The Value Proposition for Cross-Laminated Timber
Bio-pathways is a joint project among FPInnovations, FPAC, the CFS, and provincial governments in BC, Québec, Ontario. The Focus of the project was “How to support the forest sector in choosing the right Transformation Strategies?” It has been a two phase project with this document beginning release under the second phase which had a market focus.
Introduction

As part of Bio-pathways II the team was asked to look in detail at the market for some of the technologies on the list. This was phrased as a deep dive and it was decided that the first deep dive should be made on Cross-laminated Timber (CLT) as it was one of the more promising technology options. This document contains that deep dive presented in a NABC format (Market Needs, Approach to Market, Benefits of the Products and Competition).

CLT is a cost-competitive wood-based solution that complements existing light- and heavy-frame building options. It is a suitable substitute for some building types which currently use concrete, masonry and steel. It is fast to erect, environmentally sound, performs well and represents an important outlet for the forest industry, without disrupting the existing value chain. Below is a summary of NABC findings for Cross-laminated Timber.

Need (What is the Important Quantitative Customer and Market Need?)

Developers demand a fast building system, allowing for faster capital turnover that is cost-competitive against other systems.

- Large demand in the mid-rise construction industry (70 to 200 million square feet of floor area/year)
- Forest industry needs further penetration in non-residential markets (1 to 3 BBF/year opportunity)
- New outlets are needed for small dimension lumber and low-quality lumber (e.g., MPB-cracked)
- Occupants demand a livable space, that is energy-efficient and cost-competitive

Approach (What is the Specific Quantitative Approach to satisfying that need?).

- Define short-, mid- and long-term goals for the CLT business, e.g.,
  - Short: Floor slabs, focus: res and non-res
  - Mid1: Floors and walls, focus: industrial
  - Mid2: Entire buildings from limited portfolio based on competitiveness
  - Long: Custom projects
- Build partnerships and alliances to better access the market; sawmills, distributors, developers
- Approach immediate projects via one-offs
- Support advocacy groups to increase awareness
- Support developing a generic product standard
- Draw from its environmental credentials to seek subsidies/credits, government building programs
- Build expandable plants as demand increases
Benefits (What are the quantitative Benefits per Costs from the Approach?)

- 10 to 50% less expensive shell costs
- Good environmental credentials (e.g., high carbon storage, and less greenhouse gas emissions)
- Prefabricated system (fast, safe, precise)
- Good seismic, fire and acoustic performance

Competition (Who is the Competition and what are the alternatives now and in the future, and why are your Benefits per cost superior?)

CLT competes – in cost and socially – favorably with concrete/steel buildings, especially in the non-residential and multi-family mid-rise market niche. Another competitive type is industrial buildings, typically built with tilt-up concrete, which are simple, profitable and represent a large demand. Low-rise educational is also attractive.
About the Methodology

The NABC value assessment method was developed by SRI (Stanford Research Institute) and it has been adopted by FPInnovations. NABC stands for Needs, Approach, Benefits and Competition. These four categories try to answer the following questions:

**Needs** – What is the important customer and market Need?
Vision / Mission statement
Key Capabilities
Strategy
Who is the customer?
What does the customer need?

**Approach** – What is the unique Approach for addressing this need?
Product or Service descriptions

**Benefits** – What the specific Benefits per cost that result from this approach?
How will the customer benefit from this?
What is the $ value of the benefit and how much will it cost to implement?
How much of the market will this allow you to capture?

**Competition** – How are these benefits per cost superior to the Competition’s and the alternatives?
What is the competition/Who is the competition?

The NABC puts a significant amount of emphasize on quantifying the results/metrics used in the analysis. It also focuses heavily on understanding the ‘ecosystem’ surrounding the market and product. A NABC can be used to assess the impacts of an initiative on various stakeholders however in this report NABC presented is designed from the perspective of someone in the forest industry wanting to enter the CLT market.
Need

The fundamental need in the marketplace is the demand of developers for fast building systems that are cost-competitive with other systems allowing them to increase their capital turn over and reduce project risk. In order to further understand this Need, FPInnovations examined in detail the use of building systems in various commercial and residential applications, and estimated the potential size of the Need. The findings are below:

• There is a need for viable prefabricated systems suitable for use in both residential and non-residential applications. CLT can serve both.

• Multi-family construction is on the rise. CLT is well suited, especially for 5+ storeys. Light wood-frame dominates the 1 to 4 storey segment.

