Life Cycle Assessment of Mass Ply Panels Produced in Oregon

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ABBREVIATIONS

APA	American Panel Association
CNC	Computer Numerical Controlled
CORRIM	Consortium for Research on Renewable Industrial Materials
Cubic foot	ft^3
Cubic meter	m^3
EPDs	Environmental Product Declarations
ESP	Electrostatic precipitators
ft	Feet
ft3	Cubic feet
GHG	Greenhouse gases
GWP	Global Warming Potential
GWP_{TRACI}	Global Warming Potential as an output from the TRACI impact methods. Does not include carbon dioxide released from biogenic sources
GWP_{Bio}	Carbon dioxide only released from the combustion of biogenic materials (eg wood)
ISO	International Organization for Standardization
kg	kilogram
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LVL	Laminated Veneer Lumber
m	meters
m^3	cubic meters
MC	moisture content
MJ	megajoule
MPP	Mass ply panels
odkg	oven dry weight of wood in kilograms
PCR	Product Category Rules
PM	Particular matter
PNW	Pacific Northwest
odkg	oven dry weight of wood in kilograms
SCL	Structural composite lumber
tkm	metric tonne – kilometers
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
VOC	Volatile organic compounds

GLOSSARY OF TERMS

Allocation – A way of dividing emissions and resource use among the different products of a process. The partitioning can be made on weight basis, energy content, or economic value.

Cradle-to-gate – LCA model which includes upstream part of the product life cycle, i.e. all steps from raw material extraction to product at factory gate.

Declared Unit - Quantity of a wood building product for use as a reference unit, e.g. mass, volume, for the expression of environmental information needed in information modules.

Functional Unit – expresses the function of studied product in quantitative terms and serves as basis for calculations. It is the reference flow to which other flows in the LCA are related. It also serves as a unit of comparison in comparative studies.

Laminated Veneer Lumber (LVL) - is an engineered wood product that uses multiple layers of thin wood assembled with adhesives.

Life cycle assessment (LCA) – Method for the environmental assessment of products covering their lifecycle from raw material extraction to waste treatment

Life cycle inventory (LCI) – LCA study that goes as far as an inventory analysis but does not include impact assessment.

Life cycle impact assessment (LCIA) – Phase of an LCA study during which the environmental impacts of the product are assessed and evaluated.

Product Category Rules (PCR) – Set of specific rules, requirements, and guidelines for the development of type III environmental declarations for one or more product categories (ISO 14025).

Structural composite lumber (SCL) - includes LVL, PSL, LSL, and OSL, is a family of engineered wood products in which the grain runs primarily in the same direction.

System boundary – A set of criteria that specifies which unit processes are part of a product system (adapted from ISO 104044)

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1 INTRODUCTION

Every material has an environmental footprint. Mass Plywood Panel, a new entrant in the mass timber category, has the potential to revolutionize the mass timber sector. The environmental consequences of producing Mass Ply Panels (MPP) are carried forward into the life cycle of products made from it, such as wooden structures. Life cycle inventory (LCI) data cover forest regeneration through to final product at the mill gate. There is over 20 years of life cycle assessment (LCA) research on major US produced forest products, both structural and nonstructural, from four major regions (www.corrim.org).

This report describes the cradle-to-gate (mill) energy and materials required for producing MPP produced in Oregon and the subsequent releases into the environment. The environmental impacts, global warming, ozone depletion, acidification, smog, and eutrophication are discussed.

The MPP facility located in Lyons, Oregon was surveyed to collect the material use and energy consumption for the 2018 calendar year. Inputs included logs, fuels, packaging materials, resins, and chemicals necessary for MPP production. The facility also produces plywood and veneer (green and dry) that is sold. Although data was collected for the entire facility operation, results for only producing MPP are reported here.

The data collection was performed under "CORRIM Guidelines for Performing Life Cycle Inventories on Wood Products", undated, but current in the fall of 2012, a scientifically sound and consistent process established by CORRIM (Consortium for Research on Renewable Industrial Materials). It follows ISO 14040 standards (ISO 2006a-c), ISO 21930 (ISO 2017), the Product Category Rules (PCR) for North American Structural and Architectural Wood Products (UL 2019) that will provide the guidance for preparation of North American wood product Environmental Product Declaration (EPD) and Part A: Life Cycle Assessment Calculations Rules and Report Requirements (UL 2018).

2 LIFE CYCLE ASSESSMENT

Life-cycle assessment (LCA) has evolved as an internationally accepted method to analyze complex impacts and outputs of a product or process and the corresponding effects they might have on the environment. LCA is an objective process to evaluate a product's life cycle by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials uses and releases on the environment; and to evaluate and implement opportunities to effect environmental improvements. LCA studies can evaluate full product life cycles, often referred to as "cradle to grave", or incorporate only a portion of the products life cycle, referred to as "cradle-to-gate", or "gate-to-gate". This study can be categorized as a cradle-to-gate LCA as it includes forestry operations though the manufacturing of MPP ready to be shipped at the mill gate.

As defined by the International Organization for Standardization (ISO 2006a-b), LCA is a multiphase process consisting of a 1) Goal and Scope Definition, 2) Life Cycle Inventory (LCI), 3) Life Cycle Impact Assessment (LCIA), and 4) Interpretation (Figure 1). These steps are interconnected, and their outcomes are based on goals and purposes of a study.

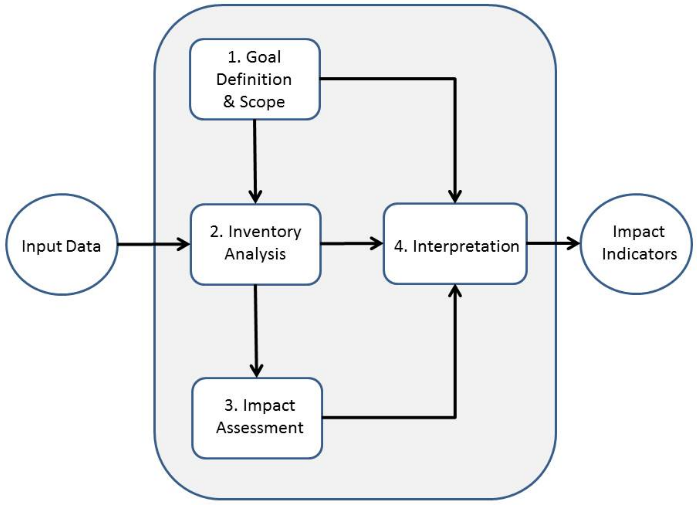

Figure 2-1 Steps involved in a life cycle assessment.

An LCA begins with a project goal, scope, functional unit, system boundaries, any assumptions and study limitations, method of allocation, and the impact categories that will be used.

The key component is the LCI which is an objective, data-based process of quantifying energy and raw material requirements, air emissions, waterborne effluents, solid waste, and other environmental releases occurring within the system boundaries. It is this information which provides a quantitative basis for comparing wood products, their manufacturing processes and, most importantly from the forest industry point of view, wood products performance against competitors who use other resources to create alternative products.

The LCIA process characterizes and assesses the effects of environmental releases identified in the LCI into impact categories such as global warming, acidification, carcinogenics, respiratory effects, eutrophication, ozone depletion, ecotoxicity, and smog.

The life cycle interpretation is a phase of LCA in which the findings of either the LCI or the LCIA, or both, are evaluated in relation to the defined goal and scope to reach conclusions and recommendations. This final step in an LCA involves an investigation of significant environmental aspects (e.g., energy use, greenhouse gases), their contributions to the indicators under consideration, and which unit processes in the system are generating the emissions. For example, if the results of a LCIA indicate a particularly high value for the global warming potential indicator, the analyst could refer to the inventory to determine which environmental flows are contributing to the high value, and which unit processes contribute to those outputs. This is also used as a form of *quality control*, and the results can be used to refine the scope definition to focus on the more important unit processes. This step also supports arriving at more certain conclusions and supportable recommendations.

