Athena Sustainable Materials Institute

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A Life Cycle Assessment of Cross-Laminated Timber Produced in Canada

Prepared for:

FPInnovations

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Abbreviations

PAH: Polycyclic aromatic hydrocarbons

PM (10/2.5): Particulate matter less than 10/2.5 micrometers in diameter

SO_2: Sulfur dioxide

TRACI: Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts

UNEP: United Nations Environment Program

US EPA: United States Environmental Protection Agency

USLCI: United States Life Cycle Inventory Database

VOCs: Volatile Organic Compounds

Glossary

Based on ISO 14040:2006- Terms and Definition Section [1].

Allocation: Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.

Cradle-to-gate: A cradle-to-gate assessment considers impacts starting with extracting raw materials from the earth (the "cradle") and ending at the plant exit "gate" where the product is to be shipped to the user. In-bound transportation of input fuels and materials to the plant is included. Out-bound transportation of the product to the user is not included. The use phase, maintenance and disposal phase of the product are also not included within the scope of this study. Disposal of on-site waste at the plant and outside and transportation within the plant (if applicable) are included.

Cradle-to-grave: A cradle-to-gate assessment considers impacts starting with extracting raw materials from the earth (the "cradle") and ending with the end of life treatment (the "grave"). In-bound transportation of input fuels and materials to the plant is included as well as out-bound transportation of the product to the user. The use phase, maintenance and disposal phase of the product are also included within the scope of this study. Disposal of on-site waste at the plant and outside and transportation within the plant (if applicable) are similarly included.

Functional Unit: Quantified performance of a product system for use as a reference unit.

Life cycle: Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life Cycle Assessment (LCA): Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life Cycle Inventory (LCI): Phase of Life Cycle Assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Life Cycle Impact assessment (LCIA): Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.

Life cycle interpretation: Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

1. Introduction

FP Innovations engaged the Athena Institute to complete a cradle-to-gate life cycle assessment of Canadian average cross-laminated timber (CLT) manufacture. The cradle-to-gate analysis included primary LCI data collection for the CLT production process that included all material resources, ancillary and energy input flows entering the CLT production facility as well as all emissions to air, water and land associated with the production of the finished product.

The project was a collaborative effort between the Athena Institute and FPInnovations. The Institute was responsible for project management, survey design, questionnaire validation and the final LCA report detailing the findings. FP Innovations was responsible for identifying and engaging study participants. . Jennifer O'Connor and Lal Mahalle from FPI also provided an internal review of the draft report, based on compliance of the LCA with the PCR, and their comments were incorporated into this report.

To complete the gate-to-gate portion of the LCI data collection, surveys were distributed to Canadian CLT manufacturers in the winter of 2011/2012 to capture the manufacturing LCI inputs and outputs for the 2011 production year.

The LCA was completed in accordance with FP Innovations product category rules for North American Structural and Architectural Wood Products[1]. The methodology outlined in this PCR document draws on published ISO standards (14040, 14044, 21930, and 14025) that include general "best practices" for LCA as well as specific reporting requirements and supported impact categories.

In addition to Section 2, which serves as a primer for LCA methodology in general, Section 3 documents the goal and scope decisions that were made in accordance with the PCR's requirements for business-to-business (BtoB) EPD's. Section 4 then details the life cycle inventory modeling that was undertaken and Section 5 provides the impact assessment results that may be used to develop and support future EPD's of Canadian CLT.

[1] FP Innovations (2011): Product Category Rules (PCR) for preparing an Environmental Product Declaration for North American Structural and Architectural Wood Products, Version 1 (UNCPC 31, NAICS 321), November 8, 2011. http://www.forintek.ca/public/pdf/Public_Information/EPD%20Program/PCR%20November%208%202011%20Final.pdfhttp://www.forintek.ca/public/pdf/Public_Information/EPD%20Program/PCR%20April%202011%20pilot%20version.pdf

2. Life Cycle Assessment Methodology

Life cycle assessment is an analytical tool used to comprehensively quantify and interpret the energy and material flows to and from the environment over the entire life cycle of a product, process, or service[2]. Environmental flows include emissions to air, water, and land, as well as the consumption of energy and material resources. By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product and a more accurate picture of the true environmental trade-offs in product selection. Two international standards, ISO 14040:2006 and ISO 14044:20062, describe an iterative four-stage or phased methodology framework for completing an LCA, as shown in Figure 1: (1) goal and scope definition, (2) life cycle inventory, (3) life cycle impact assessment, and (4) interpretation.

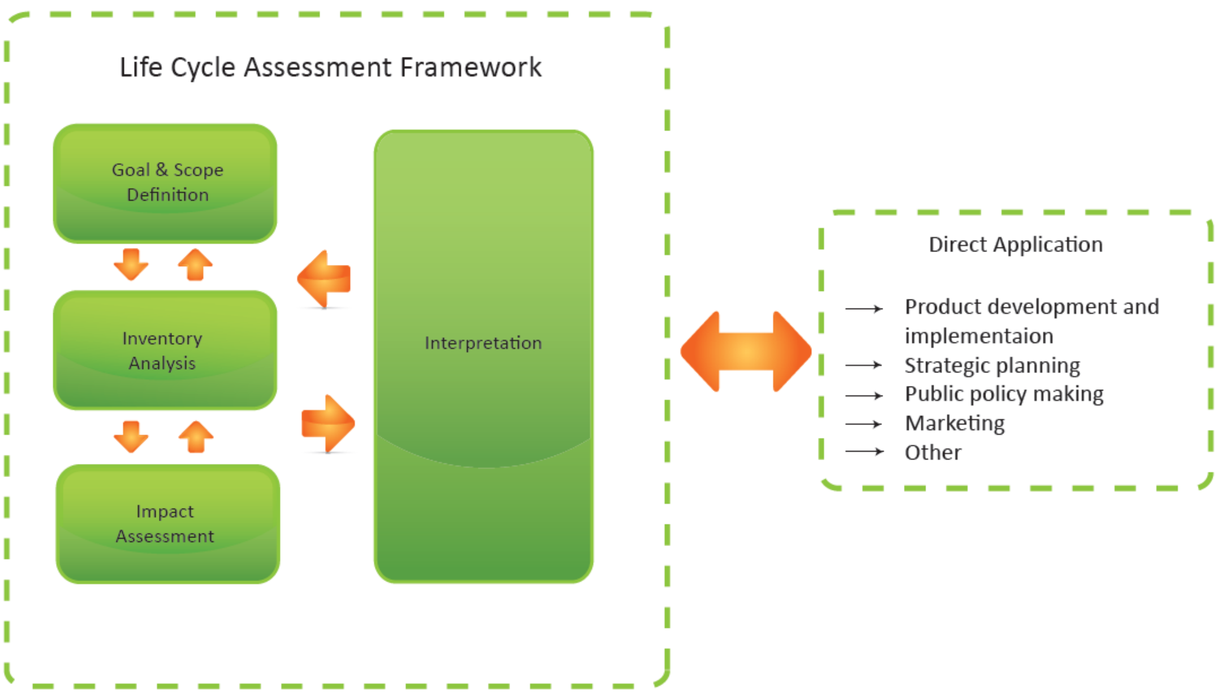

Figure 1: Stages of an LCA as per ISO 14044:2006

An LCA starts with an explicit statement of the goal and scope of the study; the functional unit; the system boundaries; the assumptions and limitations; the allocation methods used, and the impact categories chosen. The goal and scope includes a definition of the context of the study, which explains how and to whom the results are to be communicated. The ISO standards

[2] ISO 14040:2006. Environmental Management – Life Cycle Assessment – Principles and Framework.
ISO 14044:2006. Environmental Management – Life Cycle Assessment – Requirements and guidelines.

require that the goal and scope of an LCA be clearly defined and consistent with the intended application. The functional unit defines what is being studied. The purpose of the functional unit is to quantify the service delivered by the product system and provide a reference to which the inputs and outputs can be related. Allocation is the method used to partition the environmental load of a process when several products or functions share the same process. In inventory analysis a flow model of the technical system is constructed using data on inputs and outputs. The flow model is often illustrated with a flow chart that includes the activities that are going to be assessed and gives a clear picture of the technical system boundary. The input and output data needed for the construction of the model are collected (such as materials and energy flows, emissions to air and water, and waste generation) for all activities within the system boundary. Then, the environmental loads of the defined system are calculated and related back to the functional unit, and the flow model is finished.

