Athena Sustainable Materials Institute

www.athenasmi.org

A Cradle-to-Gate Life Cycle Assessment of Cross-Laminated Timber (CLT) and Glued-laminated Timber (Glulam) Manufactured by ELEMENT5

EPD Project Report

Prepared for:

ELEMENT5 LP – MODERN TIMBER BUILDINGS
70 Dennis Rd, St. Thomas, Ontario N5P 0B6

By:

Athena Sustainable Materials Institute
Ottawa, ON

EPD Program Operator:

ASTM International

December 2022

This EPD project report contains **confidential** information and is not intended for public release. Required EPD results are presented in a rolled-up format (A1 to A3 modules) in Element5's EPD documents, suitable for public release.

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General summary

This document serves as the project background life cycle assessment (LCA) report to support Type III Environmental Product Declarations (EPDs) for Element5's CLT and Glulam, as manufactured at Element5's St. Thomas, Ontario facility for the reference year 2021.

This EPD project is commissioned by the Element5 and certified by ASTM International (ASTM). Specifically, this LCA background report ("The Project Report") has been prepared according to the requirements of UL Environment PCR Part A 2018 (1), UL Environment PCR Part B 2019 (2), ISO 21930:2017 (3), ISO 14025 (4), ISO 14040/44 standards (5), (6), and ASTM General Program Instructions for Type III Environmental Declaration (7). This Project report is verified by ASTM to conform to the requirements of UL Environment PCR Part A 2018 (1), UL Environment PCR Part B 2019 (2), ISO 21930 (3), 14040 (5), 14025 (4), and 14040/44 (6).

General Summary	
EPD Owner	**ELEMENT5 LP – MODERN TIMBER BUILDINGS** 114 - 67 Mowat Avenue Toronto, ON M6K 3E3 Link (URL): https://elementfive.co/ Element5 is a mass timber manufacturer offering an integrated suite of products and services to support mass timber projects across Canada, the USA and internationally. Element5 serves a community of forward-thinking architects, owners, developers, and general contractors to help affect change by providing timber construction cost consulting, design consulting, engineering, fabrication, and assembly services. *The owner of the declaration is liable for the underlying information and evidence.*
Production Locations	70 Dennis Rd, at Ontario N5P 0B6
Product Group and Names	CSI code 06 17 19, Cross-Laminated Timber (CLT) CSI code 06 18 00, Glued Laminated Timber (Glulam)
Product Group Definition	CLT is a proprietary engineered wood product that is prefabricated using several layers of kiln-dried lumber, laid flat-wise, and glued together on their wide faces. Panels typically consist of three, five, seven or nine alternating layers of dimension lumber. The alternating directions of the CLT laminations provide it with high dimensional stability (8). Glulam is an engineered structural wood product that consists of multiple individual layers of dimension lumber that are glued together under controlled conditions. All Canadian glulam is

	manufactured using waterproof adhesives for end jointing and for face bonding and is therefore suitable for both exterior and interior applications. Glulam has high structural capacity and is also an attractive architectural building material (9).
Product Category Rules (PCR)	UL Environment PCR Part B 2019 for North American Structural and Architectural Wood Products (2)
Certification Period	12/15/2022 – 5-year validity
Declared Unit	One cubic meter (1 m3) of CLT and Glulam manufactured at St. Thomas, Ontario facility
ASTM Declaration Numbers	EPD 407, EPD 408
EPD and Project Report Information	
Program Operator	ASTM International
Declaration Holder	ELEMENT5 LP – MODERN TIMBER BUILDINGS

Declaration Type

A "Cradle-to-gate" production stage EPD for Element5's CLT and Glulam. Production stage activities covered include the raw material supply, transport, and manufacturing (modules A1 to A3). The declaration is intended for Business-to-Business (B-to-B) communication.

Applicable Countries

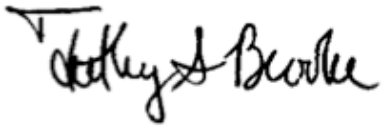
Canada and United States

Product Applicability

Element5's CLT can be used in many structural applications including floors, walls, roofs, shearwalls, elevator cores, and stairs (10).

Element5's Glulam can be used as a column, beam, rafter, purlin, or brace. It is suited for use in many diverse applications, including residential, commercial, institutional, and industrial buildings (11).

The Project Report *Note that this Project Report is not part of the public communication (ISO 21930, 10.1).*	A Cradle-to-Gate Life Cycle Assessment of Cross-Laminated Timber (CLT) and Glued-laminated Timber (Glulam) Manufactured by ELEMENT5, December 2022.
Prepared by  	Lindita Bushi, Ph.D., Grant Finlayson, and Jennifer O'Connor Athena Sustainable Materials Institute 280 Albert Street, Suite 404 Ottawa, Ontario, Canada K1P 5G8 info@athenasmi.org www.athenasmi.org

This EPD project report was independently verified to be in accordance with ISO 14025, ISO 14040/44, and ISO 21930 by:		Thomas P. Gloria, Ph. D. Industrial Ecology Consultants 35 Bracebridge Rd. Newton, MA
This EPD was independently verified by ASTM in accordance with ISO 14025 and the ISO 21930:		 Tim Brooke, ASTM International
Internal	**External** **X**	

Terms and definitions

ISO 14040:2006/Amd1:2020 and ISO 14044:2006/Amd1:2017/Amd2:2020 – Clause 3 Terms and definitions:

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.

Comparative assertion: Environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.

Life cycle: Consecutive and interlinked stages, 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 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.

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.

Product system: Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product.

System boundary: Boundary based on a set of criteria specifying which unit processes are part of the system under study

Sensitivity check: Process to determine whether the information obtained from a sensitivity analysis is relevant for reaching the conclusions and for giving recommendations

Uncertainty analysis: Systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability.
Note: Either ranges or probability distributions are used to determine the uncertainty in the results.

ISO 21930:2017 – Clause 3 Terms and definitions:

Co-product: Any of one or more products from the same unit process, but which is not the object of the assessment.

Declared unit: Quantity of a construction product for use as a reference unit in an EPD based on LCA for the expression of environmental information in information modules.

Information module: Compilation of data to be used as a basis for an EPD, covering a unit process or a combination of unit processes that are part of the life cycle of a product.

Product category: Group of construction products that can fulfill equivalent functions.

ISO 14025:2006 – Clause 3 Terms and definitions:

Type III Environmental Product Declaration (EPD): Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information
Note 1 the predetermined parameters are based on the ISO 14040 series of standards.
Note 2 the additional environmental information may be quantitative or qualitative.

Product Category Rules (PCR): Set of specific rules, requirements, and guidelines for developing Type III environmental declarations for one or more product categories.

Acronyms and abbreviations

ADP_f	Abiotic depletion potential for fossil resources
AP	Acidification potential
Athena	Athena Sustainable Materials Institute
ASTM	American Society for Testing and Materials
B2B	Business-to-business
BD+C	Building Design and Construction, LEED
CFC-11	Trichlorofluoromethane
CLT	Cross Laminated Timber
CO_2	Carbon dioxide
CRU	Components for re-use
D	Direct (the source of data)
E	Estimated (the source of data)
EE	Recovered energy exported from the product system
EP	Eutrophication potential
EPD	Environmental product declaration
FFD	Fossil fuel depletion
FW	Consumption of fresh water
FSC	The Forest Stewardship Council
GHG	Greenhouse gas
Glulam	Glued Laminated Timber
GWP 100	Global warming potential, 100 years' time horizon
HAP	Hazardous air pollutant
HLRW	High-level radioactive waste, conditioned, to final repository
HWD	Hazardous waste disposed
I	Indirect (the source of data)
ID+C	Interior Design and Construction, LEED
ILLRW	Intermediate- and low-level radioactive waste, conditioned, to final repository
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
kg	Kilogram
km	Kilometer
kWh	kilowatt hours
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment

ID+C	Interior Design and Construction, LEED
LHV	Lower heating value
MER	Materials for energy recovery
MF	Melamine Formaldehyde adhesive or hardener
MJ	Mega joule
MR	Materials for recycling
N	Nitrogen
NCV	Net caloric value
ND	Neighborhood development
NHWD	Non-hazardous waste disposed
NMVOC	Non-methane volatile organic compounds
$NRPR_M$	Non-renewable primary energy carrier used as material
$NRPR_E$	Non-renewable primary energy carrier used as energy
NRSF	Non-renewable secondary fuel
O_3	Ozone
ODP	Ozone depletion potential
PUR	Polyurethane reactive adhesives
RE	Recovered energy,
RF	Reference year
RPR_M	Renewable primary energy carrier used as material
RPR_E	Renewable primary energy carrier used as energy
RSF	Renewable secondary fuel
SFP	Smog formation potential
SM	Secondary material
SO_2	Sulfur dioxide
SPF	Spruce-pine-fir
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
UL	Underwriters Laboratories
U.S. EPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds

1. Introduction

Element5 is a mass timber manufacturer offering an integrated suite of products and services to support mass timber projects across Canada, the USA and internationally. Element5 is a dedicated team of designers, craftspeople, and assembly experts. Element5 serves a community of forward-thinking architects, owners, developers, and general contractors to help affect change by providing timber construction cost consulting, design consulting, engineering, fabrication, and assembly services. Element5 strives to make a positive contribution to communities, the environment, and future generations.