• Current non-res buildings in wood are limited to low heights, mostly 4-storeys or less. CLT can help increase wood’s share.

• Market share for wood in non-residential construction is low, with less than 10% of the 1.3 billion sq. ft. ($228 billion) US market (2008) and 6% of the 5- to 6-storey residential. CLT is especially suited to help stop the erosion of wood to steel/concrete.

• The Canadian forest products industry needs to diversify its product portfolio, especially seeking value-added alternatives. CLT does not require high-end lumber and it can be an outlet for less valuable species or grades.

• Depending on the penetration rate used CLT could represent a 0.84 to 2.4 billion bf market (see Figure 1).

<table>
<thead>
<tr>
<th>Storey class</th>
<th>Floor area (Millions ft²)</th>
<th>CLT (Million m³)</th>
<th>Lumber (BBF)</th>
<th>Shell Value ($ Billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-rise (1 to 4)</td>
<td>52 156</td>
<td>0.9 2.7</td>
<td>0.6 1.8</td>
<td>1.1 3.3</td>
</tr>
<tr>
<td>Mid-rise (5 to 10)</td>
<td>16 48</td>
<td>0.3 0.9</td>
<td>0.2 0.6</td>
<td>0.4 1.2</td>
</tr>
<tr>
<td>Total</td>
<td>68 204</td>
<td>1.2 3.6</td>
<td>0.8 2.4</td>
<td>1.5 4.5</td>
</tr>
</tbody>
</table>

Note: The Canadian market can be estimated at 5 to 10% of the US market on a floor area basis.

Figure 1. Market Opportunity for CLT by Scenario. From: Cross-laminated Timber: a Primer FPInnovations. 2010.

Two scenarios were considered for market penetration rates 5%/15%. The 15% penetration rate was used as a mid to longer term estimate.

3.1 Detailed Needs Analysis

Wood currently has a 10% share of the US non-residential market (Figure 2 shows the US non-residential market by State, storey class, and wall frame (000 sq. ft.). This market segment has shown some resiliency to the economic crisis, however 2009 was marked by a strong decrease in construction area (~-40%). This report assumes the markets will pick up, and uses 2008 volumes as a proxy for near term demand. Since the Canadian market is only 5 to 10% of the US market, the focus is on the US.

1See report ‘A Strategic Plan for the Commercialization of CLT in North America’. 2010. Natural Resources Canada
In the analysis of the non-residential market we split the market into two separate classification; 1-to 4-storeys and 5+ storeys. This approach was taken to ensure that in the analysis we were taking into account the effect of current wood use in 1- to 4-storey buildings. Also on the maps presented, the size of the market is represented by the size of the pie chart. As a result we were able to identity both the specific application in which CLT could be competitive, and the size of that market.

The overall market estimated is based on an average usage factor of 0.62 ft$^2$ of CLT per ft$^2$ of construction area and 17.5 board feet of lumber per ft$^3$ of CLT. These volumes were tallied up by building type and storey class, assigning a competitiveness factor to CLT for each case and multiplying this factor by the market size$^1$. As stated, the stats correspond to 2008 (McGraw-Hill), grossed up by 25% to adjust for sampling issues. To estimate the volume of wood or size of the market the study looked only at the shell of the building. The shell corresponds to the structure of the building – basically floors and exterior walls. The shell value is the product of the estimated total footage by assembly and the unit cost for CLT ($8 to $11 per ft$^2$ depending on panel thickness).

Although not completed in the same detail as building type, FPInnovations also explored different options to utilise CLT including:

- Elevator shafts and stairwells: 0.2 to 0.4 BBF
- Balconies and stairs: N/A
- Additions to existing buildings
- Parkades.

Sales to these applications were not included in the Need forecast.

Figure 2.
Non-residential Market by State, Storey Class and Wall Frame (000 SqFt.). The size of the circle represents the relative size of the market. For example, New York uses about 20% of wood in their 1- to 4-storey buildings but they do not use wood in 5 to 10 storeys.