Inventory analysis is followed by impact assessment, where the life cycle inventory data are characterized in terms of their potential environmental impacts; for example, resulting in acidification, ozone depletion, and global warming. The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. Classical life cycle impact assessment (LCIA) consists of the following mandatory elements: selection of impact categories, category indicators, and characterization models; and continues with the classification stage, where the inventory parameters are sorted and assigned to specific impact categories.

The categorized LCI flows are then characterized using one of many possible LCIA methodologies into common equivalence units and then are summed to provide an overall impact category total. This equivalency conversion is based on characterization factors as prescribed by the selected LCIA methodology.

In many LCAs, characterization concludes the LCIA analysis; this is also the last compulsory stage according to ISO 14044:2006. However, in addition to the mandatory LCIA elements (selection, classification, and characterization), other optional LCIA elements (normalization, grouping, and weighting) may be conducted depending on the goal and scope of the LCA study. In normalization, the results of the impact categories from the study are usually compared with the total impact in the region of interest. Grouping consists of sorting and possibly ranking of the impact categories. During weighting, the different environmental impacts are weighted against each other to get a single number for the total environmental impact. As per ISO 14044:2006, “weighting, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public”. While this study does not make explicit comparative assertions, readers and users of this study may infer a comparison and thus weighting and other optional LCIA elements are excluded to be consistent with the goal and scope of the LCA study and the ISO 14044:2006 protocol.

The results from the inventory analysis and impact assessment are summarized during the interpretation phase. The outcome of the interpretation phase is a set of conclusions and recommendations for the study. According to ISO 14040:2006 the interpretation should include:

- Identification of significant issues based on the results of the LCI and LCIA phases of LCA
- Evaluation of the study considering completeness, sensitivity, and consistency checks
- Conclusions, limitations, and recommendations.

The working procedure of LCA is iterative as illustrated by the back-and-forth arrows in Figure 1. The iteration means that information gathered in a later stage can cause effects in a former stage. When this occurs, the former stage and the following stages have to be reworked taking into account the new information. At the end, the results and conclusions of the LCA will be completely and accurately reported to the intended audience. The data, methods, assumptions, limitations, and results will be transparent and presented in sufficient detail to allow the interested parties to comprehend the complexities and trade-offs inherent in the LCA. The report will also allow the results and interpretation to be used in a manner consistent with the goals of the study.

3. Goal and Scope

This section sets out the intent and protocol for undertaking the cradle-to-gate LCA study of Canadian CLT. The goal and scope provides a roadmap for completing the life cycle inventory (LCI) data collection, its compilation, as well as its interpretation via a set of robust impact indicators in order to satisfy the goals of the study.

3.1 Goals and Objectives

3.1.1 Goals

The primary goal of the study is to generate unit process data for gate-to-gate CLT manufacture and to use that data to develop a cradle-to-gate profile of this product. This cradle-to-gate model will be developed in accordance with FPI's PCR on Structural and Architectural Wood Products to facilitate future business to business EPD's.

In addition to providing the impact assessment results of the allocated profiles, the inventory data is presented as unallocated flows to facilitate the data's use in future LCA that may employ either consequential or attributional logic in dealing with co-products in a decision context.

A third goal of the LCA is to inform internal sustainability objectives by recognizing "hot spots" in the CLT life cycle that should be the focus of impact abatement efforts.

3.1.2 Intended Audience

The intended audience for the results of this LCA study is primarily internal FP Innovations and Athena Institute LCA practitioners. The data will be used to develop future LCAs of CLT systems as well as derivative work products such as an environmental product declaration (EPD).

3.1.3 Comparative Assertions

This LCA does not include or infer any comparative assertion to similar or other building materials or systems.

3.2 Scope of Considered System

3.2.1 Definition of the Functional Unit

The functional unit serves as the starting point for defining the scope of the study that will seek to consider its environmental impacts. The *functional unit* is defined in ISO 14040:2006 as the quantified performance of a product system for use as a reference unit.

The functional unit subject to analysis in this LCA is defined as follows:

- CLT Production: Cradle-to-gate production of 1 m^3 CLT product output that includes harvesting, lumber milling, and CLT manufacture.

The cradle-to-gate LCI was generated by combining the CLT manufacturing LCI data with previously published datasets for upstream manufacturing of wood and adhesive resins, as well as data for Canadian and provincial electricity generation, common thermal fuels, and ancillary materials use. The report presents both the gate-to-gate and cradle-to-gate results on an mass allocation LCI basis (Section 5) as well as an economic allocated basis (in Appendix 3). The mass allocated profile was selected as the default presentation because this profile corresponds with the allocation criteria described in FPI's wood PCR.

3.2.2 System Boundaries

This cradle-to-gate life cycle assessment considers impacts starting with extracting raw materials from the earth (the "cradle") and ending with the packaging of the "ready-to-ship" CLT product at the manufacturer "gate". The raw material "cradle" for wood products included all forest operations that typically take place prior to and after logging that includes fertilizer use, seedling production, and replanting. Transportation of materials and energy inputs within and between all activity stages is included within the receiving life stage. The use phase, maintenance and disposal of the product systems are not included within the scope of this study. Disposal of on-site waste from product manufacture is included in the system boundary. Table 1 lists the inclusions and exclusions from the system boundaries considered in this study**.**

The cradle-to-gate CLT product system is presented in Figure 2.

Table 1: General overview of the System Boundaries for this LCA study

INCLUDED	EXCLUDED
• Input raw materials, energy, and fuel in forestry, logging, milling, and secondary manufacturing	• Fixed capital equipment and facilities
• Transportation of materials throughout the cradle-to-gate manufacturing life stages	• Transportation of employees
• Packaging	• Land use
	• Construction, maintenance, use, and end of life treatment