3 Goal and Scope

It is the goal and scope that provide the plan for conducting the LCI including data collection, compilation, and interpretation.

3.1 Goals and Objectives

3.1.1 *Goals*

The primary goal is to generate a gate-to-gate LCA of MPP manufacturing. The cradle-to-gate LCA will follow data and reporting requirements as outlined in the PCR (UL 2019) will provide the guidance for preparation of a business-to-business EPD[1].

3.1.2 *Intended Audience*

The primary audience for the results of this LCA report is Freres Lumber Company, Lyons, Oregon

3.1.3 *Comparative Assertions*

The report does not include product use and end of life phases, which are required for comparative assertions relative to substitute products. If future comparative studies are intended and disclosed to the public, the LCA boundary would need to be expanded to include the use and end of life phases consistent with the ISO 14044:2006 guidelines and principles and ISO 21930 core rules for EPDs (ISO 2006a-c, ISO 2017), and compliance with the Wood Products PCR, Part A and B (UL 2018 and 2019).

3.2 Scope of Considered System

3.2.1 *Geographical distribution*

MPP is produced at one facility located in Lyons, Oregon on the westside of the Cascade Mountains. All data for the LCA study were obtained from the manufacturer. Total MPP production for 2018 was 75 thousand cubic feet (2,124 cubic meters).

3.2.2 *System boundary*

This study is a cradle-to-gate LCA study (Figure 3-1). Information modules included in the LCA are included in Table 3-1. The LCA is divided into three information modules. The information modules A1, A2, and A3 are based on actual and representative data of the production process of MPP. Excluded from the system are both human activity and capital equipment, transportation of employees, construction, maintenance, use, and end of life treatments.

[1] The report is written so Freres Lumber could proceed to an EPD if they decide to do so.

Table 3-1 MPP System Modules Included

Information Module		Description
A1	Raw Material Production	Includes: – The cradle-to-gate production of LVL and resins that are used in the MPP manufacture. – Production of upstream processes for all resources, raw materials, fuels, and energy for LVL – Regeneration processes include: 1.) nursery operations (fertilization, irrigation, energy), 2.) site preparation (herbicide, slash piling, slash burning), planting, fertilization, thinnings, and other forest management operations
A2	Raw Material Transportation	Average or specific transportation of raw materials (including secondary materials and fuels) from source to manufacturing site.
A3	Manufacturing	Manufacturing of MPP including packaging

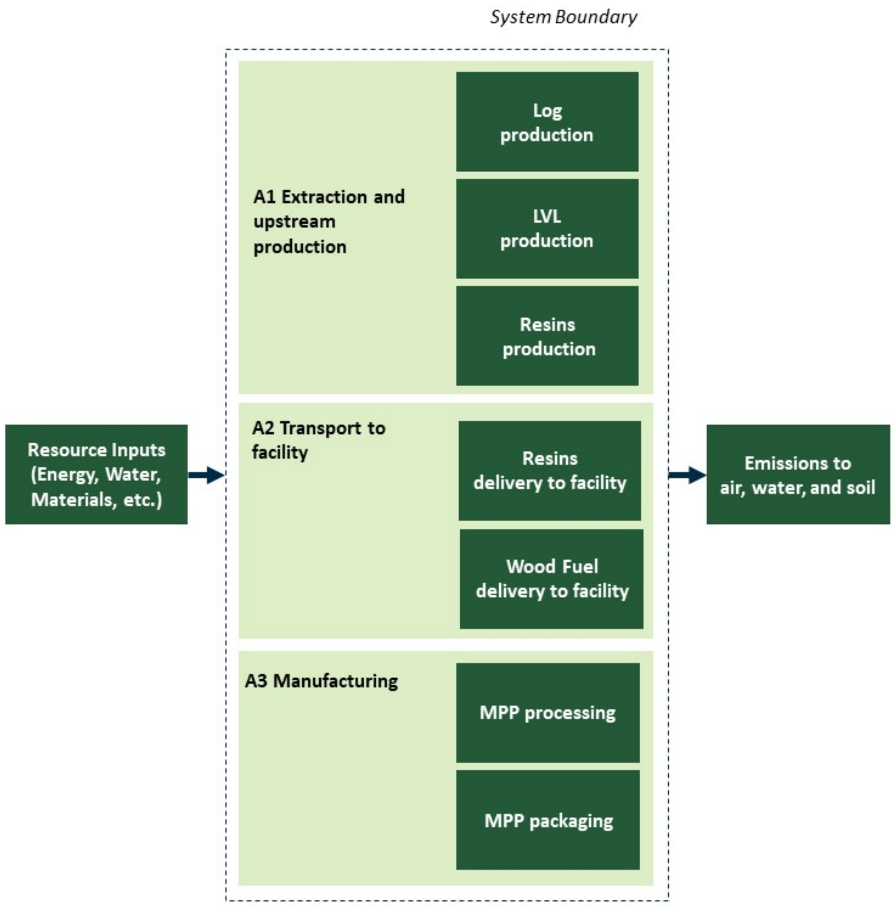

Figure 3-1 Cradle-to-gate system boundary for MPP

3.2.3 CUT OFF RULES

According to the PCR, if the mass/energy of a flow is less 1 percent of the cumulative mass/energy of the model flow it may be excluded, provided its environmental relevance is minor. The cut-off rules are not applied to hazardous and toxic materials and are all included in the life cycle inventory. This analysis for MPP included all energy and mass flows for primary data. No material or energy input or output was knowingly excluded from the system boundary.

3.2.4 DATA COLLECTION

Surveys were used to collect the LCI data in accordance with CORRIM guidelines and ISO 14044 standards. This study relied almost exclusively on production and emissions data provided by the MPP producer, with some secondary data on fuels and electrical grid inputs from the US LCI database and European datasets (Datasmart2018 and Ecoinvent 3.4). There is only one facility that produces MPP and they provided data for 2018 structural composite lumber (SCL) and MPP production, raw material and fuel use, electricity consumption, and on-site emissions.

3.2.5 CALCULATION RULES

MPP is commonly reported in cubic feet. The survey results were converted to a unit production basis, one cubic meter. One cubic foot of LVL equals 0.02832 m3 with an oven-dried moisture content of 8%. SimaPro, version 9.0 (Pré Consultants 2019) was used as the accounting program to track all of the materials.

Missing data is defined as data not reported in surveys. There were no missing data noted in the survey.

3.3 FUNCTIONAL AND DECLARED UNIT

In accordance with the PCR the declared unit for MPP is one cubic meter which represent the area of the panel multiplied by its thickness. This value is presented as 1.0 m^3. A declared unit is used in instances where the function and the reference scenario for the whole life cycle of a wood building cannot be stated (UL 2019). The inventory input data is presented as unallocated flows, all input and output flows allocated to the main product. This analysis does not take the declared unit to the use stage no service life is assigned.

One cubic meter of MPP is comprised of the following:

SCL = 534.37 od kg

Resin = 11.63 kg

Total mass = 546.0 od kg, 586 kg at 8%

The cradle-to-gate LCI was generated by combing MPP manufacturing data with previously published datasets for upstream manufacturing of forestry and harvesting operations, fuels, electricity, and ancillary material use.

3.4 ALLOCATION RULES

Allocation is the method used to partition the environmental load of a process when several products or functions share the same process. The input material for producing SCL is a log. Processing of the log at involves multiple processes with multiple outputs (coproducts). The input to MPP is SCL with multiple outputs (coproducts). A mass allocation for these multiple coproduct outputs was conservatively chosen.