Wall Frame
- Light Gauge Steel
- Pre-Engineered Metal
- Pre-Fabricated Modular Comp
- PrecastConcrete
- Reinforced Concrete
- Structural Steel
- Wall Bearing
- Wood

$^1$See report ‘A Strategic Plan for the Commercialization of CLT in North America’. 2010. Natural Resources Canada
In developing the Approach for potential CLT manufacturers, FPInnovations looked at several strategies and identified one strategy for the short-, medium- and long-term approaches. We also reviewed possible distribution channels for the product. The summarized findings for the Approach follow:

**• CLT Manufacturers:**
- Define short-, mid- and long-term goals, e.g.,
  - Short: Floor slabs, focus: res and non-res
  - Near Mid: Floors and walls, focus: industrial
  - Far Mid: Entire buildings from limited portfolio, based on competitiveness
  - Long: Custom projects (Europe Model)

**• Industry at large (rest of the stakeholders):**
- Build partnerships and alliances to better access the market; sawmills, distributors, developers
- Approach immediate projects via one-offs
- For the short-term a proprietary approach is OK, e.g., APA stamp
- Make sure the demonstration buildings (NRCan) are built and properly showcased
- Align North American industry around the development of a generic product
- NLGA/CSA 086
- Import and test European panels to support code approval for the US and Canada
- Encourage partnerships with leading companies, e.g., KLH North America
- Develop training venues, e.g., carpentry, CNC/CAD operation, building inspectors
- Increase awareness at Universities so future specifiers know about it
- Showcase panels at trade shows

**• Display integrated solutions:**
- Insulation, HVAC, connectors/fasteners, pre-fitted electric system
- Explain economics (building savings for shell and total, plus savings in time, work out example for large multi-unit projects )
- Seek awareness/approval among specifiers (architects, engineers) and developers
- Environmental virtues, construction time, flexibility of design (CNC machines), performance and code compliance
- Target tilt-up concrete buildings, industrial, mid-rise res/non-res (5+), floor slabs
- Manufacturers could produce custom-made panels and/or raw panels to be further processed by the builder or by the pro dealer/wholesaler (e.g., cut floor slab to size and spline it for joint)
- Simulations have shown a roughly balanced demand for floor and wall panels. Similarly, manufacturing costs seem to be equivalent, regardless of the assembly type

In order to provide the wider picture each approach needed to be detailed so the impacts of the approach could be better understood.
4.1 Detailed Short-term Approach: Floor Slabs

In the detailed short-term strategy it was assumed the company would want to manage its investment and risk and run a very lean facility without needing complicated computer controlled equipment or higher overhead from an extensive sales team. Therefore it was assumed that the company would move directly into full building assemblies.

- It may make economic sense to enter the market with floor slabs:
  - Large demand (600 million sq.ft.)
  - Less code burden
  - Building inspectors like it because of lower chance of collapse during fire
  - Easier to fabricate and build with
  - More profitable for CLT manufacturer (simpler, less waste)
  - Easier to ship.

- Floor systems may eventually find a way into the single-family residential market. Preliminary benchmark analysis suggests this may be feasible in the high-end segment.

- In the future, a manufacturer can grow to include both assembly types.

- Furthermore, a CLT manufacturer could include the manufacturing of columns and beams (as a by-product or as a second line) similar to glulam to take advantage of the available panels and or capabilities and reduce costs v. glulam. At the very least, partner up with a glulam or Parallam™ manufacturer.

- Other applications and/or byproducts may include stair steps. The common practice in Europe is to grind the residues and burn them for energy.

- Eastern Canada likely to use small dimensions, like 2x3s and 1x4 (spruce and pine).

- Western Canada likely to use 2x6s and 2x4s (SPF).

- Research should look at using lesser known species, e.g., poplar and higher moisture content, e.g., 19%.

- Research on using low-quality (cracked) MPB-killed lumber is needed.

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**Figure 3.** Demand by Assembly

**Figure 4.** Stair steps using 9-ply CLT
4.2 Detailed Mid-term Approach 1: Industrial Buildings, the Tilt-up Concrete Segment

One potential next step for a CLT manufacturer is to target whole building development. In this approach it is assumed that the manufacturer moves first to more standardized buildings such as tilt-up concrete structures.

- Industrial buildings are especially suitable for CLT assemblies. This market segment is large and dominated by concrete and steel (see Figure 5).
- This segment is especially suitable for CLT penetration. These buildings are found in business/industrial centers and have the following features:
  - Low rise (1-to 2-storeys)
  - Tall storey heights (10’-to 24’)
  - Box-type shape
  - Flat roof
  - Large window area in the front, the rest without openings
  - Long spans.
- Warehouses are typically built with tilt-up concrete and/or steel.
- Self-storage warehouses are normally built with concrete blocks.
- These two types represent a significant share of the non-res market see Figure 6.
- Studies have shown that a 5-ply CLT tall wall plus metal siding is cost-competitive for box-type warehouses.
- Self-storage warehouses are typically built using concrete blocks and are very economical and hence difficult to compete with on a cost basis.
- Building safety is important in these markets.