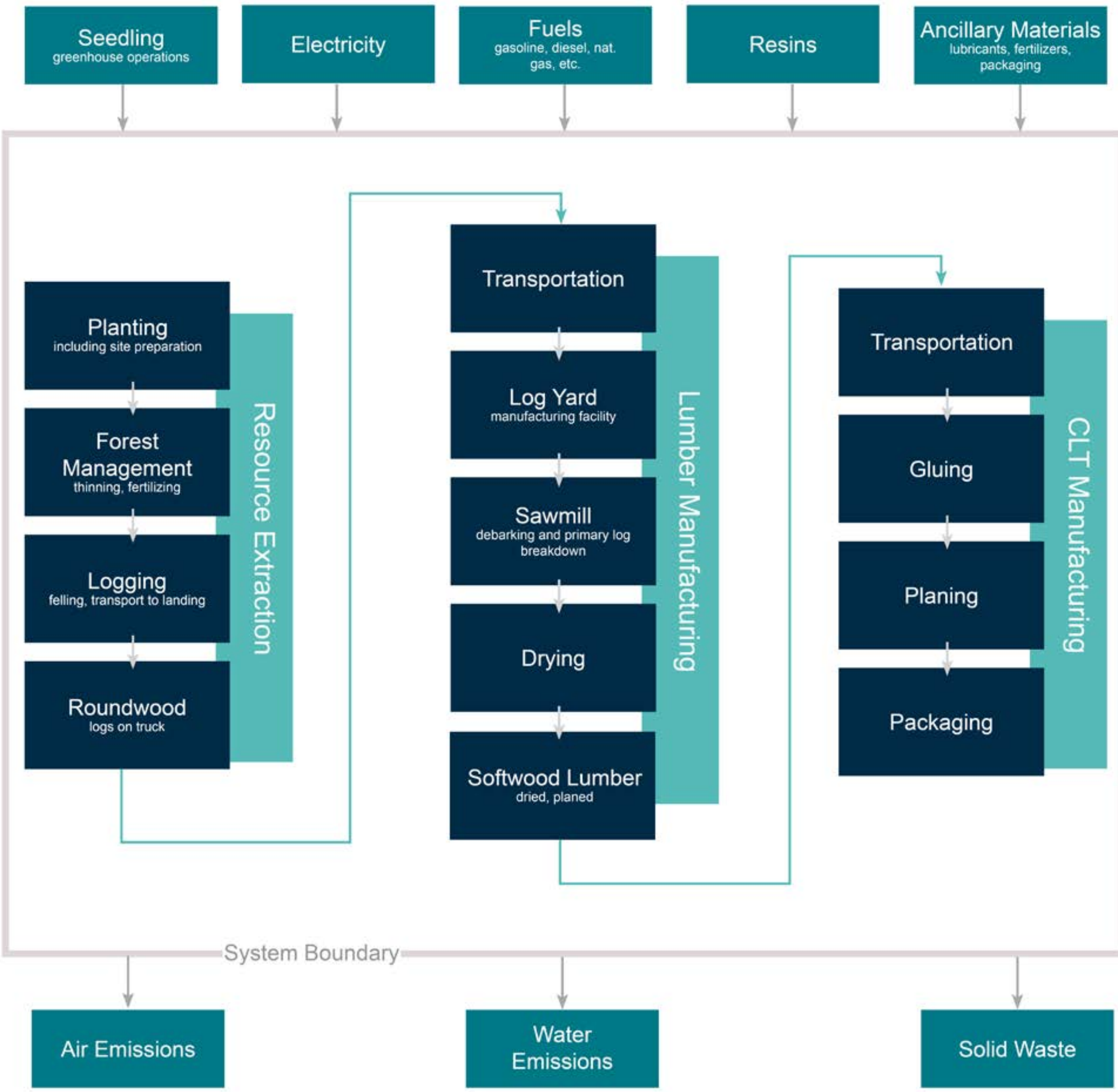

Figure 2: Cradle-to-Gate CLT Product System

3.2.3 Multiple-output Allocation

Allocation, where necessary, was conducted following the methodology outlined in FPI's wood product PCR. The PCR explicitly requires mass based allocation for all cases in which the primary product is less than 10 times the value of the co-products. This requirement leads to a mass allocation for the default case as the lumber coproducts fall within this threshold (coproducts greater than 10% of primary product value) while CLT production is a single-product process and thus requires no allocation. A sensitivity case is also shown in Appendix 3 in which an economic allocation is applied to the lumber input.

3.2.4 Cut-off Criteria

The cut-off criteria for input flows to be considered within each system boundary are given in Table 2 below:

Table 2: Cut-off Criteria

CUT-OFF CRITERIA	THRESHOLD
Mass	If a flow is less than 1% of the total mass input of the product system being modeled it may be excluded, providing its environmental relevance is minor
Energy	If a flow is less than 1% of the total product system's energy inputs it may be excluded, providing its environmental relevance is minor
Environmental relevance	If an input flow meets the above two criteria, but is determined (via secondary data analysis) to contribute 2% or more to any product life cycle impact category (see below), it is included within the system boundary

The sum of the neglected input flows must not exceed 3% of the total mass, energy or environmental relevance. Similar cut-off criteria were also used to identify which outputs should be traced to the environment; for example, by including waste treatment processes.

The primary LCI data for this study was collected from two Canadian facilities for the reference year 2011. Plant personnel provided unallocated data for each of the gate-to-gate product systems considered in the scope of the system.

For other ancillary or process materials, such as the production of chemical inputs, fuels and power, secondary data from commercially available LCI databases were deemed acceptable during the goal and scope development for the project (e.g., US LCI Database, North American adjusted Ecoinvent database, etc.).

No reported input or output LCI flows were subject to the cut-off criteria.

3.2.5 Data Quality

This section documents the achieved data quality requirements relative to ISO 14044 requirements. Data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied on a study serving as a data source) and representativeness (geographical, temporal, and technological). The data sources that were used in this study are provided in Appendix 2 and are in accordance with the following data quality criteria.

Precision and Completeness

Primary data on raw materials, energy, and emissions were provided by the study particpants, based on input purchases, production output, and reported process emissions over the 2011 production year. All upstream and downstream secondary data is consistently applied with sometimes unknown, but similar precision. See Appendix 2 for secondary data sources.

All components of the final product were modeled and all raw material inputs, energy flows and emissions were included. All inventory flows were modeled and at no time were data excluded due to application of the study's cut-off criteria.

Consistency and Reproducibility

To ensure consistency, only primary data as provided by the study participants were used to model gate-to-gate processes. All other secondary upstream data were consistently applied across the three product systems of interest. At various points in the study (data collection and modeling) a quality and consistency check was performed. The objective of these checks was to ensure that the data collection, the development of the LCI model, and the final results remained consistent with the scope of the study, and that the study delivered the required information. The quality check process included a review of the precision and completeness of the collected primary data (e.g. mass and energy balance was performed), applicability of LCI datasets used, general model structure, and results plausibility (e.g. comparison to other similar reports and the Athena Impact Estimator for Buildings database). The data was found to be within acceptable ranges compared to internally and publically available information.

Reproducibility by third parties is possible using the aggregated inventory data and background LCIs documented in Appendix 2. Due to the diverse nature of background LCI datasets used in completing the project a statistical analysis of uncertainty was not possible.

Temporal Coverage

Primary data collected from the manufacturing facilities for their operational activities related to the product processes of interest are representative for the year 2010 (reference year). Additional data necessary to model base material production and energy use, etc. was adapted from various secondary databases (US LCI database, ecoinvent, etc.) and their use is described in Appendix 2.

Geographical Coverage

The geographical coverage for this study is based on Canadian and North American (NA) system boundaries for all processes and products. Whenever Canadian or North American background data was not readily available, European data (adjusted for N. American system boundaries) was used as a proxy (see Appendix 2).

4. Life Cycle Inventory

4.1 Gate-to-Gate LCI

The life cycle inventory in this section presents the unit process flows for both the metric unit of measurement, 1 m^3 (1 cubic meter), and the imperial measurement 1 mbfm (one thousand board foot measure). The conversion of cubic meters to mbfm is assumed 1.59 m^3/mbfm. The LCI was calculated based on 2011 production and the corresponding flows of materials during that period. The hogfuel input was extrapolated based on the 2010 consumption of hogfuel as determined from a glulam study that Athena previously completed for the participating facilities. This was done to fill a data gap as the manufacturers did not provide this data.

4.1.1 Outputs

The allocation applied in this study is outlined in Section 3.2.3. The outputs of the manufacturing process are the CLT product itself and wood waste, hence no allocation is required for this process. The lumber input data is based on a mass allocation consistent with the requirements of the PCR that requires mass allocation in all cases in which the primary product is less than 10 times the value of the coproducts. The results based on economic allocation in the lumber system are shown in the profiles in Appendix 3.