3.5 BIOGENIC CARBON

Wood is a biobased material and thus contains biogenic carbon. The accounting of biogenic carbon follows the requirements set out in ISO 21930:2017 section 7.2.7 and 7.2.12. Per ISO 21930, biogenic carbon enters the product system (removal) as primary or secondary material. The carbon removal is considered a negative emission. The biogenic carbon leaves the system (emission) as product, coproducts, and directly to the atmosphere when combusted. These mass flows of biogenic carbon from and to nature are listed in the LCI and expressed in kg CO2.

In the LCIA, the LCI flow of biogenic carbon removal is characterized with a factor of -1 kg CO2e/kg CO2 of biogenic carbon in the calculation of the GWP[2]. Likewise, the LCI flow of biogenic carbon emission is characterized with a factor of +1 kg CO2e/kg CO2 of biogenic carbon in the calculation of the GWP. Emissions other than CO2 associated with biomass combustion (e.g., methane or nitrogen oxides) are characterized by their specific radiative forcing factors in the calculation of the GWP.

The UL PCR 2019 specifies TRACI as the default LCIA method for GWP. The TRACI method does not account for the removals or emissions of biogenic CO2. We have thus manually calculated the component of the global warming potential related to biogenic carbon separately. We have reported the GWP indicator both with and without the biogenic CO2 component for maximum transparency.

The results for global warming potential (GWP) and biogenic CO2 are as follows:

- GWPTRACI: includes greenhouse gases (GHG) emissions from the combustion of fossil resources, and GHG emissions other than CO2 from the combustion of biogenic resources (TRACI method)
- GWPBIO: adds the net emissions of biogenic carbon to the GWP (TRACI method + net biogenic carbon)
- LCI flows of biogenic carbon emissions and removals (see Table 3.2 under 'Additional Inventory Parameters')

3.6 Impact Categories / Impact Assessment

The life cycle impact assessment (LCIA) phase establishes links between the life cycle inventory results and potential environmental impacts. The LCIA calculates impact indicators, such as global warming potential and smog. These impact indicators provide general, but quantifiable, indications of potential environmental impacts. The target impact indicator, the impact category, and means of characterizing the impacts are summarized below. Environmental impacts are determined using the TRACI method (Bare 2011, 2012). Each impact indicator is a measure of an aspect of a potential impact. This LCIA does not make value judgments about the impact indicators, meaning comparison indicator values are not valid. Additionally, each impact indicator value is stated in units that are not comparable to others. For the same reasons, indicators should not be combined or added. Additionally, the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks. The primary fuels categorized into non-renewable (fossil and nuclear) and renewable (biomass, geothermal, solar, wind, hydro). Table 3.2 summarizes the source and scope of each impact category reported in this report as required to be in conformance with the PCR.

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[2] ISO 21930 requires a demonstration of forest sustainability to characterize carbon removals with a factor of -1 kg CO2e/kg CO2. ISO 21930 Section 7.2.1 Note 2 states the following regarding demonstrating forest sustainability: "Other evidences such as national reporting under the United Nations Framework Convention on Climate Change (UNFCCC) can be used to identify forests with stable or increasing forest carbon stocks." Canada's UNFCCC annual report Table 6-1 provides annual net GHG Flux Estimates for different land use categories. This reporting indicates non-decreasing forest carbon stocks and thus the source forests meet the conditions for characterization of removals with a factor of -1 kg CO2e/kg CO2.

Table 3-2 Selected Impact Category Indicators and Inventory Parameters

Core Mandatory Impact Indicator	Abbreviation	Units	Method
Global warming potential, biogenic[3]	GWP	kg CO2e	TRACI 2.1 V1.05 + LCI Indicatory
Global warming potential, fossil	GWP	kg CO2e	TRACI 2.1 V1.05
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11e	TRACI 2.1 V1.05
Acidification potential of soil and water sources	AP	kg SO2e	TRACI 2.1 V1.05
Eutrophication potential	EP	kg PO4e	TRACI 2.1 V1.05
Formation potential of tropospheric ozone	SFP	kg O3e	TRACI 2.1 V1.05
Abiotic depletion potential (ADP fossil) for fossil resources;	ADPf	MJ, NCV	CML-IA Baseline V3.05
Fossil fuel depletion	FFD	MJ Surplus	TRACI 2.1 V1.05
Use of Primary Resources			
Renewable primary energy carrier used as energy	RPRE	MJ, NCV	CED (LHV) V1.00
Renewable primary energy carrier used as material	RPRM	MJ, NCV	LCI Indicator
Non-renewable primary energy carrier used as energy	NRPRE	MJ, NCV	CED (LHV) V1.00
Renewable primary energy carrier used as material	NRPRM	MJ, NCV	LCI Indicator
Secondary material, secondary fuel and recovered energy			
Secondary material	SM	kg	LCI Indicator
Renewable secondary fuel	RSF	MJ, NCV	LCI Indicator
Non-renewable secondary fuel	NRSF	MJ, NCV	LCI Indicator
Recovered energy	RE	MJ, NCV	LCI Indicator
Mandatory Inventory Parameters			
Consumption of freshwater resources;	FW	m3	LCI Indicator
Indicators Describing Waste			
Hazardous waste disposed	HWD	kg	LCI Indicator
Non-hazardous waste disposed	NHWD	kg	LCI Indicator
High-level radioactive waste, conditioned, to final repository	HLRW	kg or m3	LCI Indicator
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	kg or m3	LCI Indicator
Components for re-use	CRU	kg	LCI Indicator
Materials for recycling	MR	kg	LCI Indicator
Materials for energy recovery	MER	kg	LCI Indicator
Recovered energy exported from the product system	EE	MJ, NCV	LCI Indicator
Additional Inventory Parameters for Transparency			
Biogenic Carbon Removal from Product	BCRP	kg CO2e	LCI Indicator
Biogenic Carbon Emission from Product	BCEP	kg CO2e	LCI Indicator
Biogenic Carbon Removal from Packaging	BCRK	kg CO2e	LCI Indicator
Biogenic Carbon Emission from Packaging	BCEK	kg CO2e	LCI Indicator
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	BCEW	kg CO2e	LCI Indicator

[3] This indicator includes both biogenic and fossil-based carbon released. The TRACI method was modified to included CO2, biogenic removals and emissions

4 DESCRIPTION OF INDUSTRY

Established in 1922, Freres Lumber produces finished plywood products, lumber, veneers, structural composite lumber, and MPP (since 12/2017) with around 450 employees. The company operates 2 veneer plants, a veneer drying facility, plywood plant, cogeneration facility, a stud mill, their own log and highway trucks, and the MPP production facility (Figure 4-1).

Figure 4-1 Freres Lumber Facility, Lyons Oregon (Left) and MPP facility Lyons, Oregon (Right) (Photo credit Freres Lumber)

5 DESCRIPTION OF PRODUCT

Mass Ply panels (MPP) is a veneer-based engineered wood product (Figure 5-1). MPP is a recent addition to the mass timber product line. Mass timber is a category of timber products typically characterized by large structural elements such as panels or beams that use multiple layers of wood for wall, floor, and roof construction. Products may include cross laminated timber, nail-laminated timber, glued-laminated timber, Mass Ply panels (MPP), laminated veneer lumber (LVL), and wood-concrete composites.

Mass Ply panels are made with Douglas-fir (*Pseudotsuga menziesii)*. Phenol formaldehyde resin is the primary adhesive type used in SCL production and melamine formaldehyde resin is used in MPP production.

Figure 5-1 Mass Ply Panels (Photo credit Freres Lumber)

Mass Ply panels (MPP) is an innovative veneer-based engineered mass timber product and can be manufactured using veneers from small-diameter trees, which minimizes a loss of wood during its production. MPP is built by gluing and cold-pressing 25.4 mm-thick 1.6E [4] Douglas-fir laminated veneer lumber (LVL) (APA PR L 325 2018).

