

5 Results .......................................................................................................................................................... 4

6 Discussion ................................................................................................................................................... 4

6.1 Industrial Computed Tomography (CT) Scanning of Alpine Fir ................................................................. 4

6.2 Characterization of Basic Properties of Alpine Fir ................................................................................... 5

6.3 Suitability of Alpine Fir for Veneer Products .......................................................................................... 5

6.4 Suitability of Alpine Fir for Specialty Lumber Products ......................................................................... 6

6.4.1 Lumber Manufacturing of 5/4" Alpine Fir Lumber .............................................................................. 6

6.4.2 Kiln Drying of 5/4" Alpine Fir Lumber ............................................................................................ 6

7 Conclusions ................................................................................................................................................ 7

7.1 Industrial Computed Tomography (CT) Scanning of Alpine Fir ................................................................. 7

7.2 Characterization of Basic Properties of Alpine Fir ................................................................................... 8

7.3 Suitability for Veneer Products .............................................................................................................. 8

7.4 Suitability for Specialty Lumber Products ........................................................................................... 8

8 Recommendations ..................................................................................................................................... 9

8.1 Preservative Treated Wood Products .................................................................................................. 9

8.2 Decking .................................................................................................................................................... 10

8.3 Exterior Cladding .................................................................................................................................. 10

9 References* ............................................................................................................................................... 11

| Attachment 1. | Computed Tomography (CT) Scanning of Alpine Fir Logs |
| Attachment 2. | Characterization of Basic Properties of Alpine Fir |
| Attachment 3. | Suitability of Alpine Fir for Veneer Products |
| Attachment 4. | Suitability of Alpine Fir for Specialty Lumber Products |
List of Figures

Figure 1: Alpine fir project organization chart ................................................................. 2
Figure 2: Unloading of alpine fir trees at Forintek lab in Vancouver ................................ 3
1 Objective

To investigate opportunities to extract the maximum value from the B.C. alpine fir (Abies lasiocarpa, (Hook.) Nutt.) resource by exploiting the attributes of alpine fir wood fibre and breaking down alpine fir logs to recover the highest value fibre for higher-margin products.

2 Introduction

Alpine fir is one of four species classified together by B.C. lumber manufacturers as Spruce-Pine-Fir (SPF), the other species being white spruce (Picea glauca (Moench) Voss), Engelmann spruce (Picea Engelmannii Parry) and lodgepole pine (Pinus contorta Dougl). Of the four species, alpine fir is considered the least desirable because of its relatively low wood density, high moisture content, occurrence of high moisture pockets and lower drying rate compared to the other species. The predominant utilisation practice in B.C. has been to process the four SPF species together for dimension lumber, with the residuals used for pulp and paper.

B.C. lumber production is estimated at 13.5 billion board feet per year with about 11 billion board feet of SPF species. The current alpine fir share of the SPF species group is about 10%, which translates to over one billion board feet of lumber production annually. The availability of alpine fir is projected to increase significantly, and in some regions as high as 30% of the SPF mix. Therefore, the B.C. production of alpine fir lumber can conceivably increase to 1.5 to 2 billion board feet per annum within a relatively short period of time (i.e. 5 to 10 years). As an example, converting 150 million board feet (10% of the projected alpine fir volume) of alpine fir lumber to value-added products commanding US$100 / Mfbm premium will represent an additional value of US$15 million to the B.C. economy. The US$100 / Mfbm premium for value added products over structural dimension lumber is a conservative assumption, given that specialty lumber products and veneer typically command premiums of US$200/Mfbm and upward compared to structural dimension lumber [19].

Forintek, Canfor and others have carried out a number of studies of alpine fir. However, the majority of the work has been aimed at determining basic wood properties, sawing and drying of structural lumber in dimension sizes. Basic wood property studies have looked at things such as wood density, fibre dimensions, mechanical and chemical properties [1-3,5,7,8,18]. Several studies have evaluated lumber recovery factors for alpine fir [9,10]. Other studies have looked at drying of alpine fir dimension lumber, in particular looking at the influence of wet wood pockets on drying [4,6,13,14]. Forintek has carried out a limited amount of work evaluating alpine fir for veneer products, but that work was concerned with resin impregnation of the veneer to increase its strength properties for use in LVL [15,16]. Additional Forintek studies have looked at the suitability of alpine fir for pressure treatment [11,12], and its machining properties [17].