Table 3: Outputs to Technosphere from Manufacturing CLT Product

OUTPUTS TO TECHNOSPHERE	UNIT	AMOUNT/m^3	AMOUNT/mbfm
Primary Product			
Cross Laminated Timber Product	m^3 (kg @ 13% mc)	1.00 (475.45)	1.59 (759.05)
Wood Portion	*odkg*	*417.03*	*664.76*
Resin Portion	*kg*	*4.20*	*7.87*
Coproducts			
Off-spec and End Cuts	odkg	60.43	96.33

4.1.2 Lumber Inputs

Canadian CLT manufacturers use rough sawn dry lumber as the primary input to the manufacturing process. The lumber input is delivered from suppliers between 129 and 530 km away from their facilities. The weighted average amount of this wood input per m^3 or mbfm output and its transportation to the facility is indicated in Table 4.

Table 4: Lumber Inputs to CLT Manufacturing Process

LUMBER INPUTS	UNIT	AMOUNT/m^3	AMOUNT/mbfm
Rough Sawn Dried Lumber	m^3 (odkg)	1.14 (477.46)	1.83 (761.09)
Lumber Delivery by Truck	tkm	170.69	272.09

4.1.3 Resin Inputs

The manufacturers use several glue types in the finger jointing and face bonding sub-processes. These glues are polyurethane, polyurethane epoxy precursors (polyols and emulsion polymer isocyanate) and arclin melamine. The resins are sourced both domestically and overseas and thus require a mix of truck and ship delivery to the facility as indicated with their amounts in Table 5.

Table 5: Resin Inputs to CLT Manufacturing Process

RESIN INPUTS	UNIT	AMOUNT/m^3	AMOUNT/mbfm
Polyurethane (face bond)	kg	2.82	4.49
Polyurethane (finger joint)	kg	0.64	1.02
Emulsion polymer isocyanate (finger joint)	kg	0.16	0.26
Acrilin Melamine (finger joint)	kg	0.58	0.93
Resin Transport (truck)	tkm	3.59	5.73
Resin Transport (ship)	tkm	8.99	14.33

4.1.4 Energy Inputs

The primary energy inputs include electricity, natural gas, propane and hogfuel (wood biomass, which is generated on-site) and are reported in Table 6. In the cradle-to-gate LCI model, the delivered electricity input was modeled based on a weighted average of the Quebec and BC specific electricity generation technology (coal, hydroelectric, nuclear etc.) including line losses. The electricity grids were derived from data published by Statistics Canada[3] and was calculated as the following contribution by fuel source per 1 kWh available at the Grid (including line loss):

[3] Statistics Canada (2010): Report on Energy Supply and Demand in Canada;
Statistics Canada (2010) CANSIM tables used for Stats Can Report on Energy Supply and Demand in Canada

Quebec Electricity Grid (per 1 kWh at user)

- Hydropower: 1.03 kWh
- Nuclear: 0.025 kWh
- Natural Gas: 0.001 kWh
- Residual Fuel Oil: 0.005 kWh

British Columbia Electricity Grid (per 1kWh at user):

- Hydropower: 1.01 kWh
- Natural Gas: 0.047 kWh
- Residual Fuel Oil: 0.005 kWh

Table 6: Energy Inputs to CLT Manufacturing Process

ENERGY INPUTS	UNIT	AMOUNT/m^3	AMOUNT/mbfm
BC Electricity	kWh	46.57	74.24
PQ Electricity	kWh	69.99	111.57
Gasoline	liters	0.01	0.01
Propane	kg	0.09	0.14
Fuel Oil	liters	0.45	0.72
Natural Gas	m3	1.28	2.04
Propane	liters	0.69	1.10
Biomass	odkg	9.53	15.19

4.1.5 Ancillary Material Inputs

In addition to the primary materials that are consumed, the machinery also uses hydraulic fluid and lubricants. The manufacturers did not provide data for these inputs, and thus an industry average was applied to include them in the LCI accounting.

Table 7: Ancillary Inputs to CLT Manufacturing Process

ANCILLARY INPUTS	UNIT	AMOUNT/m^3	AMOUNT/mbfm
Hydraulic Fluid	L	0.04	0.06
Lubricants	L	0.04	0.06
Packaging (Lumber Wrap)	Kg	0.46	0.72
Consumables Trucking	tkm	0.71	1.13

4.2 Cradle-to-gate LCI

The cradle-to-gate LCI model was completed by linking the gate-to-gate manufacturing data to upstream softwood lumber production data from a previously completed CIPEC project. The lumber LCA project was completed in 2009 and developed a Canadian average forest management, harvesting and log transportation process data as well as unit process data for rough milling, drying, and planing. The rough milling and drying processes were included in the lumber input profile to represent the shop grade rough lumber input that is used in the CLT manufacturing process.

5. Life Cycle Impact Assessment

5.1 LCIA Methodology

The impact categories and assessment methods were chosen in accordance with FP Innovations PCR on Structural and Architectural Wood Products. FPI's PCR draws heavily on ISO 21930 *Sustainability in building construction – Environmental declaration of building products*, and the mid-point indicators from the U.S. EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) v 4.03 were implemented to meet these reporting requirements. The TRACI impacts include primary energy (fossil fuel depletion), global warming, ozone depletion, photochemical oxidants (smog), eutrophication, and acidification potential. In addition to the LCIA results presented in this section, Appendix 4 includes the raw material inputs for the product system and may be used to meet the remaining LCI-based requirements in the PCR for water, renewable and non-renewable resource use.

Typically, LCIA is completed in isolation of the LCI, that is, the LCI requests a complete mass and energy balance for each unit process or product system under consideration and once completed the LCI is sifted through various LCIA indicator categories to determine possible impacts. For this study, we have relied on ISO 21930[4] to identify the various impact categories to be included in the LCIA and TRACI as the LCIA methodology. ISO 21930 provides an internationally accepted scope for decisions as to which LCIA categories should be supported for building sustainability metric analysis, while the TRACI LCIA methodology provides a North American context for the actual measures to be supported. ISO21930 stipulates a number of mid-point LCIA characterization measures to be supported and while not opposing end-point measures, dissuades their use until they are more internationally accepted. The measures advocated by ISO 21930 include:

1. Use of Resources and Energy
    a. Depletion of non-renewable primary energy
    b. Use of renewable primary energy
2. Climate change
3. Destruction of the ozone layer
4. Formation of photochemical oxidants

4 ISO 21930:2007 – Building and Construction Assets – Sustainability in building constructions – Environmental declaration of building products.

5. Acidification of land and water sources
6. Eutrophication

Optional end-point LCIA measures listed in ISO 21930 include human toxicity and ecotoxicity; however, their uncertainty increases with movement from mid-point to end-point measures. And due to the high degree this uncertainty these end-point measures have been excluded from the list of supported impact indicators. It is important to note that the impacts described by an LCA are estimates of relative and potential impacts, rather than direct measurements of real impacts, with limitations as described in the ISO international standards series 14040:2006. Table 8 sets out the impact categories supported by TRACI (2.0) and their inherent impact potential.