The performance of MPP is dependent on adhesive bonds, including the phenol-formaldehyde bonds used to create the LVLs and the EPI bonds used for laminating the LVLs together and in the scarf joints.

In addition, the thickness of MPP can be increased by 25.4 mm (1 inch) increments, which offers versatility in terms of product design and material optimization. Owing to its lightweight, good insulating, and environmentally friendly properties, MPP, like cross-laminated timber, can be used as a substitute for traditional building materials.

While at the mill, MPP panels are cut to size, including door, and window openings, with state-of-the art Computer Numerical Controlled (CNC) routers, capable of making complex cuts with high precision. MPPs are strong, with superior acoustic, fire, seismic, and thermal performance. MPP is easy to install at the building site and generates almost no waste onsite.

MPP is certified under APA-EWS and ICC-ES:

- SCL-ASTM D5456 – Standard Specification for Evaluation of Structural Composite Lumber Products
- ICC-ES AC 47 – Structural Wood Based Products
- ANSI/APA PRG 320-2018 – Standard for Performance Rated Cross-Laminated Timber
- ICC-ES A C 455 – Cross Laminated Timber Panels for use as Components in Floor and Decks

Mass Ply panels can be used for floors, walls and roof systems and is categorized by United Nations Standard Products and Services Code (UNSPSC) 111220 and Construction Specifications Institute (CSI) codes for Engineered Wood Products 06 11 13 and Heavy Timber construction 06 13 00. Mass Ply Panels falls into the North American Industry Classification System (NAICS) Code 321231 for Engineered Wood Member (except Truss) Manufacturing.

[4] Module of Elasticity for Douglas-fir = 1,600,000 lb/in^2

5.1 Typical emission control measures

Common emission control devices are electrostatic precipitators (ESPs) and cyclones for the removal of particulate matter or particle pollution (PM) scrubbers for PM and gaseous emissions, multi cone (thermal oxidizers) for volatile organic compounds (VOC's), odors, and hazardous air pollutants (HAPs), and bag house for dust collection. The MPP facility reported the installation and use of five cones, 3 cyclones, one each ESP, bag house, and scrubber between 2000 and 2019.

5.2 Wood species

Mass Ply Panels is made of Douglas-fir (*Pseudotsuga menziesii)* from westside forests in Oregon. MPP product density was 546 kg/m^3 at, 8 percent moisture content, dry basis or 514 kg/m^3 oven dry.

5.3 Moisture content

For products and coproducts produced prior to drying a 50 percent moisture content (MC) on a dry basis was assumed. For products and coproducts produced after drying an 8 percent MC on a dry basis was assumed.

6 Life cycle inventory analysis

The LCI was calculated based on 2018 production and the corresponding flows of materials during that period. No data gaps were recorded. As shown in Figure 3-1, the cradle-to-gate process for MPP production is considered to comprise wood resource (log) extraction, the transport of the logs, SCL and MPP production. These, steps are described separately below.

6.1 A1- Resource extraction

6.1.1 Harvesting operations

Table 6-1 summarizes the management inputs needed to establish crop trees and grow them to harvestable size. It includes per hectare data for inputs needed for planting, site preparation, conifer release, pre-commercial thinning, and fertilization, including fuels needed to apply herbicides and fertilizers and move crews to and from the plantations. In both Oregon and Washington, forest regeneration following harvest is required by law. Minimum stocking standards (number of trees per hectare) and requirements to protect them from being overtopped by competing vegetation are set forth in the Washington Administrative Code (Washington State Legislature 2005, WAC 222-34-010) (WSL 2019) and the Oregon Forest Practices Act (Oregon Department of Forestry 2008, 629-610-0020) (USDA 2008). While regeneration from naturally occurring, seed is permitted under these regulatory frameworks, it is not commonly used because the delays in regeneration can be substantial and costly, and this method can result in a failure to adequately reforest the harvest area. Given that large private and industrial landowners are focused on the efficient production of their crops of trees, it also does not make economic sense to forego planting in favor of an uncertain outcome from naturally regenerated stands. Over the past decade, plantation management strategies have moved away from dense planting for early crown closure to a more targeted approach that relies on early weed control, low-density planting, and post planting herbicide applications as required. All harvested acres are planted, with an average planting density of 1,092 trees per ha (442 trees per acre).

Table 6-1 Management and Harvest Timeline and Yield (Oneil and Puettmann, 2017)

Prescription Scenarios	Commercial Thin	Ground	Cable
Entry Period/Rotation Age	25	50	50
Planting Density (Trees/ha)	0	1092	1092
Fertilization	None	35	None
Pre-commercial Thin	None	Year 15	None
Number of Trees/ha	0	741	0
Commercial Thin (m3/ha)	92	0	0
at Year	25	0	0
Final Harvest (m3/ha)	0	575	531
at Year	0	50	50
Total Harvest (m3/ha)	92	575	531
Percent Thinned	100%	14%	0%
Average Yield (m3/ha/year)	4	12	11
Percent Land in Category - Base	8%	52%	40%

No primary data using time motion studies or similar methods were collected for this project. Productivity data for forest harvesting operations were based on logging equipment and equipment configurations developed in spreadsheet models used by Johnson et al. (2005) and Han et al. (2014) and cross validated to primary survey data for the suite of available equipment options and sizes that are commonly used in the Pacific Northwest (PNW) Douglas-fir region (Table 6-2). Final fuel consumption rates are based on the allocation of total volume harvested using each harvest system to arrive at an average fuel consumption per cubic meter for the region. Fuel consumption for crew transport to conduct harvest operations was calculated from average haul distance, fuel efficiency of common vehicle types (4 x 4 trucks), and equipment productivity estimates (cubic meters per day per operation). Two-person crews per vehicle were assumed.

Table 6-2 Harvesting Inputs (per cubic meter) (Oneil and Puettmann, 2017)

System	Fuel Consumption	Lubricant Consumption
	L / m³	**L / m³**
Commercial Thinning (cut-to-length processor, skidder, loader)	2.372	0.043
Ground based Harvesting (feller-buncher, shovel yarder, slide boom processer, loader)	3.172	0.057
Cable Harvesting (hand felling, skyline, cut-to-length processor, loader)	3.029	0.055
Weighted average - ground harvesting systems	3.062	0.055
Overall weighted average - all harvest systems	3.051	0.055
Weighted average, crew transport all harvest operations	0.210	0.002

6.1.2 LVL MANUFACTURING
The LVL is made with seven layers of veneers in a long-ply direction and two layers of veneers in the cross-ply direction for face layers [F-16-3 layup (APA PR L325 2020)] and 5 veneers in long-ply direction and 4 veneers in cross ply direction for the core layers. These layers are manufactured with E rated veneers and in the process is like manufacturing of plywood including resin type, application, pressure, and heat requirements.

Once manufactured, these face and core layer LVLs are sanded to prepare them for adhesive application. Nominal 4 x 8 LVL panels (billets) are then scarf-jointed in length, with staggered seams by length and width (Figure 6-1). Adhesive is used for scarf joint with a 60 second radio frequency curing time. Number of lamellae depends on engineering specifications.

Figure 6-1 Scarf joint of LVL (Photo credit Freres Lumber)

6.1.3 RESINS
Phenol formaldehyde resin was used for LVL manufacture. It is a thermoset (cured by heating) adhesive that provides a waterproof and irreversible bond between the veneers. Melamine formaldehyde resin was used for the MPP manufacture to bond the LVL billets together.

6.2 A2 - TRANSPORTATION
The A2 module includes those resources for the production of MPP only (Table 6-3). Transport of logs, green and dry veneer, resin for LVL manufacture, and wood fuel are included in the A1 module.