The project was structured in two parallel track project areas whose objectives were:
1. To generate greater in-depth knowledge of the fibre characteristics and properties within alpine fir trees, so that, better decisions can be made to extract maximum value;

2. To explore value-added product opportunities by exploiting the inherent attributes of alpine fir fibre for specific product applications including veneer products and appearance grade lumber products.

The work was carried out in the following separate, inter-related studies.

- Industrial Computed Tomography (CT) Scanning of Logs
- Characterization of Basic Properties
- Suitability for Veneer Products
- Suitability for Specialty Lumber Products
  - Sawing and Grading of 5/4 inch Lumber
  - Drying of 5/4 inch Lumber

### 3 Staff

Scientists leading the five individual studies comprising the overall project were:

Robert M. Knudson, Ph.D.  Team Leader, Composite Wood Products, Forintek
Kenneth K. Lau, M.S., P.Eng.  Research Scientist, Canfor Research and Development
Sencer Alkan, Ph.D.  Research Scientist, CT Imaging Centre, Forintek
Laszlo Orbay, M.Sc.  Research Scientist, Lumber Manufacturing, Forintek
Luiz C. Oliveira, Ph.D.  Group Leader, Lumber Drying, Forintek

Project organization is shown in Figure 1.

### Figure 1: Alpine fir project organization chart
4 Materials and Methods

4.1 Materials — Alpine Fir Trees

Canfor Woodlands’ staff selected five dominant, five co-dominant and five intermediate tree types from a typical stand of alpine fir trees in the Fort St. James region of B.C. The 15 trees were delivered to the Forintek facility on November 14th, 2002. Figure 2 shows the unloading of the alpine fir logs at Forintek. Three trees, one of each tree type (dominant, co-dominant and intermediate), were selected for CT scanning and basic property studies. A second group of three trees, again one of each type, were selected for veneer and specialty lumber products evaluations. Additional information regarding the trees selected for the different portions of the study can be found in Attachments 1 to 4.

Figure 2: Unloading of alpine fir trees at Forintek lab in Vancouver.

4.2 Methods

Procedures for the different studies are found in the attachments to this report:

- Industrial CT Scanning of Logs – Attachment 1
- Characterization of Basic Properties – Attachment 2
- Suitability for Veneer Products – Attachment 3
- Suitability for Specialty Lumber Products (Lumber Manufacturing and Drying) – Attachment 4
5 Results

Results of the different studies are found in the attachments to this report:

- Industrial CT Scanning of Logs – Attachment 1
- Characterization of Basic Properties – Attachment 2
- Suitability for Veneer Products – Attachment 3
- Suitability for Specialty Lumber Products (Lumber Manufacturing and Drying) – Attachment 4

6 Discussion

6.1 Industrial Computed Tomography (CT) Scanning of Alpine Fir

(see detailed report in attachment 1)

The objective of this study was to investigate the feasibility of using industrial x-ray tomography (CT) to visualize internal log defects such as wet-wood, knots, and cracks in alpine fir logs. Non-invasive scanning of logs (e.g. computer tomography (CT) scanning) has been used by researchers as means to determine internal log features. To put the internal information to its optimal use, a variety of methods have been employed to visualize, locate and identify log features in CT images. These studies, using medical CT scanners, have shown that different sawing methods utilizing internal defect data could potentially improve value recovery by approximately 10 percent over sawyer grade-sawing methods.

Sample logs from three alpine fir trees of one dominant type, one co-dominant type and one intermediate type, were scanned at cross sectional slice planes located 25 mm apart along their longitudinal axes. Tomographic reconstructions were made from the scan data collected at these planes. Preliminary software modules were used to visualize 2D log features and to identify log shape, pith, and sapwood-heartwood boundary from the reconstructed tomographic images.