Table 8: Impact categories in Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI)

IMPACT CATEGORY	NATURAL ENVIRONMENT	HUMAN HEALTH	RESOURCES
Global warming	♦		
Acidification	♦	♦	
Ozone depletion	♦	♦	
Eutrophication	♦	♦	
Photochemical Smog	♦	♦	
Ecotoxicity	♦		
Human health: criteria air		♦	
Human health: cancer		♦	
Human health: non-cancer		♦	
Fossil fuel			♦

While TRACI supports fossil fuel depletion (on a global scale), it does not readily report primary energy use. For purposes of this study the total primary energy use was tabulated and summarized as an impact indicator directly from the LCI results. Further, the study adopts the "Cumulative Energy Demand" method to organize and report primary energy resource use[5]. Total primary energy is the sum of all energy sources drawn directly from the earth, such as natural gas, oil, coal, biomass or hydropower energy. The total primary energy can be further broken down into categories. For this reason, the study provides a measure of total primary energy derived from the direct LCI flows broken down into renewable and non-renewable energy sources. Higher heating value (HHV) of primary energy carriers is used to calculate the primary energy values reported in the study.

[5] R. Frischknecht and N. Jungbluth (Editors), *Implementation of Life Cycle Impact Assessment Methods*, DataV1.1, Ecoinvent Report No. 3, 2004.

With respect to the other LCIA measures, the following TRACI impact categories (IC) and characterization factors (CF)[6] were calculated and reported (also see Table 9).

a. **Global warming (IC) -** TRACI uses global warming potentials (CF), a midpoint metric proposed by the International Panel on Climate Change (IPCC), for the calculation of the potency of greenhouse gases relative to CO2. The 100-year time horizons recommended by the IPCC and used by the United States for policy making and reporting are adopted within TRACI. Global warming potential (GWP) – the methodology and science behind the GWP calculation can be considered one of the most accepted LCIA categories. GWP_{100} will be expressed on equivalency basis relative to CO_2 – i.e., equivalent CO_2 mass basis.

b. **Acidification (IC) -** As per TRACI, acidification comprises processes that increase the acidity (hydrogen ion concentration, [H+]) of water and soil systems. Acidification is a more regional rather than global impact effecting fresh water and forests as well as human health when high concentrations of SO_2 are attained. The Acidification potential (CF) of an air emission is calculated on the basis of the number of H+ ions which can be produced and therefore is expressed as potential moles H+ equivalents per kg of contributing emission.

c. **Ozone depletion (IC) -** Stratospheric ozone depletion is the reduction of the protective ozone within the stratosphere caused by emissions of ozone-depleting substances. International consensus exists on the use of Ozone Depletion Potentials (CF), a metric proposed by the World Meteorological Organization for calculating the relative importance of CFCs, hydrochlorofluorocarbons (HFCs), and halons expected to contribute significantly to the breakdown of the ozone layer. TRACI is using the ozone depletion potentials published in the Handbook for the International Treaties for the Protection of the Ozone Layer (UNEP-SETAC 2000), where chemicals are characterized relative to CFC-11.

d. **Eutrophication (IC) -** In TRACI, eutrophication is defined as the fertilization of surface waters by nutrients that were previously scarce. This measure encompasses the release of mineral salts and their nutrient enrichment effects on waters – typically made up of phosphorous and nitrogen compounds and organic matter flowing into waterways. The result is expressed on an equivalent mass of nitrogen (N) basis. The characterization factors estimate the eutrophication potential of a release of chemicals containing N or P to air or water, per kilogram of chemical released, relative to 1 kg N discharged directly to surface freshwater.

e. **Photochemical smog (IC) -** *Photochemical ozone formation potential (CF)* – Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level where, in the presence of sunlight, they produce photochemical smog, a

[6] Characterization factor is a factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator. The common unit allows calculation of the category indicator result [ISO 14040:2006].

symptom of photochemical ozone creation potential (POCP). While ozone is not emitted directly, it is a product of interactions of volatile organic compounds (VOCs) and nitrogen oxides (NO_x). The "smog" indicator is expressed on a mass of equivalent ozone (O_3) basis.

f. **Total primary energy (IC) –** Total primary energy is the sum of all energy sources which are drawn directly from the earth, such as natural gas, oil, coal, biomass or hydropower energy. The total primary energy contains further categories namely non-renewable and renewable energy, and fuel and feedstock energy. *Non-renewable energy* includes all fossil and mineral primary energy sources, such as natural gas, oil, coal and nuclear energy. *Renewable energy* includes all other primary energy sources, such as hydropower and biomass. *Feedstock energy* is that part of the primary energy entering the system which is not consumed and/or is available as fuel energy and for use outside the system boundary. Total Primary Energy is expressed in MJ.

Table 9: Selected Impact Indicators

IMPACT CATEGORY	UNIT	SOURCE METHOD	LEVEL OF SITE SPECIFICITY
Global warming	kg CO2 eq	TRACI	Global
Smog	kg O3 eq	TRACI	North America
Acidification	mol H+ eq	TRACI	North America
Ozone depletion	kg CFC-11 eq	TRACI	North America
Eutrophication	kg N eq	TRACI	North America
Total energy*	MJ eq	CED – Adapted	Global
Fossil energy	MJ eq	CED – Adapted	Global
Nuclear energy	MJ eq	CED – Adapted	Global
Renewable, biomass	MJ eq	CED – Adapted	Global
*Other renewables***	MJ eq	CED – Adapted	Global

* Fossil energy, Nuclear energy, and Renewables are subsets of Total energy

** Other Renewables includes hydro, solar, biomass, and geothermal energy

5.2 LCIA Results

5.2.1 Cradle-to-gate LCIA Results

The first step of the LCIA was to assess the impacts of the entire cradle-to-gate production system. The LCIA results for the mass allocation cradle-to-gate model are presented in Table 10a in impact category-specific units, Table 10b on a percentage basis, and in Figure 3 to show the contribution of each life stage. The results for the economically allocated cradle-to-gate model are provided in Appendix 3. It should be noted that the reported global warming potential (GWP) results do not account for forest carbon uptake, but does exclude CO_2 emissions associated with wood combustion in accordance with FPI's PCR on wood products.

Table 10a: Cradle-to-gate CLT LCIA Results, mass allocation, absolute basis

Impact category	Unit	Total	Logging	Lumber Milling	CLT Manufacturing
Global Warming	kg CO2 eq	**79.99**	11.70	27.87	40.43
Acidification	H+ moles eq	**41.98**	1.23	25.78	14.97
Eutrophication	kg N eq	**1.08E-01**	1.60E-03	8.94E-02	1.66E-02
Smog	kg O3 eq	**16.34**	0.54	11.53	4.27
Ozone Depletion	kg CFC-11 eq	**3.06E-07**	5.77E-10	7.34E-10	3.05E-07
Total Energy	MJ eq	**3336.58**	175.61	1727.16	1433.80
Non renewable, fossil	MJ eq	**1338.02**	173.46	443.03	721.53
Non-renewable, nuclear	MJ eq	**158.93**	1.79	67.06	90.08
Renewable, biomass	MJ eq	**1326.57**	0.00	1135.77	190.80
Renewable, other	MJ eq	**513.05**	0.36	81.29	431.39

Table 10b: Cradle-to-gate CLT LCIA Results, mass allocation, percentage basis

Impact category	Total	Logging	Lumber Milling	CLT Manufacturing
Global Warming	100%	15%	35%	50%
Acidification	100%	3%	62%	35%
Eutrophication	100%	1%	83%	15%
Smog	100%	3%	71%	26%
Ozone Depletion	100%	0%	0%	100%
Total Energy	100%	5%	52%	43%
Non renewable, fossil	100%	13%	34%	53%
Non-renewable, nuclear	100%	1%	43%	56%
Renewable, biomass	100%	0%	86%	14%
Renewable, other	100%	0%	16%	84%