Table 6-3 Deliver distances of input materials for MPP production

Material	Transportation Method	Distance [1]	
		(km)	(miles)
Ancillary Materials	Truck	63	39
Resin	Truck	113	70
Packaging	Truck	200	124
TOTAL		376	233

6.3 A3-MPP MANUFACTURING

The LVL billets are stacked on top of each other and cold-pressed as per adhesive manufacturers pressure and time requirement to form the MPP panel (Figure 6-2). MPP can be manufactured with dimensions up to 12 ft wide by 48 feet long with a maximum thickness of 0.6 m (2 ft). The performance of MPP is dependent on adhesive bonds, including the phenol-formaldehyde bonds used to create the LVLs and the resin bonds used for laminating the LVLs together and in the scarf joints. The MPP then goes through fabrication steps as outlined by the engineering requirements using a 5 axis CNC machine.

Figure 6-2 Production of LVL showing scarf joints (Left), one layer of LVL (center), and LVL panels lay-up in press to form a finished MPP. Photo credit Freres Lumber

MPP can be manufactured using veneers from small-diameter trees, which minimizes a loss of wood during its production. In addition, the thickness of MPP can be increased by 1- inch (25.4 mm) increments, which offers versatility in terms of product design and material optimization. Owing to its lightweight, good insulating, and environmentally friendly properties, MPP, like cross-laminated timber, can be used as a substitute for traditional building materials. Panel dimensions and quantities produced in 2018 are shown in Table 6-4. The MPP then goes through fabrication steps as outlined by the engineering requirements using a 5 axis CNC (computer numerical control) machine.

Table 6-4 Mass Ply Panel sizes producted in 2018

Mass Ply Panel Thickness – inches (millimeters)	Quantity-ft3	Quantity-m3	# of Panels	Panel Size-feet	Panel Size-meters	% Produced by thickness	% of total production
3” (76.2mm) MPP	4,357.50	123.39	30	12’ x 48.5’	3.7m x 4.8m	20.8%	5.8%
3” (76.2mm) MPP	680	19.26	8	8’ x 42.5’	2.4m x 3.0m	3.3%	0.9%
3” (76.2mm) MPP	5,952	168.54	186	8’ x 16’	2.4m x 4.9m	28.5%	7.9%
3” (76.2mm) MPP	4,984	141.13	178	8’ x 14’	2.4m x 4.3m	23.8%	6.6%
3” (76.2mm) MPP	4,928	139.55	154	8’ x 16’	2.4m x 4.9m	23.6%	6.5%
Total 3" (76.2mm) MPP	**20,902**	591.88				100.0%	**27.8%**
4” (101.6mm) MPP	3,880	109.87	30	8’ x 48.5’	(2.4m x 14.8m	59.9%	5.2%
4” (101.6mm) MPP	292	8.27	2	12’ x 36.5’	3.7m x 11.1m	4.5%	0.4%
4” (101.6mm) MPP	582	16.48	3	12’ x 48.5’		9.0%	0.8%
4” (101.6mm) MPP	226.66	6.42	2	8’ x 42.5’	2.4m x 13.0m	3.5%	0.3%
4” (101.6mm) MPP	1,493.70	42.30	35	8’ x 16’	2.4m x 4.9m	23.1%	2.0%
Total 4" (101.6mm) MPP	**6,474.36**	**183.33**				100.0%	**8.6%**
5” (127.0mm) MPP	1,516.67	42.95	14	8’ x 32.5’	2.4m x 9.9m	65.3%	2.0%
5” (127.0mm) MPP	320	9.06	6	8’ x 16’	2.4m x 4.9m	13.8%	0.4%
5” (127.0mm) MPP	485	13.73	2	12’ x 48.5’	3.7m x 14.8m	20.9%	0.6%
Total 5" (127.0mm) MPP	**2,321.67**	**65.74**				100.0%	**3.1%**
6” (152.4mm) MPP	1,552	43.95	8	8’ x 48.5’	2.4m x 14.8m	40.0%	2.1%
6” (152.4mm) MPP	2,328	65.92	8	12’ x 48.5’	3.7m x 14.8m	60.0%	3.1%
Total 6" (152.4mm) MPP	**3,880**	**109.87**				100.0%	**5.2%**
7” (177.8mm) MPP	1,190	33.70	4	12’ x 42.5’	3.7m x 13.0m	100.0%	1.6%
Total 7” (177.8mm) MPP	**1,190**	**33.70**				100.0%	**1.6%**
8” (203.2mm) MPP	2,069.34	58.60	8	8’ x 48.5’	2.4m x 14.8m	51.9%	2.7%
8” (203.2mm) MPP	358	10.14	1	12’ x 48.5’	3.7m x 14.8m	9.0%	0.5%
8” (203.2mm) MPP	1,560	44.17	6	12’ x 32.5’	3.7m x 9.9m	39.1%	2.1%
Total 8" (203.2mm) MPP	**3,987**	**112.90**				100.0%	**5.3%**
9” (228.6mm) MPP	720	20.39	6	8’ x 20’	2.4m x 6.4m	100.0%	1.0%
Total 9" (228.6mm) MPP	**720**	**20.39**				100.0%	1.0%
10” (254.0mm) MPP	405	11.47	1	12’ x 40.5’	3.7m x 12.3m	55.5%	0.5%
10” (254.0mm) MPP	325	9.20	1	12’ x 32.5’	3.7m x 9.9m	44.5%	0.4%
Total 10" (254.0mm) MPP	**730**	**20.67**				100.0%	**1.0%**
12” (304.8mm) MPP	14,356	406.52	37	8’ x 48.5’	2.4m x 14.8m	40.9%	19.1%
12” (304.8mm) MPP	2,160	61.16	18	4’ x 30’	1.2m x 9.1m	6.2%	2.9%
12” (304.8mm) MPP	2,560	72.49	16	4’ x 40’	1.2m x 12.2m	7.3%	3.4%
12” (304.8mm) MPP	16,000	453.07	200	4” x 20’	1.2m x 6.1m	45.6%	21.3%
Total 12" (304.8mm) MPP	**35,076.00**	**993.24**				100.0%	**46.6%**
Total 2018 Production	**75,280.87**	**2,131.72**	**964**				

6.4 LCI INPUTS (GATE-TO-GATE)

Wood flow for MPP production involved the input of LVL which is produced from veneers peeled from logs. Table 6-5 list the products and coproducts from MPP manufacture. Unaccounted wood accounted for 4.5 percent. Internal consumption is wood used for marketing displays and for research and testing.

Table 6-5 Wood mass balance for MPP

Inputs	kg/m3	Allocation
LVL	1,079.69	
Total	**1,079.69**	
Outputs	-	
MPP	546.00	50.6%
LVL trim @ MPP	1.28	0.1%
Sawdust @ MPP	137.03	12.7%
Panel trim @ MPP	31.50	2.9%
Wood waste @ MPP unaccounted wood	48.97	4.5%
Internal Consumption	314.92	29.2%
Total	**1079.69**	100.00%

Table 6-6 summarizes the gate-to-gate LCI flows associated with MPP production. These flows were linked to upstream processes associated with LVL, which would include forestry operations, harvesting, LVL production, and raw material transportation profiles to calculate a complete cradle-to-gate profile for MPP.

Table 6-6 Gate to gate LCI flows for MPP, unallocated

A1 - Raw Materials	Quantity	Unit
Wood Input		
Laminated Veneer Lumber	1.82	m3
Resins		
Melamine formaldehyde	22.99	kg
Water		
Water		
A2 - Transportation		
Resins Trucking	2.5898	tkm
Ancillary Materials Trucking	*0.1790*	*tkm*
Packaging Trucking	*0.0207*	*tkm*
A3 - Manufacturing		
Energy		
Electricity	369.70	kwh
Natural gas	45.81	m3
Ancillary		
Hydraulic fluid	1.1082	kg
Lubricating fluid	1.5486	kg
Motor oil	0.1489	kg
Greases	0.0410	kg
Antifreeze	0.0020	kg
Solvent	0.0025	kg
Wrapping material	0.1039	kg
Waste	-	
Motor Oil	0.1371	kg
Hydraulic & lubricating fluids	0.0101	kg
Other (Antifreeze)	0.0022	kg

6.5 SECONDARY DATA SOURCES

Tables 6-7, 6-8, and 6-9 show the secondary LCI data sources used in the MPP LCA study.