Element5 sees timber as the essential building material of the 21st century and is producing a Type III Environmental Product Declaration (EPD) for CLT and Glulam. This business-to-business EPD will provide transparent information on the potential environmental impacts of the two (2) declared products. They will be valid toward the US Green Building Council's Leadership in Energy and Environmental Design (LEED) certification program, specifically designating credit points when certifying through LEED v4 (12) and v4.1 (13) in the materials and resources (MR) credit[1].

Element5 commissioned the Athena Institute to perform a production stage or cradle-to-gate environmental Life Cycle Assessment (LCA) to support the development of the EPDs. Life cycle assessment is an analytical technique 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 (5), (6). Environmental flows include emissions to air, water, land, and the consumption of energy and material resources. By including the potential impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product. This LCA study has been conducted in accordance with UL Environment PCR Part A 2018 (1), UL Environment PCR Part B 2019 (2), ISO 21930 (3), ISO 14025 (4), ISO 14040/44 standards (5), (6), and ASTM General Program Instructions for Type III Environmental Declaration (7).

An EPD provides quantified environmental data using predetermined parameters and, where relevant, additional environmental information (4). The predetermined parameters are based on the ISO 14040 series of standards (5), (6) and ISO 21930 (3). Other additional environmental information may be quantitative or qualitative. The third-party verified EPDs will be publicly available on the ASTM website[2].

1 LEED v4, MR Credit 2, EPDs- Option 1 applies to: Building Design and Construction (BD+C) rating system (New Construction, Core & Shell, Schools, Retail, Data Centers, Warehouses & Distribution Centers, Hospitality, and Healthcare: 1 point); Interior Design and Construction (ID+C) rating system (Commercial Interiors, Retail, and Hospitality: 1 point); Neighborhood Development (ND) rating system (new land developments, land redevelopments, residential, mixed use, commercial, and industrial: 1 point); and - Homes rating system (Homes, Multifamily Lowrise, Multifamily Midrise: 1 point) (12). LEED v4.1, MR Credit 2, EPDs- Option 1 (similar to v4): 1 point (13).
2 ASTM website link: https://www.astm.org/products-services/certification/environmental-product-declarations/epd-pcr.html

2. Study goals

2.1. Goals of the study

This is a company-specific project commissioned by Element5 to conduct an LCA to support the development of an EPD for its CLT and Glulam products according to UL Environment PCR Part A 2018 (1), UL Environment PCR Part B 2019 (2), ISO 21930 (3), ISO 14025 (4), ISO 14040/44 standards (5), (6), and ASTM General Program Instructions for Type III Environmental Declaration (7) as manufactured at its at Element5's St. Thomas, Ontario facility, Canada. In total, this LCA project report supports the development of two EPDs for CLT and Glulam products.

2.2. Intended applications and audience

This project report is intended to support the development of Element5 EPDs for use in Business-to-Business communication. The resulting EPDs are specified as "Product-specific Type III EPDs" under LEED v4.1 (13). *Products with third-party certification (Type III), including external verification and external critical review, are valued as 1.5 products for the purposes of credit achievement calculation* (13). Element5 EPDs will be publicly available and, in general, will externally help educate its customers and partners on their products. More specifically, the intended audience for this EPD includes Element5 company divisions, their suppliers, architectural, engineering, and specifying professionals, LCA practitioners and tool developers, academia, governmental organizations, policymakers, and other interested value chain parties who require reliable information on Element5's CLT and Glulam products.

This project report contains ***confidential*** information and is intended to be internal to Element5. The LCA results can be used to look closer at operations within Element5's facility, should they choose to use the LCA results to identify where potential improvements could be made in the future.

2.3. Comparative assertions

The EPDs based on this project report do not constitute "comparative assertions." Only EPDs prepared from cradle-to-grave life cycle results and based on the same function, Reference Service Life (RSL), quantified by the same functional unit, and meeting all the conditions for comparability listed in ISO 14025 (4) and ISO 21930 (3) can be used to compare between products.

Per ISO 21930, 10.1 (3), this project report is made available to the verifier with the requirements on confidentiality stated in ISO 14025 (4). This Project Report has been independently verified by Tom Gloria, PhD, in accordance with ISO 14025 (4), ISO 14040/44 (5), (6), and the ISO 21930 requirements (3).

3. Product identification

3.1. Product description

This LCA study focuses on two (2) declared CLT and Glulam products as manufactured at the St. Thomas, Ontario facility.

Figure 1 Element5 CLT manufacturing line [Photo courtesy: Element5]

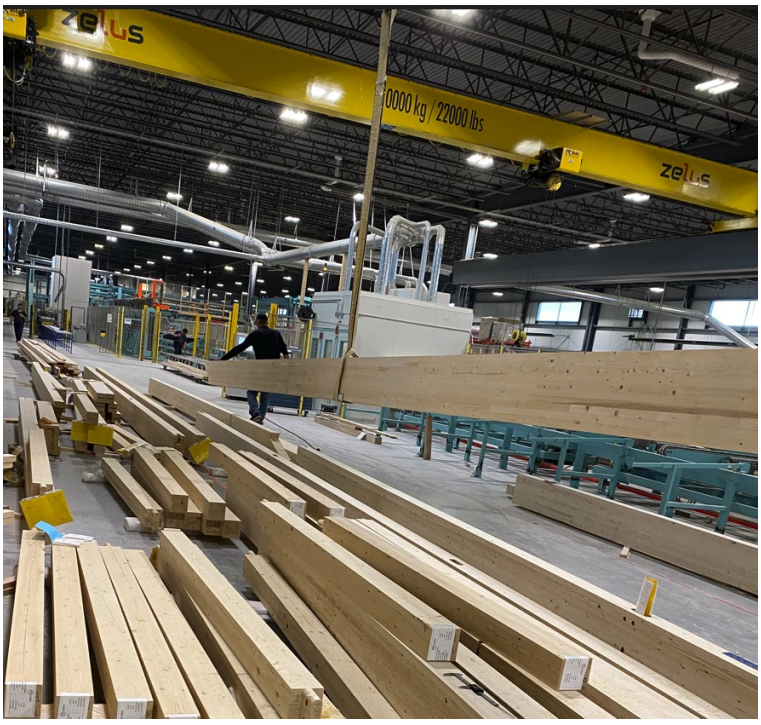


Figure 2 Element5 Glulam manufacturing line [Photo courtesy: Element5]

CLT is a proprietary engineered wood product that is prefabricated using several layers of kiln-dried lumber, laid flat-wise, and glued together on their wide faces. Panels typically consist of three, five, seven or nine alternating layers of dimension lumber. The alternating directions of the CLT laminations provide it with high dimensional stability (8).

Element5 CLT is manufactured in the St. Thomas plant (a Forest Stewardship Council (FSC) certified facility) using sustainably sourced wood from northern Ontario forests – see Figure 3. At 3.5m maximum width, the St. Thomas press produces the widest panels available in Canada, delivering enhanced efficiency to any build. The fully automated, state-of- the-art factory in St. Thomas, Ontario produces visually superior, edge glued CLT panels made from sustainably sourced spruce-pine-fir (SPF) lumber. CLT can be used in many structural applications including floors, walls, roofs, shearwalls, elevator cores, and stairs (10).

Glulam is an engineered structural wood product that consists of multiple individual layers of dimension lumber that are glued together under controlled conditions. All Canadian glulam is manufactured using waterproof adhesives for end jointing and for face bonding and is therefore suitable for both exterior and interior applications. Glulam has high structural capacity and is also an attractive architectural building material (9).

Element5 Glulam is an engineered wood product made from machine stress rated SPF dimensional lumber that is bonded together under pressure with strong, waterproof adhesives. Glulam can be used as a column, beam, rafter, purlin, or brace. It is suited for use in many diverse applications, including residential, commercial, institutional, and industrial buildings. Glulam can be left exposed in many applications, offering the architectural freedom to celebrate the structure of your building (11).