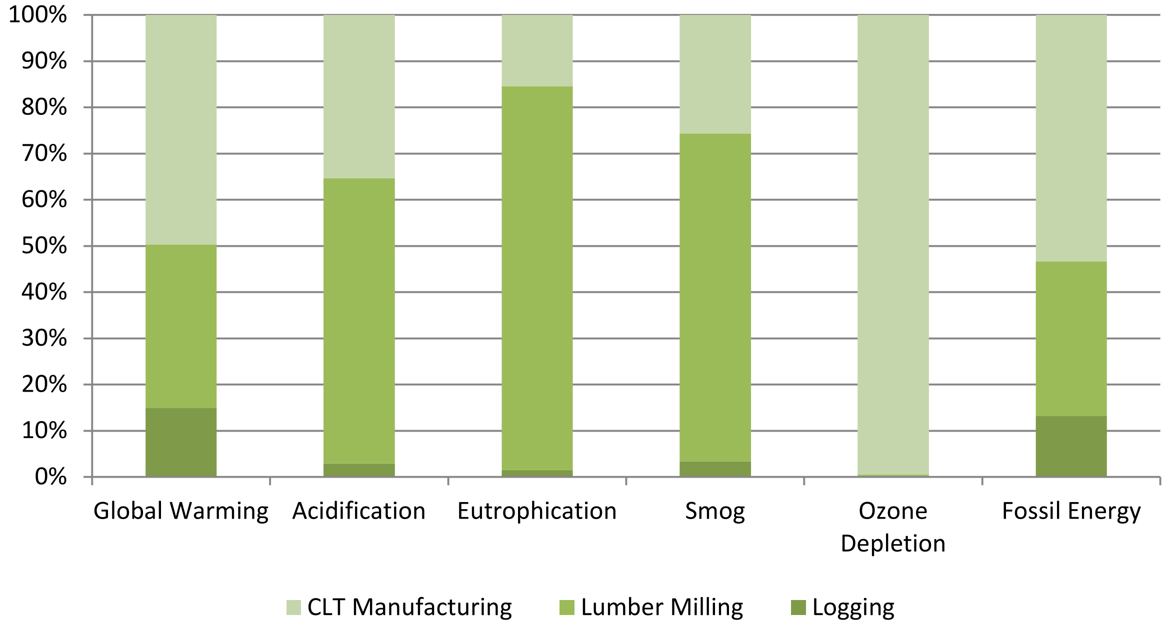

Figure 3: Cradle-to-gate CLT LCIA Results, mass allocation, cumulative percentage basis

The CLT manufacturing process accounts for 50% of global warming impacts and 53% of fossil fuel consumption. The manufacturing portion accounts for roughly equivalent impacts as the logging or lumber milling life stages in every impact category except smog and biomass energy. Logging, which relies heavily on diesel-fueled heavy equipment, typically causes disproportionate smog impacts in wood LCA studies relative to overall energy use and other impacts. The lumber milling stage relies heavily on biomass energy for drying and similarly causes disproportionate impacts for fossil energy use.

The ozone depletion caused by the CLT manufacturing process is also noteworthy in that this stage causes 100% of cradle-to-gate impacts. These impacts may be considered as noise, however, as the overall ozone depletion impacts are only 3.05×10^{-7} kg CFC-11, and thus the high CLT manufacturing contribution is indicative of how low these impacts are overall.

5.2.2 Gate-to-gate LCIA Results

The next step of the LCIA was to assess just the impacts of the gate-to-gate manufacturing process. The LCIA results for the gate-to-gate model are presented in Table 11a in impact category-specific units, Table 11b on a percentage basis, and Figure 4 to show the contribution of each life stage.

Table 11a: Gate-to-gate CLT LCIA Results, absolute basis

Impact category	Unit	Manufacturing Total	Resins	Energy	Transport	Packaging
Global Warming	kg CO2 eq	**40.43**	**15.34**	8.11	16.35	0.64
Acidification	H+ moles eq	**14.97**	**6.28**	3.17	4.79	0.72
Eutrophication	kg N eq	**1.66E-02**	**9.28E-03**	1.59E-03	5.57E-03	1.57E-04
Smog	kg O3 eq	**4.27**	**0.80**	0.70	2.74	0.03
Ozone Depletion	kg CFC-11 eq	**3.05E-07**	**3.04E-07**	1.48E-10	6.23E-10	3.06E-11
Total Energy	MJ eq	**1433.80**	**398.10**	771.60	225.29	38.81
Non renewable, fossil	MJ eq	**721.53**	**328.47**	131.64	223.07	38.36
Non-renewable, nuclear	MJ eq	**90.08**	**67.83**	19.91	1.90	0.45
Renewable, biomass	MJ eq	**190.80**	**0.22**	190.58	0.00	0.00
Renewable, other	MJ eq	**431.39**	**1.58**	429.48	0.33	0.00

Table 11b: Gate-to-gate CLT LCIA Results, percentage basis

Impact category	Total	Resins	Energy	Transport	Packaging
Global Warming	100%	43%	19%	37%	2%
Acidification	100%	46%	20%	30%	5%
Eutrophication	100%	57%	10%	32%	1%
Smog	100%	22%	19%	58%	1%
Ozone Depletion	100%	100%	0%	0%	0%
Total Energy	100%	28%	54%	15%	3%
Non- renewable, fossil	100%	49%	17%	28%	6%
Non-renewable, nuclear	100%	69%	28%	2%	1%
Renewable, biomass	100%	0%	100%	0%	0%
Renewable, other	100%	0%	100%	0%	0%

The transportation input of lumber and resin production are the primary drivers of impacts in the manufacturing life stage. The lumber input is trucked between 125 and 530 km to the facilities, which causes 37% of the gate-to-gate global warming impact and consumes 28% of fossil fuels in this life stage. The resin use contributes to 43% of the global warming impact and 49% of fossil energy use. The one notable impact of the resin use is the generation of ozone depletion impacts. While overall negligible in absolute terms (3.06e-7 kg CFC-11 eq.), the impacts can be traced to upstream polyurethane resin manufacturing processes and the emissions of methane tetrachloride (CFC-10) in chlorine and sodium hydroxide background processes.