Table 6-7 Raw Material Supply Processes

A1: Raw Material Inputs				
Inputs	**LCI Data Source**	**Geography**	**Year**	**Data Quality Assessment**
LVL	Freres Lumber, Primary data	Oregon	2018	– **Technology**: Excellent Process models product specific technology. – **Time**: Excellent – **Geography**: Excellent Data specific to product
Melamine Formaldehyde	Datasmart: Melamine formaldehyde resin, at plant/US- US-EI U	Europe with US Electricity	2018	– **Technology**: good Process represents European average production modified w/ US electricity – **Time**: good Data is less than 5 years old – **Geography**: good Data is specific to Europe – modified with US electricity

Table 6-8 Transportation Processes

A2: Raw Material Transportation				
Inputs	**LCI Data Source**	**Geography**	**Year**	**Data Quality Assessment**
Trucking	Database: US EI 2.2 (Datasmart2018) Process: Transport, combination truck, Diesel powered NREL/US U	North America	2018	– **Technology**: very good Process models average North American technology – **Time**: good Data is less than 5 years old – **Geography**: good

Table 6-9 Manufacturing Processes

A3: Manufacturing				
Energy Inputs	**LCI Data Source**	**Geography**	**Year**	**Data Quality Assessment**
Electricity	Freres Lumber, Primary data for Cogen operations	Oregon	2018	– **Technology:** Excellent Process models product specific technology. – **Time:** Excellent – **Geography:** Excellent Data specific to product

Natural gas	Database: Natural gas, combusted in industrial boiler NREL/US U	North America	2018	– **Technology:** very good Process represents combustion of biomass in an industrial boiler. – **Time:** good Data within 5 years – **Geography:** good
Hydraulic Fluid and Lubricants	Database: US EI 2.2 (Datasmart2018) Process: Lubricating oil, at plant/US- US-EI U	North America	2018	– **Technology**: very good Process models average North American technology – **Time**: good Data is less than 5 years old – **Geography**: good Data is representative of North American processes.
Antifreeze	Database: US EI 2.2 (Datasmart2018) Process: ethylene glycol, at plant/US - US-EI U	North America	2018	– **Technology**: very good Process models average North American technology – **Time**: good Data is less than 5 years old – **Geography**: good Data is representative of North American processes.
Solvents	Database: US EI 2.2 (Datasmart2018) Process: Hexane, at plant/US- US-EI U	North America	2018	– **Technology**: very good Process models average North American technology – **Time**: good Data is less than 5 years old – **Geography**: good Data is representative of North American production and combustion.
Greases and oils	Database: US EI 2.2 (Datasmart2018) Process: Proxy Oil and grease, at plant NREL/US U	North America	2018	– **Technology**: very good Process models average North American technology – **Time**: good Data is less than 5 years old – **Geography**: good Data is representative of North American processes.
Wrapping Materials	Database: US EI 2.2 (Datasmart2018) High density polyethylene resin, at plant NREL/RNA U Low density polyethylene resin, at plant NREL/RNA U Low density polyethylene resin, at plant NREL/RNA U	North America	2018	– **Technology**: very good Process models average North American technology – **Time**: good Data is less than 5 years old – **Geography**: good Data is representative of North American processes.

7 LIFE CYCLE IMPACT ASSESSMENT, USE OF RESOURCES, AND GENERATION OF WASTE

7.1 A1-A3 - CRADLE-TO-GATE

This section discusses the cradle-to-gate results for the declared unit. Table 7-1 presents the LCIA results for A1-A3 information modules in the production of MPP (mass allocations)

Table 7-1 Cradle-to-gate LCIA results for1 m³ of MPP, absolute basis

Core Mandatory Impact Indicator			TOTAL	A1	A2	A3
Global warming potential, biogenic[5]	GWP_{BIO}	kg CO2e	259.16	(2,105.83)	0.1807	2,364.80
Global warming potential, TRACI 2.1	GWP_{TRACI}	kg CO2e	259.16	199.47	0.1807	59.51
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11e	8.17E-06	6.97E-06	3.02E-10	1.20E-06
Acidification potential of soil and water sources	AP	kg SO2e	1.1276	1.0708	0.0010	0.0558
Eutrophication potential	EP	kg PO4e	0.2928	0.2834	0.0001	0.0093
Formation potential of tropospheric ozone	SFP	kg O3e	22.94	21.74	0.03	1.17
Abiotic depletion potential (ADP fossil) for fossil resources;	ADPf	MJ, NCV	4,648.67	-	-	4,648.67
Fossil fuel depletion	FFD	MJ Surplus	700.06	548.48	0.34	151.24
Use of Primary Resources						
Renewable primary energy carrier used as energy	RPRE	MJ, NCV	5,075.60	5,063.57	0.0049	12.02
Renewable primary energy carrier used as material	RPRM	MJ, NCV	12,693.47	12,693.47		
Non-renewable primary energy carrier used as energy	NRPRE	MJ, NCV	4,876.60	3,951.71	2.29	922.60
Renewable primary energy carrier used as material	NRPRM	MJ, NCV	1,151.49	1,151.49	-	-
Secondary material, secondary fuel and recovered energy						
Renewable secondary fuel	RSF	MJ, NCV	1,260.04	1,260.04		
Mandatory Inventory Parameters						
Consumption of freshwater resources;	FW	m3	0.5772	0.5668	0.0000	0.0103
Indicators Describing Waste						
Hazardous waste disposed	HWD	kg	0.0050	0.0033	0.0000	0.0016
Non-hazardous waste disposed	NHWD	kg	69.71	68.51	0.0524	1.1424
High-level radioactive waste, conditioned, to final repository	HLRW	m3	6.08E-08	6.07E-08	1.30E-12	1.48E-10
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m3	3.21E-06	2.79E-06	6.31E-10	4.15E-07

[5] This indicator includes both biogenic and fossil-based carbon released. The TRACI method was modified to included CO2, biogenic removals and emissions

Table 7-2 shows *additional inventory parameters* related to biogenic carbon removal and emissions. All carbon dioxide flows presented in Table 7-2 are unallocated to include coproducts leaving the system boundary in module A3. Even though the system boundary for this LCA only includes module A1-A3. In accordance with ISO 21930, emission from packaging (BCEK) is reported in A5 and emission from main product (BCEP) is reported in C3/C4. The net carbon emission across the cradle-to-gate life cycle is zero. It is assumed that all carbon removed from the atmosphere is eventually emitted to the eventually emitted to the atmosphere as CO2.

Total GWP_{BIO} includes biogenic carbon emissions and removals from the information modules A1-A3, A5, and C3/C4, leading to a net zero contribution of biogenic carbon to GWP_{BIO}. Therefore, in Table 7-1, results from total GWP_{TRACI} and total GWP_{BIO} are equal.

Using the method described earlier in this report, -2,305 kg CO_2e (A1) were removed in the production of 1 m^3 of MPP. One cubic meter of MPP stores 273 kg of carbon or +1,001 kg CO_2e (C3/C4). The coproducts produced during MPP production account for an additional +958.07 kg CO_2e (A3) for a total "emission" in wood product leaving the system boundary of +1,959 kg CO_2e. The combustion of wood fuel emitted 347 kg CO_2e. Packaging resulting in removal of -0.37 kg CO_2e). In summary, total removals was -2,305 kg CO_2e and total "emissions" was +2,30 kg CO_2e from cradle-to-gate (A1-A3) (Table 7-2).