Element5 specifications for CLT and Glulam are provided in Annex A, Tables A.1 to A.4. Additional product properties and characteristics for CLT and Glulam can be viewed and downloaded from Element5's website (10), (11).

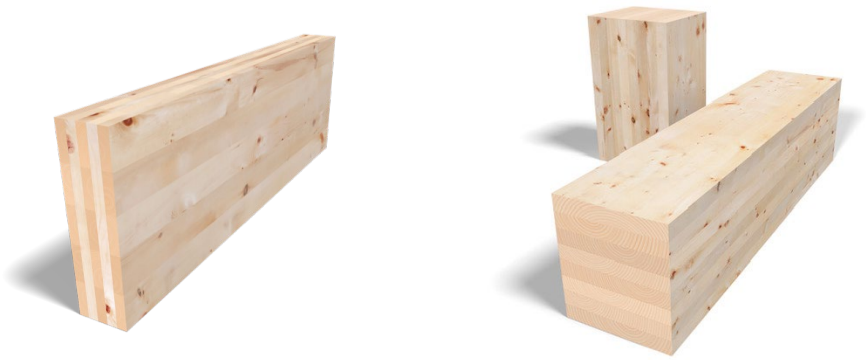


Figure 3 Element5 CLT and Glulam products (from left to right) [Photo courtesy: Element5]

3.2. CLT and Glulam standards

The Element5 CLT and Glulam products follow the applicable standards identified in Table 1.

Table 1 CLT and Glulam Standards

Products	Applicable Standards
CLT[1)]	ANSI/APA PRG 320-2019 Standard for Performance-Rated Cross-Laminated Timber (2) ASTM D9-12: Standard Terminology Relating to Wood and Wood-Based Products (2)
Glulam	CAN/CSA-O122-16 Structural glued-laminated timber (11) ANSI A190.1-2022 Product Standard for Structural Glued Laminated Timber ASTM D9-12: Standard Terminology Relating to Wood and Wood-Based Products (2)

Note:
[1)] The St. Thomas, Ontario, Canada facility is 3rd party certified to meet the certification requirements of the certifying body to manufacture cross laminated timber.

3.3. Material content

The material content (in %) per 1m^3 CLT and Glulam are provided in Tables 2.

Table 2 Material content per 1 m^3 CLT and Glulam

Material Content	CLT	Glulam
Softwood lumber	98.7%	98.7%
Adhesives and hardener	1.3%	1.3%
Total weight	100%	100%

4. Scope of the study

4.1. Declared unit

The declared unit is defined as the quantity of a construction product for use as a reference unit in an EPD based on LCA for the expression of environmental information in information modules (3). The declared product is one cubic meter (1 m^3) of CLT, and Glulam manufactured at St. Thomas, Ontario facility – see Table 3.

Table 3 Declared unit per CLT and Glulam

Property	CLT	Glulam
Declared unit	1 m^3	1 m^3
Density (kg/m^3)	448.0	448.0
Moisture Content (%)	12.0	12.0
Weighted average thickness (mm)	148	112

4.2. System boundary

For this study, the boundary is "cradle-to-gate," which is limited to the Production stage (information modules A1 to A3 as depicted in Figure 1). Construction, Use, End-of-Life stages, and optional supplementary module D are excluded from the system boundary (see Figure 4).

A declared unit is defined for "cradle-to-gate" EPDs which consists of the following alpha-numeric modules: A1 Extraction and upstream production; A2 Transport to factory; and A3 Manufacturing.

Figure 4 presents the *Production stage* system boundary for the declared CLT and Glulam manufacturing. Per ISO 21930, 7.1.7.2.1 (3), the system boundary with nature (natural environment) includes those technical processes that provide the material and energy inputs into the system and the subsequent manufacturing and transport processes up to the factory gate, as well as the processing of any waste arising from those processes.

Per ISO 21930, 7.1.7.1 (3), individual indicators for information modules A1, A2 and A3 are aggregated to a total for each indicator in the production stage.