This initial exploratory work has demonstrated that industrial CT scanning is a feasible tool to scan alpine fir logs because its design specifications offers flexible mechanical operation, high energy source, and high image resolution for large diameter logs. Ongoing research efforts enlist industry support to delineate operational parameters for various log scanning, build a technically sound Canadian wood fiber database, and improve image reconstruction and image processing algorithms. Although application of the software modules demonstrated good results, testing and evaluation of these modules with more log sample data to achieve statistical reliability are required.
6.2 Characterization of Basic Properties of Alpine Fir
(see detailed report in attachment 2)

The objectives of this study were:

- To generate the within-tree property data (i.e. shrinkage in the three anatomical directions, density and moisture profiles) for cross-sections of three alpine fir trees (one dominant, one co-dominant and one intermediate tree) to provide better insights for greater value extraction of the B.C. alpine fir wood resource, and

- To provide basic property data of cross-sections of the three trees for comparison/calibration of the CT scanned images (Attachment 1) of the log segments from the same trees.

The basic property database generated from this study provided insights to extract greater value from the B.C. alpine fir wood resource and provided the data for calibrating the CT scanned images of the log segments from the same trees. The database could also be useful for simulating the dimensional behavior of laminated products from laminates of different grain orientations or different moisture contents.

This study showed that alpine fir had the lowest radial shrinkage property among the SPF species. The mean radial shrinkage including all heartwood and sapwood samples of the three trees was 3.1% from green to oven-dry moisture content. This favorable radial shrinkage property of alpine fir opens up opportunities to produce margin-added vertical grain alpine fir products targeting applications requiring superior dimensional stability, for example exterior siding and cladding products.

A sawing/laminating strategy was also discussed in this study to produce predominantly vertical grain boards to exploit the favorable radial shrinkage property of alpine fir. The resulting vertical grain solid sawn or laminated boards would have superior dimensional stability (i.e. less warp, twist, and cupping). The proposed strategy was to sort the alpine fir lumber into flat grain and vertical grain lumber and to face laminate the flat grain boards into a laminated block. The laminated block would then be sliced into vertical grain laminated boards.

A recommendation of this study is to further investigate effective treatment solutions to enhance the durability of alpine fir for exterior applications and to exploit the unique dimensional stability property of vertical grain alpine fir boards for specific margin-added exterior product applications.

6.3 Suitability of Alpine Fir for Veneer Products
(see detailed report in Attachment 3)

A study was carried out to evaluate the suitability of alpine fir (Abies lasiocarpa, (Hook.) Nutt.) for the manufacture of veneer products including plywood and laminated veneer lumber (LVL). Logs for veneer products studies came from three alpine fir trees, one dominant, one co-dominant and one intermediate. The trees were considered representative of the site type and age class Canfor expects to be harvesting.
over the next period of years at the Fort St. James area. Processing of the alpine fir into veneer products was carried out in the Forintek Canada Corp. Composites pilot plant in Vancouver, B.C.

Study results indicate that alpine fir is a satisfactory species for manufacturing construction plywood or lower stiffness grade LVL. Visual grading identified only a small quantity of grade A veneer (8%). There were no clear, appearance grade veneers in the approximately 400 veneer sheets that were peeled from the three representative categories of trees. Stress grading identified approximately 78% of the veneer sheets as suitable for 1.5 million psi grade LVL. None of the veneer had sufficient stiffness for manufacturing 1.8 million psi grade LVL, the most common structural grade, except as inner plies in combination with higher stiffness species on the outside.

A characteristic of alpine fir veneer identified in this study was a strong tendency to check and split during drying. This characteristic could cause difficulty in commercial processing of the veneer. The incidence of checking and splitting observed in alpine fir was far greater than typically observed in other softwood and hardwood veneer species processed in the identical manner in other studies.