Table 7-2 Biogenic carbon inventory parameters for cubic meter of MPP, unallocated

Additional Inventory Parameters		A1	A2	A3	A5	C3/C4	Total
		kg CO2e					
Biogenic Carbon Removal from Product	BCRP	(2,305.30)	-	0.00	0.00	0.00	(2,305.30)
Biogenic Carbon Emission from Product	BCEP	0.00	-	958.07	0.00	1,000.62	1,958.69
Biogenic Carbon Removal from Packaging	BCRK	-	-	(0.3712)	0.00	-	(0.3712)
Biogenic Carbon Emission from Packaging	BCEK	-	-	0.00	0.00	-	
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production	BCEW	-	-	346.98	0.00	-	346.98

7.2 A1 Resource Extraction (Gate-to-Gate)

Results shown in Table 7-3 and Figure 7-1 are for the A1 module, gate to gate for “resource extraction”.

Table 7-3 A1-Gate-to-gate LCIA results for1 m³ of MPP, absolute basis

		TOTAL	Resin	Forestry Operations	LVL Production
Ozone depletion	kg CFC-11 eq	6.97E-06	3.35E-06	1.00E-07	3.51E-06
Global warming	kg CO2 eq	199.46	55.54	14.56	129.35
Smog	kg O3 eq	21.73	1.57	6.39	13.77
Acidification	kg SO2 eq	1.07	0.24	0.22	0.62
Eutrophication	kg N eq	0.28	0.04	0.02	0.22

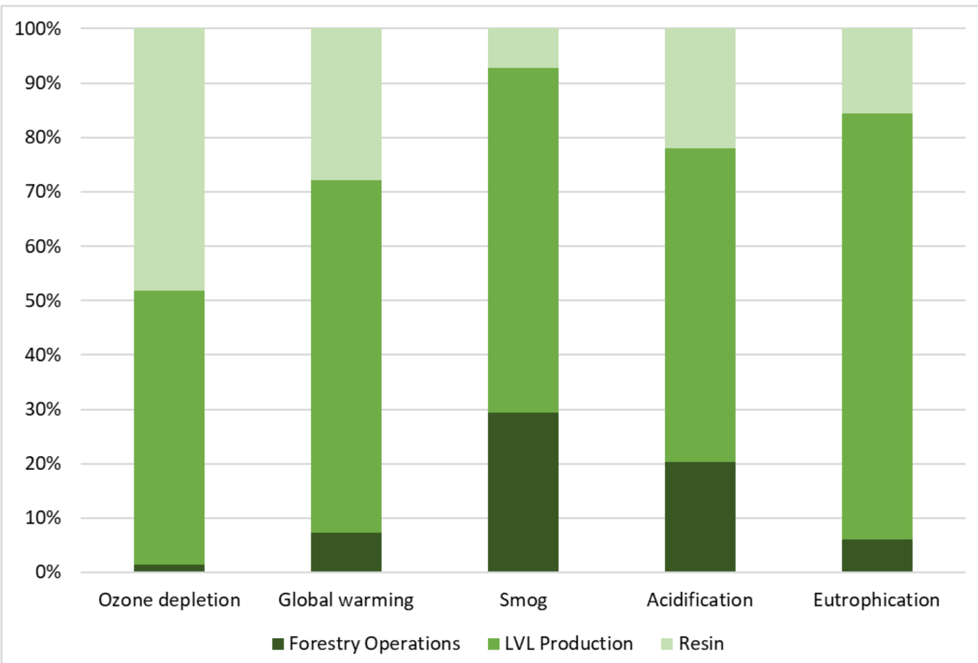

Figure 7-1 Contribution analysis for A1-Gate-to-gate LCIA results for1 m³ of MPP, relative basis

7.3 A3 MPP Production Gate-to-Gate

Results shown in Tables 7-4, 7-5, and 7-6 and Figures 7-3 and 7-4 are for the A3 module, gate to gate for "Product Production".

Table 7-4 A3-Gate-to-gate LCIA results for1 m³ of MPP, absolute basis

	TOTAL	Natural Gas	Ancillary Materials	Packaging	Electricity
Ozone depletion	1.20E-06	1.22E-08	1.18E-06	2.46E-09	2.38E-09
Global warming	5.95E+01	5.80E+01	1.41E+00	7.93E-02	3.54E-02
Smog	1.17E+00	1.07E+00	7.98E-02	3.91E-03	1.62E-02
Acidification	5.58E-02	4.34E-02	1.15E-02	2.90E-04	5.68E-04
Eutrophication	9.34E-03	4.90E-03	4.12E-03	1.17E-04	1.98E-04

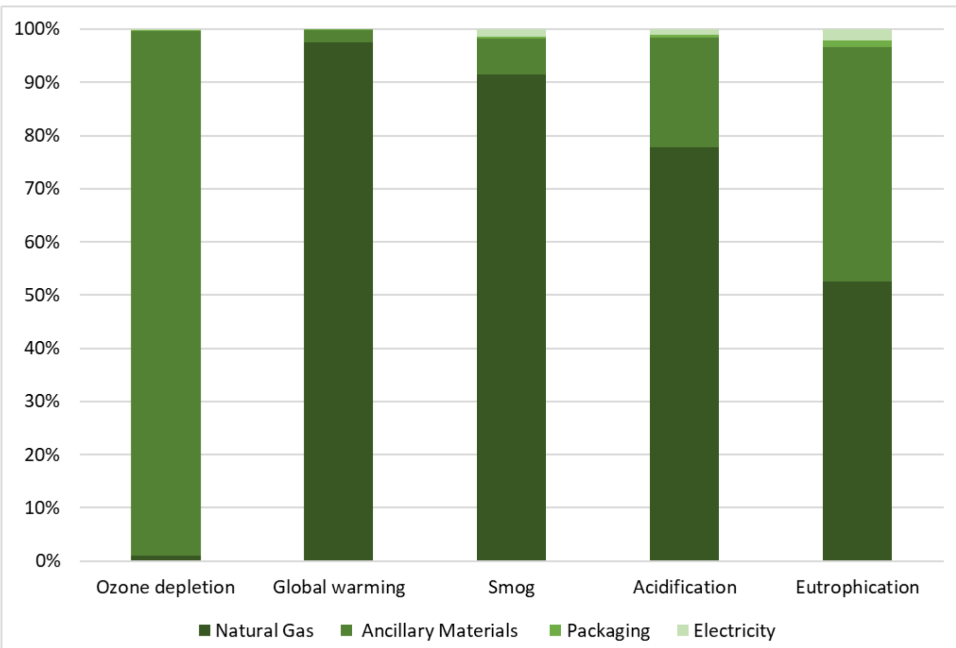

Figure 7-2 Contribution analysis for A3-Gate-to-gate LCIA results for1 m³ of MPP, relative basis

Table 7-5 A3-Gate-to-gate energy use results for1 m³ of MPP, absolute basis

Impact category	Unit	Total	Natural Gas	Ancillary Materials	Packaging	Electricity
Non-renewable, fossil	MJ	919.42	814.19	102.38	2.30	0.55
Non-renewable, nuclear	MJ	3.18	0.8136	2.1431	0.1123	0.1074
Non-renewable, biomass	MJ	0.00	0.0000	0.0000	0.0002	0.0000
Renewable, biomass	MJ	11.59	0.0204	0.0089	0.9998	10.5603
Renewable, wind, solar, geothermal	MJ	0.18	0.0281	0.1393	0.0062	0.0074

Renewable, water	MJ	0.25	0.0717	0.1591	0.0090	0.0097
TOTAL		934.62	815.12	104.83	3.43	11.24

Table 7-6 Contribution analysis A3-Gate-to-gate energy use results for 1 m^3 of MPP, relative basis