Figure 5. Industrial Floor Areas by Material: 1-to 4-Storey
Figure 6. Typical Tilt-up and Self-storage Buildings

Figure 7 takes a closer look at the industrial segment, with a focus on the 1- to 2-storey precast concrete segment. This segment accounts for 69 million ft$^3$ of annual construction area, with warehouses having the largest share (57%). This segment would represent a demand of 1.7 to 5 million ft$^3$ of CLT for the 5 to 15% scenarios.

![Figure 7: Construction Area by Building Type (1- to 2-Storey Precast Concrete)](image)

At 0.48 ft$^3$/ft$^2$
4.3 Detailed Mid-term Approach 2: Pre-Designed Building Portfolio: Parking Garages

Another mid-term approach is to look at pre-designed buildings. Each installation of these types of buildings are similar in nature, so although they do have components that are custom to a specific building the bulk of the building system is reproducible. An example of this is parking garages where the main structure is very similar while the outside look may be customized.

- Preliminary studies have shown CLT to be cost-competitive (similar) with concrete.
- Building code allows up to 5-storeys in heavy timber, once certain conditions are met.
- Wood has environmental advantage.

![Skelleftea Parking Garage (Sweden)](image)

4.4 Detailed Long-term Approach: Custom Projects

This is the European model, where the CLT manufacturer works on a by-project basis. This strategy calls for a somewhat more mature market, with greater acceptance of the product. Under this model, the CLT manufacturer must have a well developed sales and engineering force along with effective networks in the construction and design communities.

4.5 Defining the Distribution Channels

A look at the demand by metro area helps identify potential locations for manufacturing plants as well as distribution channels and shipping costs (Figure 9). It can be seen that the demand is concentrated in the East, with two other important areas, one around the Great Lakes and the other in the Southwest. Overlaying transportation costs and networks on this detailed analysis of the market will help CLT users understand the right approach by market. For example, serving a custom building market in the US South will have additional challenges posed by transportation and the need for very tightly scheduled deliveries. A CLT entrant may choose to focus on custom buildings close to their manufacturing but provide blanks or floor slabs to markets farther away.
Figure 9. CLT Demand by Metro Area (5% Penetration)

Note: Gold color text indicates less importance
5 Benefits

The market assessment completed was based on comparing the installed cost of concrete or another building system vis-à-vis the estimated installation cost of CLT. Based on this analysis the market size and locations were determined. This analysis does not represent all the benefits of CLT. There are significant other savings in using the material that will mainly accrue to the builder or developer rather than the CLT producers (depending on market management and bonus plans). Figure 10 summarizes the benefits of CLT by stakeholder, from lumber producers to occupants of CLT buildings.

Other benefits include:

- Significant savings in construction time vs. poured concrete (several weeks).
- Building System Performance:
  - It allows flexible design, has good acoustic, fire and insulation properties
  - Can be combined (e.g., glulam, Parallam™, steel)
  - It performs well under earthquake conditions, even for multi-storey buildings
  - Good fire performance and acoustics
  - Vibration and creep critical but can be solved.
- Environmental Performance:
  - Favourable preliminary life cycle analysis against steel, with 1:20 greenhouse emissions
  - High levels of CO₂ sequestration (0.75 tons/m³).
- Construction advantages (against poured concrete)
  - Rapid erection on site (other trades can begin work sooner, improved precision, e.g., cladding, windows, etc.)
  - Reduced noise from building sites
  - Provides an instant work platform with improved safety and little waste
  - Smaller/cheaper equipment (cranes, trucks)
  - Reduces job site impact and leaves a small footprint (little waste, panels could be disassembled).
- Can be produced in Canada at a competitive cost, making it attractive for builders
  - $20/ft³ in Canada (similar costs for west and east).
- Attractive outlet for low quality lumber (cracked MPB lumber?).
5.1 Manufacturing Costs

Figure 11 shows a summary of a simulation of manufacturing costs of CLT for a hypothetical plant based in Eastern Canada. This plant requires a total investment of $41 million, produces 30,000 m$^3$ of either floor assemblies or wall assemblies in panel thicknesses of 144 mm and 88 mm, respectively. A similar exercise for a Western Canada-based plant yielded similar results, with $17/ft^3$ (variable costs) and $19/ft^3$ total cost. The latter assumed 2x6 lumber whereas the Eastern-based simulation assumed 2x3s and 1x4s. Both cases consider S4S redried lumber, roughly at $400 per MBF.