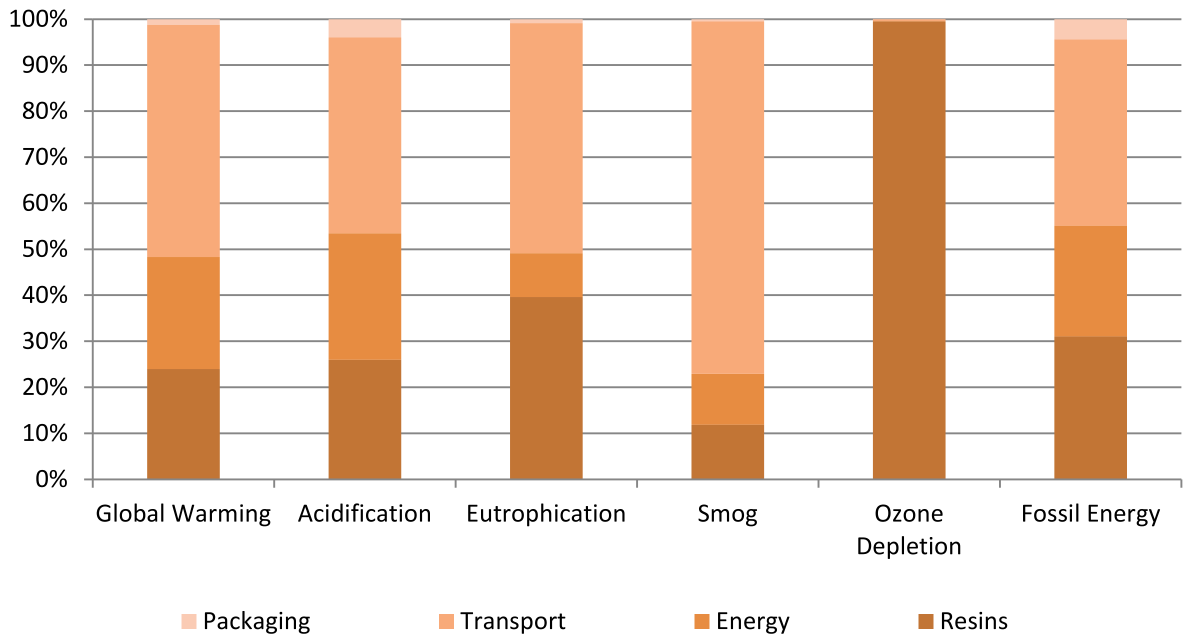

Figure 4: Gate-to-gate CLT LCIA Results, cumulative percentage basis

6. Conclusions

6.1 Limitations of LCA Study

FPI's PCR also requires additional information related to environmental issues that are beyond the scope of this LCA. This information includes impacts to forest biodiversity and any other environmental certifications that may apply to the product. Additionally, to account for biogenic carbon sequestration, the PCR also requires a statement as to the long-term sustainability of the source forest carbon stock in accordance with ASTM 7612:2010[7]. These elements were necessarily excluded from the LCA.

6.2 Applicability of LCA for EPD Development

The primary goal of this LCA was to develop life cycle inventory data and impact assessment results for CLT that could be used to develop EPD's in accordance with FPI's PCR for wood products. To this end, we developed un-allocated life cycle inventory data for cradle-to-gate production of CLT, allocated and "rolled-up" this unit process data, and calculated impact assessment results. In addition to the impact assessment results, the life cycle inventory is also provided in Appendix 4. Including the LCI enables the raw water and resource use inventory elements that are required by the PCR to be included in the EPD.

This cradle-to-gate LCA does incorporate the necessary scope to develop a "business-to-business" EPD in accordance with FPI's product category rules. The three life stages included in the LCA are logging, lumber milling, and CLT manufacturing. The impact assessment results for the three life stages indicate that no one life stage dominates the life cycle with the exception of resin use in manufacturing causing the bulk of ozone depletion. Regardless, the underlying LCI calculation details and LCIA contribution analysis allow the EPD developer the transparency to develop a verifiable EPD.

6.3 Potential for Impact Improvement

The process contribution portion of the impact assessment identified hot spots in the CLT life cycle that should be the focus of impact abatement efforts. As was noted, the CLT manufacturing process itself accounts for significant global warming impacts and fossil fuel consumption. The resin component is the greatest contributor of manufacturing impacts and to whatever degree possible, Structurlam should consider minimizing resin use or using resins with lower embodied impacts.

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[7] http://www.madcad.com/store/subscription/ASTM-D7612-10/

The contribution analysis also found that logging, which relies heavily on diesel-fueled heavy equipment, causes disproportionate smog impacts and should be minimized if possible. The ozone depletion caused by upstream emissions in the resin production system, while noteworthy in the contribution analysis, is not of serious concern as the overall impact is quite low.

The conclusion of this hot spot analysis is that overall energy and resin efficiency improvements are the greatest area for potential improvement in the CLT life cycle.

6.4 Biogenic Carbon Accounting

Because this is a cradle-to-gate LCA, it did not address biogenic carbon sequestration and its impact on the overall carbon footprint of CLT. Should that be desired and the cradle-to-grave global warming potential is to be estimated, the oven-dry mass of wood in the product is provided in Table 3 and the equivalent carbon dioxide removals from the atmosphere are given in Table 12 below. The biogenic carbon accounting for a cradle-to-grave (i.e., business-to-consumer) EPD would be based on statistical average service lives and landfill decomposition half-lives as these life stages were not included in the LCA and thus no use and end of life parameters were developed.

Table 12: Cradle-to-gate Global Warming Potential Including Biogenic Carbon Sequestration

Life Stage	**Unit**	**Total**
Carbon Uptake During Growth	kg CO2 eq	**-764.56**
Logging	kg CO2 eq	11.38
Lumber Milling	kg CO2 eq	24.33
CLT Manufacturing	kg CO2 eq	40.37
Cradle-to-Gate Net Total	kg CO2 eq	**-688.48**

The net cradle-to-gate global warming potential total is shown in Table 12 and is illustrative of the potential for carbon sequestration impacts on the cradle-to-grave carbon footprint. The scale for this credit far outweighs the global warming caused by fossil fuel consumption throughout the cradle-to-gate product system.

7. **References**

ASTM D7612:2010, Standard Practice for Categorizing Wood and Wood-Based Products According to Their Fiber Sources: http://www.madcad.com/store/subscription/ASTM-D7612-10/

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FP Innovations (2011): Product Category Rules (PCR) for preparing an Environmental Product Declaration (EPD) for North American Structural and Architectural Wood Products, Version 1 (UN CPC 31, NAICS 321), November 8, 2011. http://www.forintek.ca/public/pdf/Public_Information/EPD%20Program/PCR%20November%208%202011%20Final.pdf

ISO 14040:2006. Environmental Management – Life Cycle Assessment – Principles and Framework.

ISO 14044:2006. Environmental Management – Life Cycle Assessment – Requirements and guidelines.

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Statistics Canada (2010): Report on Energy Supply and Demand in Canada

Statistics Canada (2010) CANSIM tables used for Stats Can Report on Energy Supply and Demand in Canada

TRACI: Tool for the Reduction and Assessment of Chemical and other environmental Impacts: http://www.epa.gov/ORD/NRMRL/std/sab/traci/

USLCI Database: http://www.nrel.gov/lci

Wilson J. (2009) CORRIM: Phase II Final Report Module H Resins: A Life-Cycle Inventory of Manufacturing Resins Used in the Wood Composites Industry. http://www.corrim.org/pubs/reports/2010/phase2/Module_H.pdf

Appendix 1: CLT Data Collection Survey

ATHENA INSTITUTE CLT MANUFACTURE DATA WORKSHEET

General Information

Please complete this worksheet based on 2010 year production

If basis other than 2010 calendar year production, describe here:

PARTICIPANT INFORMATION

Prepared by:		Contact Phone Number:	
Position:		Email:	
Facility Location:		Date Prepared:	

ATHENA: Optional Section

DATA COLLECTION METHOD

Please check the boxes for the data collection methods used to fill out this survey.

	Material In	Energy In	Product Out	Waste Out	Emissions
Inventory Records					
Accounting Records					
Equipment spec's					
Engineering estimates					
Other (describe)					

TOTAL FACILITY PRODUCTION

	Amount	Units
Cross Laminated Timber Product:		m3
Lumber (Estimated by Category):		
Glulam (Estimated by Category):		
I-Joists (Estimated by Category):		
Other Products (Estimated by Category):		
Other Products (Estimated by Category):		
Other Products (Estimated by Category):		
Other Products (Estimated by Category):		
Other Products (Estimated by Category):		

Add Rows if Necessary

ATHENA: Units to be substituted with those used in company record keeping - these units are where we need to get with the analysis - i.e. area and thickness

ATHENA INSTITUTE LCI PROCESS DATA WORKSHEET

CLT Manufacturing Inputs and Outputs

PRODUCT INFORMATION

	Amount	Units
Total CLT Production in 2010		m3

CLT PRODUCT OUTPUT IN 2010

	Amount	Units	Thickness or # Layers and Lumber Dimensions	Other Spec's
CLT Type 1				
CLT Type 2				
CLT Type 3				
CLT Type 4				
Other				
Other				
Other				
Other				
Other				
Other				