Based on the results of this study, two key evaluations of alpine fir for veneer products are recommended. The first evaluation is to determine whether incising the veneer combined with drying the veneer in a commercial dryer can reduce veneer splitting and checking. The second evaluation is to determine whether alpine fir plywood will treat satisfactorily with amine-copper preservative for the manufacture of permanent wood foundation (PWF) plywood.

6.4 Suitability of Alpine Fir for Specialty Lumber Products

(see detailed report in Attachment 4)

6.4.1 Lumber Manufacturing of 5/4” Alpine Fir Lumber

The objective of this study was to estimate the volume and grade of rough green lumber recoverable from B.C. Interior alpine fir stands. Three full-length trees of alpine fir were measured, bucked into sawlogs of 8 nominal feet, then sawn 5/4 inch thick boards and edged to wane free lumber. The resulting 4, 6 and 8” wide lumber pieces were tallied and graded. The average nominal lumber volume recovery of 301 fbm/m$^3$ indicates good potential for lumber recovery despite the fact that both sawing and edging resulted in fibre losses due to butt flare. The overall lumber volume proportions of 54.9, 22.6, 5.3 and 17.2 % for the four grades (1COMMON, 2COMMON, 3COMMON and 4COMMON) suggested good fibre quality.

6.4.2 Kiln Drying of 5/4” Alpine Fir Lumber

This study was carried out to evaluate the drying of 5/4 inch (32 mm) thick alpine fir lumber. Drying alpine fir freshly green can be quite challenging. On one hand, the wide distribution of the initial moisture content makes it difficult to estimate a significant average value to guide the initial drying conditions. On the other hand, it is necessary to ensure that enough heat reaches the lumber, otherwise
wet pocket areas will not dry and therefore create quality issues at the end of the drying process or during normal service conditions.

Lumber used for the drying study came from the lumber-manufacturing portion of the project. The approximately 1000 fbm (2.4 m³) lumber was dried in a single kiln charge of the Forintek 8-foot kiln using a moderate drying schedule designed to maximize grade recovery.

The alpine fir lumber used for the study had mean green moisture content of 58.5%, with maximum and minimum individual board moisture contents ranging between 130.1% and 38.1%. This wide moisture content distribution is characteristic of alpine fir. All 200 boards were graded before and after drying by the same trained Canfor grader. Estimated degrade loss due to drying was approximately US$189 per Mfbm. The estimated degrade loss is significantly high. The results obtained in this study should be interpreted as preliminary results because of the following:

- sample size not large enough to allow definitive conclusions regarding grade recovery,
- insufficient lumber to carry out additional drying runs which should be used to validate and/or refine the proposed drying schedule, and
- appropriateness of grading the lumber before planing since it would be expected that a significant portion of the observed warp could be removed during this operation, or some uses such as laminating stock could tolerate a degree of warp.

For these reasons the amount and value of lumber degrade observed in this short study may considerably over-estimate the amount and value of degrade that would occur in a commercial practice. Additional drying studies involving a larger sample size and an industrial phase to validate the findings obtained during the laboratory study are recommended.

### 7 Conclusions

#### 7.1 Industrial Computed Tomography (CT) Scanning of Alpine Fir

- CT scanning is a feasible tool to scan alpine fir logs to identify internal log information such as wet-wood, knots, pith location, heartwood-sapwood boundary and cracks.
- The use of the CT scanning technology to determine the log shape and internal log information in combination with an effective sawing software to determine optimum cutting solutions can increase the lumber value recovery of alpine fir logs.
- Further ongoing research efforts are needed to delineate operational parameters for log scanning, to build a technically sound database for alpine fir, and to improve image reconstruction and image processing algorithms are still required.
7.2 Characterization of Basic Properties of Alpine Fir

- The results showed that alpine fir had the lowest radial shrinkage property among the SPF species. The mean radial shrinkage including all heartwood and sapwood samples of the three trees was 3.1% from green to oven-dry moisture content.
- This favorable radial shrinkage property of alpine fir opens up opportunities to produce margin-added vertical grain alpine fir products targeting applications requiring superior dimensional stability, for example exterior siding and cladding products.
- The durability issue of alpine fir will have to be addressed for exterior product applications.
- There was no obvious correlation of radial shrinkage to specific gravity.
- A slight trend of increasing radial shrinkage from the butt to the crown position was observed.
- The data also showed the heartwood to be more dimensionally stable than sapwood.
- Tree 3 (the intermediate type) had the lowest radial shrinkage in both heartwood and sapwood.
- The moisture content and density cross section profiles from this study can be useful for calibration, improvement and/or further development of the CT scanning software modules.