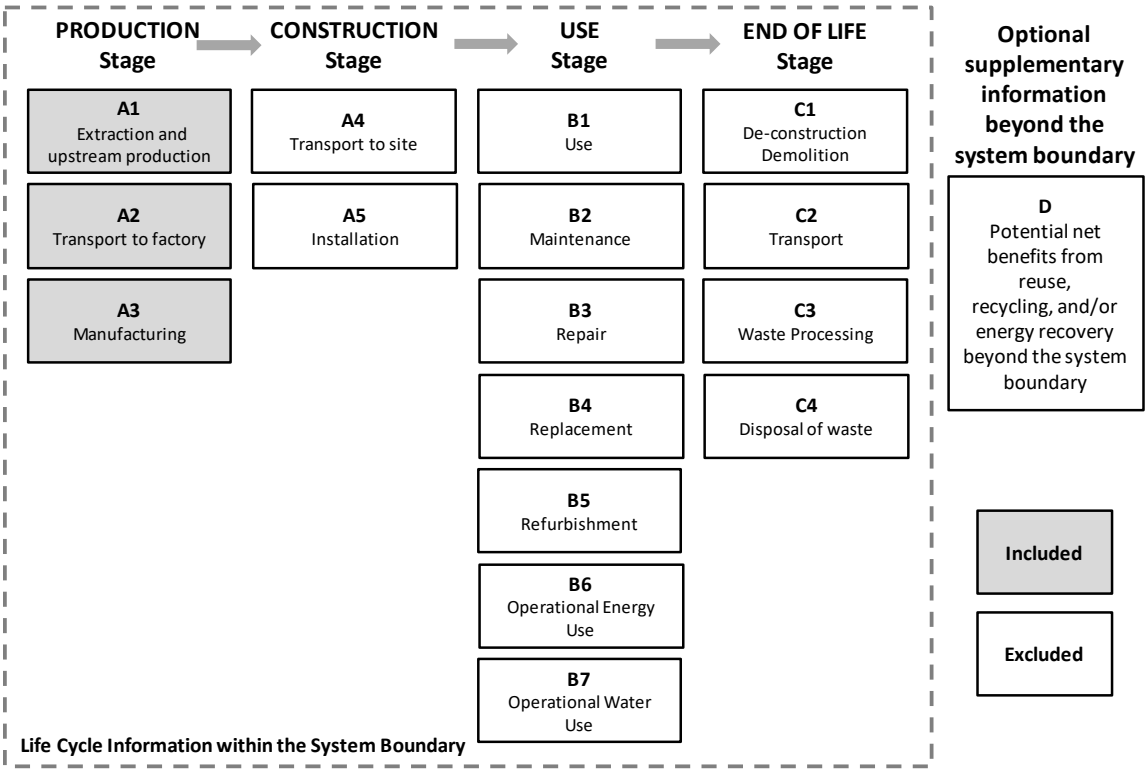


Figure 4 Life cycle stages for construction products

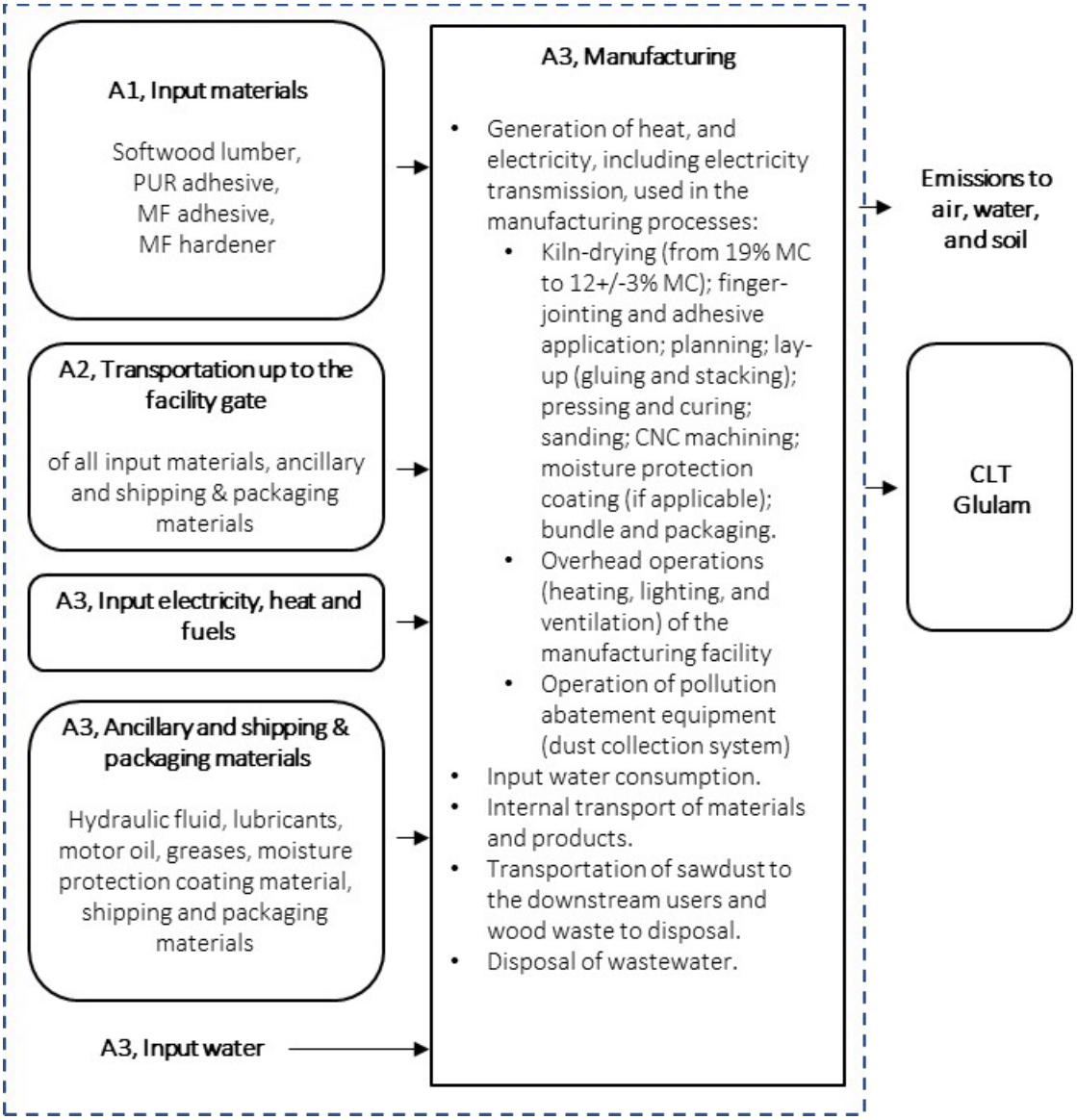


Figure 5 Production stage system boundary of Element5 CLT and Glulam

Per ISO 21930, Section 7.1.7.2 (3), the Production Stage includes the following processes:

A1, Extraction and upstream production
This information module includes:

- A1, cradle-to-gate production of Eastern Canada Surfaced dry softwood lumber (14), Polyurethane reactive (PUR) adhesive, Melamine Formaldehyde (MF) adhesive (15), and MF hardner.

Cradle-to-gate production data include raw materials extraction and processing, transportation, generation of steam, heat, and electricity, including electricity transmission; extraction, refining and transport of fuel supply, including fuel combustion; water consumption, emissions to air, water and land, and waste management including transport up to the disposal.

A2, Transport to factory
This information module includes transportation data of input materials, ancillary and shipping and packaging materials, including empty backhauls.

A3, Manufacturing
This information module includes:

- A3, upstream production of shipping and packaging materials (lumber wrap).
- A3, upstream production of ancillary materials (hydraulic fluid, lubricants, motor oil, and greases and KP-12 moisture protection coating material).
- A3, generation of heat and electricity, used in manufacturing, including electricity transmission; extraction, refining and transport of propane, including combustion for on-site transportation.
- A3, water consumption.
- A3, manufacturing of CLT and glulam.
- A3, transportation of sawdust to the downstream users; wood waste is stockpiled and picked up by third parties for disposal (e.g., reuse or combustion).
- A3, disposal of wastewater (sewage treatment).

No secondary materials (renewable and non-renewable) are used in the CLT and Glulam manufacturing processes. No energy recovered from secondary fuels and/or waste combustion is used in the manufacture of CLT and Glulam.

4.3. Cut-off criteria

The cut-off criteria as per ISO 21930, 7.1.8 (3) and UL PCR Part B, 3.6 (2) were followed for this LCA study. Per ISO 21930, 7.1.8 (3), all input/output data collected at the St. Thomas, ON facility were included in the LCI modelling developed using SimaPro v.9.4 2022 (16). The cut-off rules are not applied to hazardous and toxic material flows. No material flows of very high concern are identified in the framework of this EPD project. None of the input/output was knowingly excluded from the system boundary.
Material Data Sheets (MDSs) were used for MF hardener, plastic lumber wrap, and moisture protection coating material. Any data gaps in the MDS were filled in with two (proxy) generic LCI datasets, as appropriate (conservative assumptions): Chemical, organic {GLO}| market for | Cut-off, U; Chemical, inorganic {GLO}| market for | Cut-off, U.
This LCA study excludes the following processes:

- Capital goods and infrastructure;
- Personnel related activity (travel, furniture, office operations and supplies);

4.4. LCA software

The LCA model was developed using SimaPro v.9.4 2022 (https://simapro.com/) (16). SimaPro LCA software contains recognized databases (e.g., ecoinvent v3.8, 2021 database, Allocation, Cut-off by classification and U.S. LCI Database, 2015) that provide LCI datasets for upstream, core, and downstream material and processes. SimaPro 9.4 2022 also contains the U.S. EPA TRACI v2.1 2012 LCIA methodology (17), CML-baseline version 4.7 2016 LCIA methodology, the Cumulative Energy Demand, LHV version 1.0 2018, and RECIPE 2016 H which are used for this LCA study – see Sections 6.1 and 6.2 for details.

5. Life cycle inventory

5.1. Data collection, sources, and calculations

Primary gate-to-gate LCI manufacturing and input and output transportation data were collected for CLT and Glulam for the reference year 2021.

LCI data collection was based on a customized LCI survey for CLT and Glulam. The LCI survey covered the following primary data for the St. Thomas, Ontario facility for the 2021 reference year:

- Total manufactured products, and co-products.
- Main unit processes.
- Excluded processes.
- Pollution abatement equipment.
- Raw materials.
- Ancillary materials.
- Packaging materials.
- Electricity and fuel consumption.
- Water consumption (fresh and recycled).
- Inbound transportation distances and modes for all inputs.
- Emissions to air and water.
- Solid waste.
- Wastewater and other liquid waste.
- Waste outputs and their respective outbound transportation distances and modes.

Annex B, Tables B1 to B2 report the input/output flows per one (1) m^3 of declared CLT and Glulam. The St. Thomas plant specific data were collected for the reference year 2021 (12 consecutive months). Purchased electricity and natural gas were reported to be the primary manufacturing energy inputs. Natural gas is used in the kiln-drying process and for space conditioning. Propane is used for on-site transportation of materials and products. The St.

Thomas, ON facility uses dust collection system- Hocker Polytechnik. Quantitative primary data for shipping and packaging were also provided.

Step-by step processes for the manufacturing of the CLT and Glulam are described below:

- Lumber (2" × 6") with 19% MC enters the manufacturing system,
- Lumber is kiln-dried to 12+/- 3% MC for 3 days,
- Lumber enters the finger-jointing line (lumbers are cut to the lines and adhesive is applied),
- Planning (to achieve the desired thickness),
- Lay-up line (gluing and stacking),
- Pressing and curing,
- Sanding station,
- CNC machining (cut the pieces to the desired output),
- Add coating material for moisture protection (upon request from clients), and
- Bundle and packaging.

The source of data is specified as specified in the Annex B tables as:

Direct (D)	based on measurements or purchasing/selling records of the surveyed facilities.
Indirect (I)	based on calculations made by the personnel of the surveyed facilities.
Estimated (E)	based on the industry average data and/or expert judgment.

Annex B, Tables B3 to B4 report the transportation modes and tonne*kilometers (tkm) for all input, ancillary, shipping and packaging materials and waste outputs per 1 m^3 CLT and Glulam. Transportation data (in tkm) are calculated per input/output flow based on primary data. All calculated transportation data per input/output flow (in tkm) are then summed up to the total values (in tkm) per transportation mode. Transportation activities are included consistently in the respective life cycle modules. Trucking is the primary transportation mode for all inputs and waste outputs.

This LCA study draws on appropriate LCI datasets provided by (see Annex C, Tables C.1):

- Primary data provided by St. Thomas, Ontario facility (confidential).
- North American and global LCI databases such as the ecoinvent 3.8 2021, allocation, cut-off database (http://www.ecoinvent.org/) and U.S. LCI Database, 2015 (http://www.nrel.gov/lci/). Both are included in the LCA software SimaPro v.9.4 2022 (16).