Energy Type	A3- MPP Production	
	MJ	
Non-Renewable	922.60	99%
Renewable	12.02	1%
TOTAL	934.62	100%

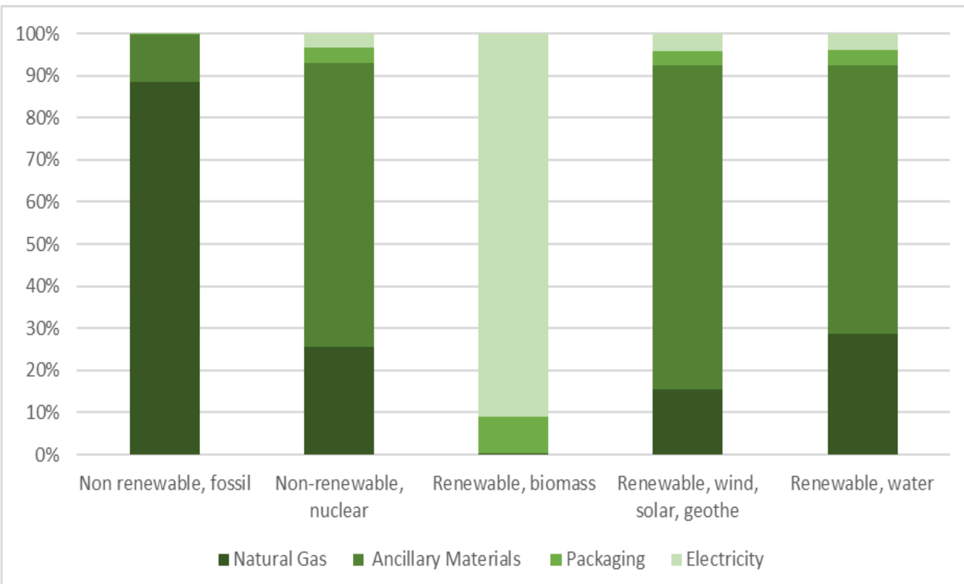

Figure 7-3 Contribution analysis for A3-Gate-to-gate energy use results for 1 m^3 of MPP, relative basis

8 INTERPRETATION

As defined by ISO (2006), the term life cycle interpretation is the phase of the LCA that the findings of either the LCI or the LCIA, or both, are combined consistent with the defined goal and scope in order to reach conclusions and recommendations. This phase in the LCA reports the significant issues based on the results of the presented in LCI and the LCIA of this report. Additional components report an evaluation that considers completeness, sensitivity, and consistency checks of the LCI and LCIA results, and conclusions, limitations, and recommendations.

8.1 CONTRIBUTION ANALYSIS

The contribution analysis focused on the included modules (A1-A3) and the contribution of selected impact categories. Table 8-1 shows the relative contribution for modules A1-A3.

Table 8-1 Cradle-togate LCIA results for the production of 1 m3 of MPP – relative basis

Core Mandatory Impact Indicator			TOTAL	A1	A2	A3
Global warming potential, TRACI 2.1	GWP_{TRACI}	kg CO2e	100%	77%	0.07%	23%
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11e	100%	85%	0%	15%
Acidification potential of soil and water sources	AP	kg SO2e	100%	95%	0%	5%
Eutrophication potential	EP	kg PO4e	100%	97%	0%	3%
Formation potential of tropospheric ozone	SFP	kg O3e	100%	95%	0%	5%
Abiotic depletion potential (ADP fossil) for fossil resources;	ADPf	MJ, NCV	100%	0%	0%	100%
Fossil fuel depletion	FFD	MJ Surplus	100%	78%	0%	22%

8.2 UNCERTAINTY AND SENSITIVITY ANALYSIS

The uncertainty and sensitivity analysis aims to assess the reliability of the final results.

The uncertainty analysis investigates input data variations within the sample of production facilities. Since the MPP LCA is a representation of one mill over one year, there is no uncertainty analysis to present.

In the sensitivity analysis, significant inventory parameters are altered to investigate the effect on the LCIA results. Since we do not have a standard deviation of the data to show a percent change from a mean, a 10% change is applied to natural gas inputs for A3 module. The change in LCIA results are presented in Table 8-2. Results shows that a 10% change of these inputs has only minor effects on the results. A 10% change in the natural gas use in A3 has a 2% change in GWP.

Table 8-2 Sensitivity analysis

Core Mandatory Impact Indicator		TOTAL	Natural gas +10%	Natural gas – 10%
GWP_{TRACI}	kg CO2e	259.16	265.04	199.56
ODP	kg CFC11e	8.17E-06	8.17E-06	6.97E-06
AP	kg SO2e	1.13	1.13	1.07
EP	kg PO4e	0.29	0.29	0.28
SFP	kg O3e	22.94	23.063	21.75
ADPf	MJ, NCV	4,648.67	713.85	548.73
FFD	MJ Surplus	700.06	265.04	199.56

8.3 Completeness and Consistency Checks

Life cycle assessment reports must be reviewed for completeness, consistency, and data sensitivity. Evaluation helps to establish and enhance confidence in, and the reliability of, the results of the LCA study, including the significant issues identified in the interpretation.

The objective of the *completeness check* is to ensure that all relevant information and data needed for the interpretation are available and complete. The data were checked for completeness including all elements such as raw and ancillary material input, energy input, transportation, water consumption, product and co-products outputs, emissions to air, water and land and waste disposal. All the input and output data were found to be complete and no data gaps were identified.

The objective of the consistency check is to determine whether the assumptions, methods, models, and data are consistent with the goal and scope of the study. Through a rigorous process, consistency is ensured to fulfil the goal of the study in terms of assumptions, methods, models, and data quality including data source, accuracy, data age, time-related coverage, technology, and geographical coverage.

9 Conclusions

This study provides a comprehensive cradle-to-gate LCA of the production of Mass Ply Panels (MPP). The primary goal of this LCA was to develop life cycle inventory data and impact assessment results for MPP that could be used to develop a product EPD. In addition to the impact assessment results, the life cycle inventory elements are also provided. Including the LCI elements enables the resource use inventory elements and waste flows as 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 UL PCR 2019.

10 Critical Review

10.1 Internal Review

The purpose of the LCA Report internal review is to check for errors and conformance with the PCR prior to submittal to for external review. The technical and editorial comments of the reviewers were carefully considered and, in most instances, incorporated into the final document. WoodLife Environmental Consultants and Freres Lumber addressed the internal review comments, as appropriate, and maintains a record of all comments and responses for future reference.

10.2 External Review

The external review process is intended to ensure consistency between the completed LCA and the principals and requirements of the International Standards on LCA (ISO 2006) and ISO 21930 - Sustainability in Buildings and Civil Engineering Works - Core Rules for Environmental Product Declarations of Construction Products and Services (ISO 2017), the Product Category Rules for North American Structural and Architectural Wood Products Part B (UL 2019) and Part A: Life Cycle Assessment Calculations Rules and Report Requirements (UL 2018).

Following the internal review evaluation, documents were submitted to ASTM International for independent external review. The independent external review performed by ASTM was conducted by

Thomas Gloria, Ph.D., Industrial Ecology Consultants, LCACP ID: 2008-03.

11 Units and Conversions

Table 3 Conversions used in developing the MPP LCI

To convert from	to	Multiply by
kWh	MJ	3.600
km	mi	0.621
kg	lbs	2.205
metric tonne	short ton	1.102
metric tonne	lbs	2204.620
short ton	lbs	1999.998
short ton	kg	907.187
metric tonne	kg	1000.000
gallon	liter	3.785
m3	ft3	35.315
MJ	MMBtu	0.001
BTU	MJ	0.001
kg	short ton	907.185
m3	yd3	1.308
m3	gallon	264.172
board feet	m3	0.002
gal	lbs	7.344
therms	cuft	97.561

12 References

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