7.3 Suitability for Veneer Products

- Alpine fir produced satisfactory plywood and LVL.
- Visual grading of the veneer yielded 8% Grade A, 24% Grade B and 68% Grade C. No clear, appearance grade veneer was generated. All veneer sheets contained at least one knot, but splits and checks were the controlling grade factor for the majority of veneer sheets.
- Stress grading of the veneer indicated 78% of the veneer was suitable for 1.5 million psi (10.34 GPa) grade LVL. The 1.5 million psi grade LVL is a lower structural grade. None of the veneer was suitable for the 1.8 million psi (12.41 GPa) grade LVL, which is the most common structural grade.
- Alpine fir had a strong tendency to check and split during drying. The incidence of checking and splitting observed in alpine fir was far greater than observed in other softwood and hardwood veneer species processed in the identical manner.

7.4 Suitability for Specialty Lumber Products

- The 5/4 inch sawing results showed good volume and grade recoveries for the sample sawlogs live-sawn on a horizontal band saw of a WoodMizer portable sawmill.
- The thin saw-kerf and accurate log positioning achieved on the WoodMizer portable sawmill might be difficult to achieve in a production sawmill environment.
- Significant volume losses were observed during the breaking down of logs and edging of boards. One cause of the significant losses was heavy taper of some of the logs.
- The sawing method resulted in a relatively large proportion of flat grain lumber as opposed to vertical grain lumber of higher value.
- The intermediate tree yielded 85.8% (the highest percentage) of the #1 Common grade lumber versus 54.9% for the dominant tree and 31.9% for the co-dominant tree.
The results of the drying study for one kiln charge of rough alpine fir lumber with a mean green moisture content of 58.5% yielded a significant loss in value (about US$189/Mfbm) due to drying degrade.

Planing of the lumber would reduce warp significantly and thus reduce drying degrade.

The overdrying of the kiln load (final average moisture content of 10.7%) versus the target moisture content of 12% might have contributed to more warp.

Drying of unsorted alpine fir lumber to a target moisture content within a reasonable drying time would be hard to achieve.

Green sorting prior to drying and a lower temperature / longer drying schedule would increase grade recovery.

Weight restraint during drying would also improve grade recovery.

8 Recommendations

This project identified that the vertical grain shrinkage property (i.e. radial direction) of alpine fir is the lowest among the Spruce-Pine-Fir species. This favorable shrinkage property of alpine fir opens up margin-added product opportunities where dimensional stability is important and if the durability issue of alpine fir can be addressed.

Our recommendations are to:

- Exploit the favorable radial shrinkage property of alpine fir for margin-added exterior products requiring superior dimensional stability.
- Investigate cost effective treatment solutions (i.e. preservative treatments and primer / topcoat treatments) to enhance the durability performance of alpine fir for exterior product applications.
- Investigate sawing and laminating concepts / strategies to produce vertical grain boards and products.
- Explore treated plywood and LVL for Permanent Wood Foundation (PWF) application by incising the veneer for better handling and preservative penetration, and taking advantage of the treatment knowledge to be developed.

The three margin-added product opportunities recommended to be investigated are Permanent wood foundation (PWF), treated decking, and exterior cladding. The combined market potential for these three margin-added opportunities for alpine fir is tremendous.

8.1 Preservative Treated Wood Products

The Canadian market for residential treated lumber products (including decking) was calculated at $400 million in 1992 and it is known to have increased substantially in volume and value since then. The Canadian Institute of Treated Wood now estimates the decking market alone at $480 million.