Data calculation procedures follow ISO 14044 (6) and ISO 21930 (3). The same calculation procedures are applied throughout this LCA study. Per ISO 21930, 7.2.2 (3), when transforming the inputs and outputs of combustible material into inputs and outputs of energy, the net calorific value (lower heating value) of fuels is applied according to scientifically based and accepted values specific to the combustible material. SI units are used for the LCA data and results.

5.2. Data quality requirements and assessments

Per ISO 21930, 7.1.9 (3) and UL PCR Part B, 3.8 (2), appropriate activity and LCI primary and secondary data shall be used to model the CLT and Glulam. LCI data should be as representative (technologically, geographically, and time-specific), complete, consistent, reproducible, and transparent as possible with regard to the goal and scope of the study (5), (6). A detailed description of collected data and the data quality assessment regarding the ISO 14044 and ISO 21930 requirements, is provided in Annex C, Table C.1. Data quality is assessed based on its representativeness (technology coverage, geographic coverage, time coverage). Completeness, consistency, reproducibility, transparency, and uncertainty (see Table 4).

Table 4 Data quality requirements and assessments

Data Quality Requirements	Description
Technology Coverage	Data represents the prevailing technology at the St. Thomas manufacturing facility in Ontario, Canada. Whenever available, for all upstream and core material and processes, technological specific or average industry LCI datasets were utilized (see Annex C). *Technological representativeness is characterized as "high".*
Geographic Coverage	The geographic region considered is Canada. The geographic coverage of all LCI databases and datasets is provided in Annex C. Whenever available, for all upstream and core material and processes, geographic specific LCI datasets were utilized (see Annex C). *Geographical representativeness is characterized as "high".*
Time Coverage	Gate-to-gate activity data are representative as of 2021 (see Annex B). Generic data: the most appropriate LCI datasets were used as found in the ecoinvent v.3.8 database for US, North America and global, 2022 and U.S. LCI Database. *Temporal representativeness is characterized as "high".*
Completeness	All relevant, specific processes, including inputs (raw materials, energy, and additives) and outputs (emissions and production volume) were considered and modeled in the framework of this EPD project. The relevant background materials and processes were taken from the ecoinvent v.3.8 LCI database for U.S., North America and global and U.S. LCI Database, and modeled in SimaPro LCA software v.9.4, 2022 (16). The completeness of the cradle-to-gate process chain in terms of inputs/outputs is rigorously assessed and benchmarked for declared CLT and Glulam and documented in Section 4.2, and Annex B.
Consistency	To ensure consistency, the input/output LCI modeling of the CLT and Glulam used the same LCI modeling structure, which consisted of input raw, secondary (if applicable), ancillary and packaging materials, intermediate products, energy flows, water resource inputs, product outputs, co-products, emissions to air, water and soil (if applicable), and solid and liquid waste disposal. Crosschecks concerning the plausibility of mass and energy flows were continuously conducted. The LCA team conducted mass and energy balances at the facility level to maintain a high level of consistency.

Data Quality Requirements	Description
Reproducibility	Internal reproducibility is possible since the data and the models are stored and available in the Athena Element5 LCI database developed in SimaPro, 2022. A high level of transparency is provided throughout the reviewed LCA report as the LCI profile is presented for each of the declared products. Key primary (manufacturer specific) and secondary (generic) LCI data sources are summarized in Annex C. External reproducibility is also possible as a high level of transparency is provided throughout the Project Report, and LCI data and sources are summarized in Annexes A, B, and C.
Transparency	Activity and background LCI datasets are transparently documented in the LCA report, including data sources (see Annexes A, B, and C). Data are rounded to an appropriate number of significant digits (2 to 5).
Uncertainty	A *sensitivity check* was conducted to assess the reliability of the reported LCA results and conclusions by determining how they are affected by value choices in the data or assumptions on calculation of LCIA and energy indicator results. The sensitivity check includes the results of the sensitivity analysis and Monte Carlo uncertainty analysis (see Section 8.2 and Annex D).

5.3. Allocation rules

The allocation rules in general conform to ISO 14044 (6), Clauses 4.3.4.1 and 4.3.4.2, ISO 21930, 7.2.5 (3) and UL PCR Part B, 3.5 (2).

Per ISO 21930 (3), *Consistent allocation procedures shall be uniformly applied to similar inputs and outputs of the system under consideration.* For example, the approaches of allocation to co-products or to secondary materials crossing the system boundary between product systems should use the same procedure used for co-products or to secondary material flows entering the product system.

The St. Thomas, ON manufacturing facility produces both CLT and Glulam, therefore allocation was necessary. Per UL PCR Part B, 3.5 (2), mass is used as the basis for co-product allocation. "Mass" based, plant specific data for 1 m^3 of CLT and Glulam were used to calculate the input raw materials consumed. "Mass" was used as the physical parameter for allocating flows between the CLT and Glulam to calculate the input energy flows (electricity, natural gas, and propane), ancillary, shipping and packaging materials used at the facility, total water consumption, process emissions to air and water (if applicable) and waste flows. The LCI modeling accounts for the manufacturing yield; see Annex C, Table C3. The manufacturing process does produce wood waste that is stockpiled and picked up for disposal. No environmental burden has been allocated to wood waste. Allocation related to transport is based on the mass of transported inputs and outputs. An explanation of the allocation methodology of upstream surfaced dry softwood lumber production is provided in the lumber LCA report (14). In conformance with the UL PCR Part B, 3.5, the cradle-to-gate surfaced dry softwood lumber data (based on mass allocation) are used in this EPD project.

6. Life cycle impact assessment

6.1. Impact assessment indicators derived from LCA

Per ISO 21930, 9.5.1 (3) and UL PCR Part B, 5.1 (2), the following impact assessment indicators describing environmental impacts derived from LCA are reported as described in Table 5. For this LCA study, the impact categories and characterization factors from the mid-point indicators of the U.S. EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) v.2.1 were applied (17). The TRACI methodologies are used for North American EPDs and are consistent with the UL PCR Part A and B (1), (2).

Table 5 LCIA category indicators

Impact category	Category indicator	Unit (per Declared Unit)	Source of the characterization method	Level of site specificity selected	Environ-mental media
Climate change	Global warming potential (GWP 100)[1)]	kg CO_2 – equiv.	TRACI 2.1 2012[1)]	Global	Air
Ozone depletion	Depletion potential of the stratospheric ozone layer (ODP)	kg CFC-11 equiv.	TRACI 2.1 2012/WMO:2003	Global	Air
Acidification	Acidification potential (AP)	kg SO_2 equiv.	TRACI 2.1 2012	North America	Air, Water
Eutrophication	Eutrophication potential (EP)	kg N equiv.	TRACI 2.1 2012	North America	Air, Water
Smog	Smog formation potential (SFP)	kg O_3 equiv.	TRACI 2.1 2012	North America	Air
Fossil fuel depletion	Fossil fuel depletion potential (FFD)	MJ, surplus	TRACI 2.1, 2012	Global	Resource use
Abiotic depletion potential, fossil	Abiotic depletion potential, fossil (ADP_f)	MJ, LHV	CML-baseline, v4.7 2016	Global	Resource use

Note to Table 5:

1) 100-year time horizon GWP factors (also known as GWP 100) are provided by the IPCC 2007 Fourth Assessment Report (AR4). GWP 100 indicator results exclude biogenic CO_2 removal and emissions associated with any biobased products, including any bio-based packaging (not applicable for Element5 CLT and Glulam; see Annex C, Table C.2). Carbon emissions from calcination, carbon removals from carbonation, and carbon emissions from combustion of waste from non-renewable sources are not applicable to the declared products. For biogenic carbon calculations and indicators see Section 6.3 Biogenic Carbon.

6.2. Inventory indicators

Per ISO 21930, 9.5.2 (3) and UL PCR Part B, 5.2 (2), the following mandatory inventory indicators describing resource use, waste categories and output flows are reported as described in Table 6. The total primary energy consumption is tabulated from the LCI results based on the Cumulative Energy Demand method, LHV (NCV) version 1.0 November 2018 (16). Lower heating value (LHV) of primary energy carriers is used to calculate the primary energy values reported in the LCA study. The consumption of freshwater parameter was calculated using the RECIPE 2016 H method (16). Other inventory parameters concerning material use, waste, and biogenic carbon were drawn from the LCI results in accordance with the ACLCA Guidance to Calculating non-LCIA Inventory Metrics in Accordance with ISO 21930:2017 (18). The LCA model was developed using SimaPro v.9.4 2022 (16).