Add Rows if Necessary

ATHENA: Only provide data for CLT portion of porduction in this section

LUMBER INPUTS FOR CLT IN 2010

	Amount	Units	Species	Moisture Content	Distance to Supplier (miles)	Mode of Transport % Road	% Rail	% Ship
Lumber Type 1								
Lumber Type 2								
Lumber Type 3								
Lumber Type 4								
Other								
Other								
Other								
Other								
Other								
Other								

Add Rows if Necessary

ATHENA INSTITUTE LCI PROCESS DATA WORKSHEET

CLT Manufacturing Inputs and Outputs

ATHENA: Only provide data for CLT portion of production in this section

ATHENA: Optional Section

RESIN INPUTS FOR CLT IN 2010	Amount	Units	Application (finger joint, face bond, etc.)	MSDS Provided?	Distance to Supplier (miles)	Mode of Transport % Road	% Rail	% Ship
Resin Type 1								
Resin Type 2								
Resin Type 3								
Resin Type 4								
Other								
Other								
Other								
Other								
Other								
Other								
Add Rows if Necessary								

ATHENA: To be given as % of inputs if CLT specific waste not tracked

CLT SPECIFIC WASTE IN 2010	Amount	Units	% of Inputs (if known)	Disposal Method: Municipal Waste	Recycle	Other Treatment
Shavings						
Chips						
Sawdust						
Resin Waste						
CLT off-spec and end cuts						
Other						
Other						
Add Rows if Necessary						

ATHENA INSTITUTE LCI PROCESS DATA WORKSHEET

CLT Manufacturing Energy Use

ATHENA: In this section please make your best estimate as to the portion of energy used to manufacture the different products

FACILITY ENERGY INPUTS IN 2010

	Amount	Units	Energy Use by Product	
			% CLT Production	% Other
Purchased Elect.		kWh		
Natural gas		m3		
Diesel fuel		liters		
Gasoline		liters		
Propane		liters		
Other (specify)				
Other (specify)				
Other (specify)				

Add Rows if Necessary

ATHENA INSTITUTE LCI PROCESS DATA WORKSHEET

CLT Manufacturing Anciliary Material Inputs and Waste

ANCILIARY MATERIAL "INPUTS" IN 2010

	Amount	Units	Distance to Supplier (miles)	Ancilary Material Use by Product: % CLT Production	% Other
Hydraulic fluid		liters			
Lubricants		liters			
Antifreeze		liters			
Shrink wrap		kg			
Pallets (not reused)		#			
Cardboard		kg			
Other					
Other					
Add Rows if Necessary					

ANCILIARY MATERIAL "WASTE" IN 2010

	Amount	Units	% of Inputs (if known)	Disposal Method: Municipal Waste	Recycle	Other Treatment
Hydraulic fluid		liters				
Lubricants		liters				
Antifreeze		liters				
Shrink wrap		kg				
Pallets (not reused)		#				
Cardboard		kg				
Other						
Other						
Add Rows if Necessary						

Appendix 2: Life Cycle Inventory Secondary Data Sources

Technosphere Input	LCI Data Source
Acrilin Melamine	USLCI data for melamine urea formaldehyde resin
Diesel Truck Delivery	USLCI data for diesel transport, combination truck, diesel powered; pre-combustion dummy processes corrected
Electricity	Athena data for BC and Quebec-specific % electricity source and line loss; USLCI data for combustion processes
Gasoline	USLCI data for gasoline combusted in equipment; pre-combustion dummy processes corrected
Hogfuel	AP42 data for biomass combustion; normalized to oven-dried kg inputs and all technosphere inputs for wood production removed to reflect internal source
Hydraulic Fluid	USLCI data for gasoline production; pre-combustion dummy processes corrected
Lubricants	USLCI data for gasoline production; pre-combustion dummy processes corrected
Natural gas	USLCI data for natural gas combusted in boiler; pre-combustion dummy processes corrected
Polyurethane	Ecoinvent data for polyurethane, flexible foam; modified by substituting USLCI energy models
Propane	USLCI data for propane combusted in equipment; pre-combustion dummy processes corrected
Softwood Lumber	CIPEC (LCA by Athena/FPI) data for rough sawn dried lumber - mass allocation profile used in the base case and economic based allocation used in the appendix profile – updated in 2012
Lumber Wrap	USLCI data for high density polyethylene resin

Appendix 3: Economic allocation LCIA Results

Table 12a: Cradle-to-gate CLT LCIA Results, economic allocated, absolute basis

Impact category	Unit	Total	Logging	Lumber Milling	CLT Manufacturing
Global Warming	kg CO2 eq	**94.50**	21.25	32.82	40.43
Acidification	H+ moles eq	**51.54**	18.07	18.50	14.97
Eutrophication	kg N eq	**3.97E-02**	1.74E-02	5.73E-03	1.66E-02
Smog	kg O3 eq	**17.97**	9.73	3.97	4.27
Ozone Depletion	kg CFC-11 eq	**3.48E-07**	1.15E-08	3.13E-08	3.05E-07
Total Energy	MJ eq	**3510.72**	291.72	1785.20	1433.80
Non renewable, fossil	MJ eq	**1711.32**	290.36	699.43	721.53
Non-renewable, nuclear	MJ eq	**172.43**	1.14	81.21	90.08
Renewable, biomass	MJ eq	**1072.46**	0.00	881.66	190.80
Renewable, other	MJ eq	**554.51**	0.22	122.90	431.39

Table 12b: Cradle-to-gate CLT LCIA Results, economic allocated, percentage basis

Impact category	Total	Logging	Lumber Milling	CLT Manufacturing
Global Warming	100%	15%	35%	50%
Acidification	100%	3%	62%	35%
Eutrophication	100%	1%	83%	15%
Smog	100%	3%	71%	26%
Ozone Depletion	100%	0%	0%	100%
Total Energy	100%	5%	52%	43%
Non renewable, fossil	100%	13%	34%	53%
Non-renewable, nuclear	100%	1%	43%	56%
Renewable, biomass	100%	0%	86%	14%
Renewable, other	100%	0%	16%	84%

Appendix 4: Other Reporting Requirements as per PCR

		Total	Logging, Lumber Milling, and Delivery to CLT Plant	CLT Manufacture
Renewable Resources				
Wood Fiber	kg	5.30E+02	5.30E+02	0.00E+00
Non-renewable Resources				
Energy Resources as Heat				
Coal, in ground	kg	6.15E+00	3.83E+00	2.32E+00
Gas, natural, in ground	kg	1.20E+01	6.11E+00	5.93E+00
Oil, crude, in ground	kg	7.10E+00	2.48E+00	4.62E+00
Uranium oxide, in ground	kg	9.94E-05	1.01E-06	9.84E-05
Uranium, in ground	kg	1.27E-04	2.39E-05	1.03E-04
Energy Resources as Feedstock - Resins				
Gas, natural, in ground	kg	1.92E+00	0.00E+00	1.92E+00
Oil, crude, in ground	kg	2.63E+00	0.00E+00	2.63E+00
Energy Resources as Feedstock - Packaging				
Gas, natural, in ground	kg	1.31E+00	7.00E-01	6.09E-01
Oil, crude, in ground	kg	3.26E+00	3.09E+00	1.64E-01
Other Non-renewable Resources - Packaging				
Iron ore, in ground	kg	7.23E-04	0.00E+00	7.23E-04
Water				
Water withdrawal	l	3.92E+02	3.97E+01	3.53E+02
Water consumption	l	1.36E+02	2.49E+01	1.12E+02
Hazardous Waste				
None				
Non-Hazardous Waste				
Wood waste	kg	1.18E+02	5.28E+01	6.51E+01
Heater and fly ash	kg	3.05E+00	3.05E+00	0.00E+00
Unspecified waste	kg	6.19E+00	5.87E+00	3.18E-01