Using the simulated costs (plus connectors, erection and markup) a cost-competitiveness analysis was performed. For each building type and storey class, a realistic assembly for the CLT was chosen (panel thickness, insulation, façade, etc.). Unit costs for anything other than the panel itself came from RSMeans. The calculated square foot cost for the shell (walls + floors) was compared again the corresponding value from McGraw-Hill. Figure 12 shows an extract with the side-by-side comparison for 12 building types/storey classes.
In addition to analysing a whole building approach we also analysed a component approach. Detailed Short-term Approach: Floor Slabs (Section 4.1) would be considered a component approach. In this analysis we specifically looked at the cost comparison of CLT against other systems for too components – floors and walls. Figure 13 shows the results of this analysis.

For floors, depending on the specific design, CLT is competitive with CIP Beam & Slab. As a wall component, CLT competes well with many of the concrete options, such as Pre-cast Concrete.

![Figure 13. Benchmarking Analysis of Assembly Costs](image)

5.2 Construction Time

CLT is an extremely fast building system. It requires small crews and simple equipment. Time savings should result in important savings in capital and faster project turn-up for developers. Below are some actual examples from Europe.
<table>
<thead>
<tr>
<th>Building Type: Educational, 3 Storeys</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Brick veneer &amp; curtain wall</td>
<td>Masonry</td>
</tr>
<tr>
<td>Location</td>
<td>SC, US</td>
<td>NC, US</td>
</tr>
<tr>
<td>Floor Area (ft²)</td>
<td>109,000</td>
<td>106,234</td>
</tr>
<tr>
<td>Stories</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Construction Period</td>
<td>Jan 98-Apr 00: 28 months</td>
<td>May 93-June 95: 25 months</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Type: Residential, Mid-Rise</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Brick</td>
<td>Brick, CMU</td>
</tr>
<tr>
<td>Location</td>
<td>NY, US</td>
<td>PA, US</td>
</tr>
<tr>
<td>Floor Area (ft²)</td>
<td>23,800</td>
<td>41,000</td>
</tr>
<tr>
<td>Stories</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Construction Period</td>
<td>Feb 94 - Mar 95: 13 months</td>
<td>Nov 92 – Feb 94: 15 months</td>
</tr>
</tbody>
</table>
For the ecosystem of CLT, FPInnovations looked at a series of issues including the viewpoint of designers and architects, other producers of CLT working in the same market, and equipment suppliers. At this point none of the hurdles registered as a 'show stopper' but the work did indicate that the producer needs to understand the market and stay close to the customer.

• Designers prefer or are forced by code to specify other incumbent materials such as concrete and steel for non-res buildings.
• Other massive panels, such as Panaloc's.
• European manufacturers who could either ship panels or open plants in North America.
• Other solutions, e.g., face-glued lumber for floors.
• Other uses for the fibre or lack of suitable grades/dimensions/specie.
• The US will likely open its own CLT plants if the product enters the market. There is evidence of increasing awareness and interest in CLT in the US. Optimal plant location and partnership with local sawmills may provide Canada an edge.
• KLH may hold proprietary technology on the pressing process (unlikely).
Conclusions

- CLT has been successfully used in Europe. It works!
- CLT-prefab systems hold great potential to increase their share as a construction system. Canada may have a competitive advantage in terms of supply and wood quality. Expertise and networking is also growing quickly.
- CLT manufacturing is straightforward and cost-effective against incumbents.
- Preliminary cost analysis shows a CLT plant in Canada to be feasible.
- Upfront construction costs are competitive when compared to concrete/steel for several building types and storey classes.
- The North American market for CLT is estimated at 1.2 to 3.6 million m³, or 1 to 3 BBF, at 5 to 15% market penetration, respectively.
- Main Applications: Tilt-up concrete buildings, industrial, mid-rise res/nonres (5+), floor slabs, other,
- Main obstacles include: production capacity, code issues, resistance from construction community against wood-based materials, perceptions of: durability, fire, acoustics.
http://www.forintek.ca/public/Eng/E3-R&D_Program/7.market.html

Natural Resources Canada. 2010. A Strategic Plan for the Commercialization of Cross-Laminated Timber in Canada and the US.
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