Table 6 Parameters describing resource use, waste categories and output flows

Parameter	Unit (per Declared unit)
Resource Use	
RPR_E: Renewable primary resources used as energy carrier (fuel)	MJ, LHV
RPR_M: Renewable primary resources with energy content used as material	MJ, LHV
$NRPR_E$: Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV
$NRPR_M$: Non-renewable primary resources with energy content used as material	MJ, LHV
SM: Secondary materials	kg
RSF: Renewable secondary fuels	MJ, LHV
NRSF: Non-renewable secondary fuels	MJ, LHV
RE: Recovered energy	MJ, LHV
FW: Consumption of freshwater (RECIPE 2016 H)	m^3
Waste Categories	
HWD: Hazardous waste disposed	kg
NHWD: Non-hazardous waste disposed	kg
HLRW: High level radioactive waste, conditioned, to final repository	m^3
ILLRW: Intermediate and low level radioactive waste, conditioned, to final repository	m^3
Output Flows	
CRU: Components for re-use	kg
MR: Materials for recycling	kg
MER: Materials for energy recovery	kg
EE: Exported energy	MJ, LHV
Additional Inventory Parameters	
BCRP: Biogenic Carbon Removal from Product	kg CO_2
BCEP: Biogenic Carbon Emission from Product	kg CO_2
BCRK: Biogenic Carbon Removal from Packaging	kg CO_2
BCEK: Biogenic Carbon Emission from Packaging	kg CO_2
BCEW: Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production	kg CO_2

6.3. 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, 7.2.7 and 7.2.12 (3). 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 CO_2.

In the LCIA, the LCI flow of biogenic carbon removal is characterized with a factor of -1 kg CO_2e/kg CO_2 of biogenic carbon in the calculation of the GWP. ISO 21930 requires a demonstration of forest sustainability to characterize carbon removals with a factor of -1 kg CO_2e/kg CO_2. The Element5 St. Thomas, ON facility is Forest Stewardship Council® certified.

Likewise, the LCI flow of biogenic carbon emission is characterized with a factor of +1 kg CO_2e/kg CO_2 of biogenic carbon in the calculation of the GWP. Emissions other than CO_2 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 Part B (2) specifies TRACI as the default LCIA method for GWP. The TRACI method does not account for the removals or emissions of biogenic CO_2. Per ISO 21930, the global warming potential related to biogenic carbon is calculated separately. The LCI indicators of biogenic carbon emissions and removals are presented in Tables 9 and 10 for CLT and Glulam.

7. LCA results

This section summarizes the life cycle impact assessment (LCIA) results including resource use and waste generated metrics based on the cradle-to-gate life cycle inventory inputs and outputs analysis. The EPD results are calculated based on the production of 1m^3 of CLT and Glulam and are reported by information module (A1-A3). *It should be noted that LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks* (6).

Tables 7 and 8 present the cradle-to-gate LCA results per UL PCR Part A and B (1), (2) and ISO 21930 (3) for CLT and Glulam. Per UL PCR Part A, "*GWP_{100}, ODP, AP, EP, SFP, and ADP_{fossil} impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development. However, the EPD users shall not use additional measures for comparative purposes*". Per ISO 21930, 7.1.7.1 (3), "individual indicators for information modules A1, A2 and A3 may be aggregated to a total for each indicator in the production stage."

Table 7 Production stage EPD Results (A1-A3) for 1 m^3 of Element5 CLT

Impact category and inventory indicators	Unit	A1, Extraction and upstream production	A2, Transport to factory	A3, Manufacturing	Total
Global warming potential, GWP 100[1)]	kg CO_2 eq	64.9	10.0	47.1	**122.0**
Ozone depletion potential, ODP[1)]	kg CFC-11 eq	5.5E-06	3.8E-10	7.1E-06	**1.3E-05**
Smog formation potential, SFP[1)]	kg O_3 eq	12.7	2.9	1.4	**16.9**
Acidification potential, AP[1)]	kg SO_2 eq	0.59	0.11	0.10	**0.80**
Eutrophication potential, EP[1)]	kg N eq	0.11	0.007	0.022	**0.14**
Fossil fuel depletion, FFD[1)]	MJ surplus	132.7	19.0	127.6	**279.4**
Abiotic depletion potential, fossil ADPf[2)]	MJ LHV	996	129	782	**1,907**
Renewable primary resources used as an energy carrier (fuel), RPR_E	MJ LHV	1,919	0	172	**2,091**
Renewable primary resources with energy content used as material, RPR_M[3)]	MJ LHV	0	0	8,857	**8,857**
Non-renewable primary resources used as an energy carrier (fuel), $NRPR_E$	MJ LHV	1,268	130	1,914	**3,312**
Non-renewable primary resources with energy content used as material, $NRPR_M$[4)]	MJ LHV	0	0	0	**0**
Secondary materials, SM[5)]	kg	0	0	0	**0**
Renewable secondary fuels, RSF[6)]	MJ LHV	0	0	0	**0**
Non-renewable secondary fuels, NRSF[7)]	MJ LHV	0	0	0	**0**
Recovered energy, RE[8)]	MJ LHV	0	0	0	**0**
Consumption of freshwater, FW[9)]	m^3	0.92	0	3.59	**4.51**
Hazardous waste disposed, HWD[10)]	kg	1.1E-05	0	0	**1.1E-05**
Non-hazardous waste disposed, NHWD[11)]	kg	7.1	0.0	21.0	**28.2**
High-level radioactive waste, conditioned, to final repository, HLRW[12)]	m^3	3.4E-08	0	4.5E-06	**4.5E-06**
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW[13)]	m^3	5.6E-07	0	5.7E-06	**6.3E-06**
Components for re-use, CRU[14)]	kg	0	0	0	**0**
Materials for recycling, MR[15)]	kg	0	0	0	**0**
Materials for energy recovery, MER[16)]	kg	0	0	0	**0**
Recovered energy exported from the product system, EE[17)]	MJ LHV	0	0	0	**0**

See notes after Table 8.

Table 8 Production stage EPD Results (A1-A3) for 1 m^3 of Element5 Glulam

Impact category and inventory indicators	Unit	A1, Extraction and upstream production	A2, Transport to factory	A3, Manufacturing	Total
Global warming potential, GWP 100[1)]	kg CO_2 eq	64.9	10.0	47.1	**122.0**
Ozone depletion potential, ODP[1)]	kg CFC-11 eq	5.5E-06	3.8E-10	7.1E-06	**1.3E-05**
Smog formation potential, SFP[1)]	kg O_3 eq	12.7	2.9	1.4	**16.9**
Acidification potential, AP[1)]	kg SO_2 eq	0.59	0.11	0.10	**0.80**
Eutrophication potential, EP[1)]	kg N eq	0.11	0.007	0.022	**0.14**
Fossil fuel depletion, FFD[1)]	MJ surplus	132.7	19.0	127.6	**279.4**
Abiotic depletion potential, fossil ADPf[2)]	MJ LHV	996	129	782	**1,907**
Renewable primary resources used as an energy carrier (fuel), RPR_E	MJ LHV	1,919	0	172	**2,091**
Renewable primary resources with energy content used as material, RPR_M[3)]	MJ LHV	0	0	8,857	**8,857**
Non-renewable primary resources used as an energy carrier (fuel), $NRPR_E$	MJ LHV	1,268	130	1,914	**3,312**
Non-renewable primary resources with energy content used as material, $NRPR_M$[4)]	MJ LHV	0	0	0	**0**
Secondary materials, SM[5)]	kg	0	0	0	**0**
Renewable secondary fuels, RSF[6)]	MJ LHV	0	0	0	**0**
Non-renewable secondary fuels, NRSF[7)]	MJ LHV	0	0	0	**0**
Recovered energy, RE[8)]	MJ LHV	0	0	0	**0**
Consumption of freshwater, FW[9)]	m^3	0.92	0	3.59	**4.51**
Hazardous waste disposed, HWD[10)]	kg	1.1E-05	0	0	**1.1E-05**
Non-hazardous waste disposed, NHWD[11)]	kg	7.1	0.0	21.0	**28.2**
High-level radioactive waste, conditioned, to final repository, HLRW[12)]	m^3	3.4E-08	0	4.5E-06	**4.5E-06**
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW[13)]	m^3	5.6E-07	0	5.7E-06	**6.3E-06**
Components for re-use, CRU[14)]	kg	0	0	0	**0**
Materials for recycling, MR[15)]	kg	0	0	0	**0**
Materials for energy recovery, MER[16)]	kg	0	0	0	**0**
Recovered energy exported from the product system, EE[17)]	MJ LHV	0	0	0	**0**

Notes to Tables 7 and 8:

[1)] Calculated as per U.S EPA TRACI 2.1 v.1.06, SimaPro v.9.4 (16).