Furthermore, changes in the 2005 edition of the National Building Code of Canada are expected to increase the requirements for preservative treatment where structural safety is an issue. We estimate that
PWF plywood represents 10,000 m$^3$ of the approximately 3.7 million m$^3$ total Canadian market for treated wood products.

B.C. has a disproportionately high number of treating plants for its population: 16 compared to 17 for Ontario and 12 for Quebec. B.C. turns out 19% of the Canadian treated wood production, and ships treated wood products to other provinces, the USA and overseas. Treating plants across Canada operate at about 50% of potential capacity, thus the industry has considerable room to grow without constructing new plants. There are increasing export opportunities in Europe, where decking is the latest fad, Asia where termites are an obstacle to using wood, and in the U.S.

### 8.2 Decking

The US decking market is about eight times larger than the Canadian market, consuming about 6 billion board feet of treated lumber per year. Canada has only captured a small fraction of this market due to the difficulty of treating our species to meet the penetration requirements of the U.S. (and Canadian) standards. Nevertheless, exports of treated wood to the U.S. grew from 9% of Canadian production in 1992 to 20% of production in 1998. This may be partly ascribed to the additions of Canadian species to American Wood Preservers’ Association (AWPA) standards, based on Forintek data, over the last 15 years. Recently, Forintek’s data have been instrumental in supporting the introduction of a new AWPA decking standard with a reduced penetration requirement for regions outside the highest decay hazard zone of the U.S. South East.

The U.S. market is predominantly served by production of treated southern pine from the U.S. Southeast. Southern pine treats very easily but the fast-grown plantation material has very poor dimensional stability. Water repellents are added to preservative formulations in the U.S. to improve this property, but they are far from fully effective. If the new AWPA decking standard could be met, Canada could access the lucrative US decking market.

Although CCA-treated wood has received an undeserved reputation as a health risk, the shift to non-arsenical preservatives is expected to mitigate damage to the treated wood market. Competitive products are anticipated to have some impact on this market. Naturally durable woods cannot be provided in sufficient volume to compete with treated wood, but plastic/wood composite lumber products pose a more serious threat. It was estimated to have captured 5% of the U.S. market in 2000 and have the potential to increase to 15% by 2010. The failure of these products to meet the performance claims for rot resistance and dimensional stability could provide a setback to these expectations.

### 8.3 Exterior Cladding

The lumber siding used for U.S. new home construction was reported at 260 million board feet for 1998 in a report titled “Wood Used in New Residential Construction, 1998 and 1995” by the NAHB Research Center, Inc. Information from the Canfor Wood Products Marketing (CWPM) indicated that the wood siding usage in the U.S. N.E. is currently about 19%, a significant drop from a 39% share in 1998, because of the substitution by alternative siding materials, such as fibre-cement and vinyl siding. A very
conservative assumption of the lumber siding used in 2003 for US new home construction is around 130 million board feet assuming the same reduction throughout the U.S.A. as in the U.S. N.E. This volume does not include the wood siding used in the U.S. repair and remodelling (R&R) market. Therefore, the actual U.S. market (including new home construction and R&R) for wood siding would be larger.

A mid-size commercial laminating facility, dedicated to producing siding, would have an annual one-shift capacity of 8.4 million board feet of 1x8 - inch bevel siding. This capacity represents about 5% of the wood siding used in the U.S.

Information from the CWPM indicated pre-primed cedar siding is about US$1,000/Mfbm and James Hardie’s fibre-cement siding is about US$500/Mfbm. A dimensionally stable and durable laminated alpine fir siding priced somewhere between the cedar and Hardy siding would offer a more cost competitive wood siding product and would potentially stem or reverse the tide of the substitution of wood siding by the James Hardie siding and siding of other materials.

9 References*


*Additional references may be cited in the Attachments.
Attachment 1.

Computed Tomography (CT) Scanning of Alpine Fir Logs
Attachment 2.

Characterization of Basic Properties of Alpine Fir
Attachment 3.

Suitability of Alpine Fir for Veneer Products
Attachment 4. a  b

Suitability of Alpine Fir for Specialty Lumber Products