GWP 100, excludes biogenic CO_2 removals and emissions associated with biobased products, including bio-based packaging (not applicable for Element5 CLT and Glulam; see Annex C, Table C.2). Carbon emissions from calcination, carbon removals from carbonation, and carbon emissions from combustion of waste from non-renewable sources are not applicable to the declared products. 100-year time horizon GWP factors are provided by the IPCC 2013 Fifth Assessment Report (AR5). FFD is required in LEED V4.1 MR Credit: Building Product Disclosure and Optimization – Environmental Product Declarations (13).

[2)] Calculated as per CML-IA Baseline V3.05, SimaPro v 9.4 (16). ADPf is also required in LEED V4.1 MR Credit: Building Product Disclosure and Optimization – Environmental Product Declarations (13).

[3)] Calculated as per ACLCA ISO 21930 Guidance (18), 6.2 Renewable primary resources with energy content used as a material, RPR_M. SPF, Softwood, 20.09 MJ/kg oven dry basis HHV; 19.05 MJ/kg oven dry basis LHV.

[4)] Calculated as per ACLCA ISO 21930 Guidance (18), 6.4 Non-renewable primary resources with energy content used as a material, $NRPR_M$. The LCA software does not allow distinguishing the primary energy used as raw material or as energy carrier. For that reason, the $NRPR_E$ presents the total NRPR ($NRPR_E$ + $NRPR_M$).

[5)] Calculated as per ACLCA ISO 21930 Guidance (18), 6.5 Secondary materials, SM. N/A for this product system.

[6)] Calculated as per ACLCA ISO 21930 Guidance (18), 6.6 Renewable secondary fuels, RSF. N/A for this product system.

[7)] Calculated as per ACLCA ISO 21930 Guidance (18), 6.7 Non-renewable secondary fuels, NRSF. N/A for this product system.

[8)] Calculated as per ACLCA ISO 21930 Guidance (18), 6.8 Recovered energy, RE. N/A for this product system.

[9)] Calculated as per ACLCA ISO 21930 Guidance (18), 9 Inventory indicators describing consumption of freshwater, RECIPE 2016 H methodology.

[10)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.1 Hazardous waste disposed. It's calculated from industry primary data for hazardous waste disposed based on the lumber and CLT and glulam manufacturing processes. N/A for this product system.

[11)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.2 Non-hazardous waste disposed. It's calculated from industry primary data for non-hazardous waste disposed based on the lumber and CLT and glulam manufacturing processes.

[12)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.3 High-level radioactive waste, conditioned, to final repository. It should be noted that the foreground system (CLT and glulam manufacturing process) does not generate any HLRW. High-level radioactive waste, e.g., when generated by electricity production, consists mostly of spent fuel from reactors." (ISO 21930:2017, clause 7.2.14).

[13)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.4 Intermediate- and low-level radioactive waste, conditioned, to final repository. It should be noted that the foreground system (CLT and glulam manufacturing process) does not generate any ILLRW. Low- and intermediate-level radioactive wastes, e.g., when generated by electricity production, arise mainly from routine facility maintenance and operations (ISO 21930:2017, clause 7.2.14).

[14)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.5 Components for re-use. N/A for this product system.

[15)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.6 Materials for recycling, i.e., secondary material. N/A for this product system.

[16)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.7 Materials for energy recovery, i.e., secondary fuels used in the next product system. N/A for this product system.

[17)] Calculated as per ACLCA ISO 21930 Guidance (18), 10.8 Recovered energy exported from the system. N/A for this product system.

To ensure transparency, Tables 9 and 10 show additional inventory parameters related to biogenic carbon removal and emissions. The carbon dioxide flows are presented unallocated to consider co-products leaving the product system in information module A3. Even though, the system boundary of this study included only the information modules A1-A3, in accordance with ISO 21930, Biogenic Carbon Emission from Packaging (BCEK) was reported in A5 and Biogenic Carbon Emission from Product (BCEP) of the main product in C3/C4.

Per ISO 21930, *the flows of biogenic carbon expressed in CO_2 in bio-based materials that are reused, recycled, or combusted as the end-of-life scenario will result in zero net contribution to the GWP when the GWP is considered over the whole life cycle (information modules A1 to C4).* The net carbon emissions across the entire life cycle of Element 5 CLT and Glulam are zero. It is assumed that all carbon removed from the atmosphere is eventually emitted to the atmosphere as CO_2. Net 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.

Table 9 Biogenic carbon inventory parameters for 1 m^3 of Element5 CLT (A1 to C4)

Additional inventory parameters	Unit	Total	A1	A2	A3	A5	C3/C4
BCRP: Biogenic Carbon Removal from Product[1)]	kg CO_2	-865.9	-865.9	0	0	0	0
BCEP: Biogenic Carbon Emission from Product[1)]	kg CO_2	865.9			90.3[2)]		775.6[3)]
BCRK: Biogenic Carbon Removal from Packaging	kg CO_2	0	0	0	0	0	0
BCEK: Biogenic Carbon Emission from Packaging	kg CO_2	0	0	0	0	0	0
BCEW: Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production	kg CO_2	0	0	0	0	0	0
Net GWP Bio	**kg CO_2**	**0**					

Table 10 Biogenic carbon inventory parameters for 1 m^3 of Element5 Glulam (A1 to C4)

Additional inventory parameters	Unit	Total	A1	A2	A3	A5	C3/C4
BCRP: Biogenic Carbon Removal from Product[1)]	kg CO_2	-865.9	-865.9	0	0	0	0
BCEP: Biogenic Carbon Emission from Product[1)]	kg CO_2	865.9			90.3[2)]		775.6[3)]
BCRK: Biogenic Carbon Removal from Packaging	kg CO_2	0	0	0	0	0	0
BCEK: Biogenic Carbon Emission from Packaging	kg CO_2	0	0	0	0	0	0
BCEW: Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production	kg CO_2	0	0	0	0	0	0
Net GWP Bio	**kg CO_2**	**0**					

Notes to Tables 9 and 10:
[1)] Biogenic CO_2 emissions are calculated on an oven-dry weight basis; Biogenic C content of the biomass is assumed 50%. To convert the amount of biogenic C to CO_2 emissions, the 44/12 molecular weight ratio is applied.
[2)] Biogenic CO_2 emissions of the biomass leaving the CLT and Glulam manufacturing system in A3.
[3)] Biogenic CO_2 emissions of the declared products at the end-of-life (assumed to be reused, recycled, or combusted).

7.1. Cradle-to grave Carbon sequestration

Tables 9 and 10 present the biogenic carbon inventory parameter results assuming the declared products are reused, recycled, or combusted at the end of life (carbon neutral approach). This assumption excludes the permanent sequestration of biogenic carbon if the LCA were to consider the typical end-of-life treatment for wood products in North America: landfilling.

UL PCR Part B (2) includes an addendum that estimates the emissions from landfill of wood products. The carbon sequestration addendum is based on the United States EPA WARM model and aligns with the biogenic accounting rules in ISO 21930, 7.2.7 and 7.2.12. Because the end-of-life fate of the declared product is unknown, the default disposal pathway from the UL PCR Part A, 2.8.5, 100% landfill is applied.

Cradle-to-grave carbon sequestration calculation for CLT:
1 m^3 CLT = 423.0 oven dry kg = 211.5 kg C = 775.6 kg CO_2 eq

Carbon sequestered in CLT at manufacturing gate: - 775.6 kg CO_2 eq

Methane emitted from fugitive landfill gas: 1.5 kg CH_4= 37.3 kg CO_2 eq emission

Carbon dioxide emitted from fugitive landfill gas and the combustion captured landfill gas: 87.2 kg CO_2 eq emission

Permanent carbon sequestration per cubic meter of CLT: - 651.1 kg CO_2 eq

Cradle-to-grave carbon sequestration calculation for Glulam:
1 m^3 Glulam = 423.0 oven dry kg = 211.5 kg C = 775.6 kg CO_2 eq

Carbon sequestered in Glulam at manufacturing gate: - 775.6 kg CO_2 eq

Methane emitted from fugitive landfill gas: 1.5 kg CH_4= 37.3 kg CO_2 eq emission

Carbon dioxide emitted from fugitive landfill gas and the combustion captured landfill gas: 87.2 kg CO_2 eq emission

Permanent carbon sequestration per cubic meter of Glulam: - 651.1 kg CO_2 eq

8. Interpretation

Interpretation is the phase of LCA in which the findings from the inventory analysis and the impact assessment are brought together, and significant issues are identified and considered in the context of the study goal and scope (5). In addition, the study's completeness, consistency of all applied information, and sensitivity to key assumptions or parameters as they relate to the goal and scope of the study are evaluated. Lastly, the interpretation phase ends by drawing conclusions, stating the study's limitations, and making recommendations (6).

8.1. Identification of the Significant Issues

ISO 14044 recommends several possible methods to identify significant issues in an LCA study. Based on established LCA practices, the following analytical techniques were applied for the interpretation phase of this LCA study (6):

- Contribution Analysis, in which the contribution of information modules and processes to the cradle-to-gate LCA results are examined.
- Dominance Analysis, in which significant contributions are examined.

Figures 6 and 7 present a percent contribution analysis by information module for the impact assessment and energy indicator results for Element5 CLT and Glulam.

Across the declared products, *Module A1 Extraction and upstream material* input production contributes the largest share of the LCIA category and energy indicator results, accounting for between 38% (NRPRE) and 92% (RPRE) of the potential environmental burdens. *Module A2 Transportation* contributed less than 17% to the overall potential impact of CLT and Glulam production stage. *Module A3 Manufacturing* contributed 39% to GWP 100 and is the second largest contributor to the overall potential environmental impacts of CLT and Glulam manufacture.

Given the importance of the cradle-to gate GWP 100 results, a process contribution analysis was conducted to examine the contribution of individual cradle-to-gate processes to the Production stage GWP 100 (in kg CO_2 eq.) of 1 m^3 CLT and Glulam. The top contributors to production stage

(A1 to A3) GWP 100 results across CLT and Glulam are lumber production, A1; natural gas production and combustion, A3; adhesive production, A1; and electricity production, A3; see Table 11 for details.

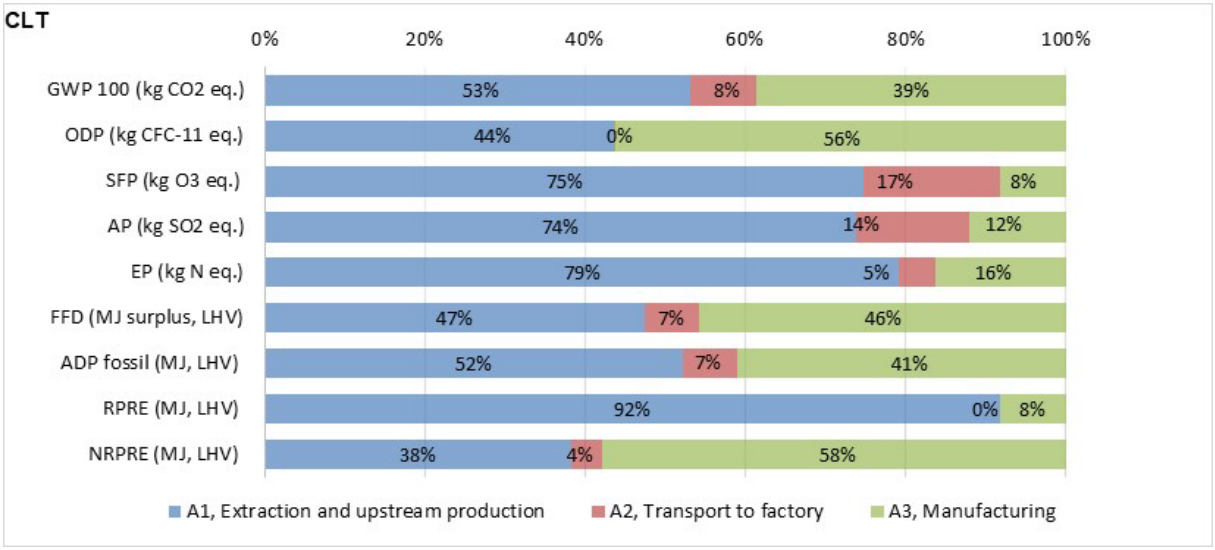


Figure 6 Impact assessment and energy indicator results by stage for 1m³ CLT

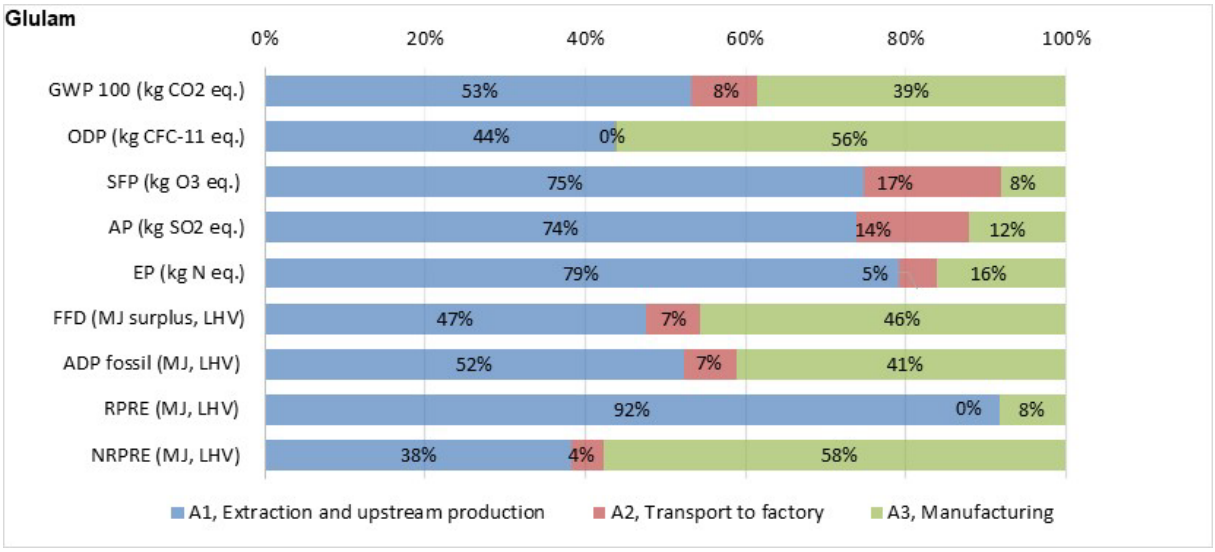


Figure 7 Impact assessment and energy indicator results by stage for 1m³ Glulam

Table 11 Top 4 significant processes contributing to production stage (A1-A3), GWP 100 results for 1 m^3 of Element5 CLT and Glulam

Production Stage (A1 to A3)	CLT		Glulam	
	kg CO_2 eq.	%	kg CO_2 eq.	%
Lumber production, A1	41.1	34%	41.1	34%
Natural gas extraction and combustion, A3	37.0	30%	37.0	30%
PUR adhesive production, A1	18.1	15%	18.1	15%
Electricity generation and transmission, A3	8.4	7%	8.4	7%
Rest of processes, A1 to A3	17.4	14%	17.4	14%
Total	**122.0**	**100%**	**122.0**	**100%**

8.2. Completeness, consistency, and sensitivity check

Evaluating the study's completeness, consistency and sensitivity helps to establish and enhance confidence in, and the reliability of, the results of the LCA study, including the significant issues identified in the first element of the interpretation (6).

The objective of the *completeness check* is to ensure that all relevant information and data needed for the interpretation are available and complete (6). CLT and Glulam data were checked for data completeness. All input and output data were found to be complete, and no gaps were identified at information modules A1 to A3 (see Annexes B and C).

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 (6). Through a rigorous process, consistency was ensured between CLT and Glulam systems in terms of calculation rules, methods, models, and data quality, including data source, time-related coverage, technology, and geographical coverage (see Section 5, and Annex C). Table 4 summarizes the data quality assessment conducted in the framework of this LCA study.

To assess how factors such as uncertainties in data and assumptions would affect the reliability of the results and conclusions, a *sensitivity check* was conducted. The sensitivity check includes the results of the sensitivity analysis and uncertainty analysis (6). The sensitivity analysis procedure is a comparison of the LCA results obtained using certain given assumptions, methods, or data, with the LCA results obtained using altered assumptions, methods, or data (5). ISO 14044 Clause B.3.3 states: "*Sensitivity can be expressed as the percentage of change or as the absolute deviation of the results. On this basis, significant changes in the results (e.g., larger than 10%) can be identified*" (6).

Scenario analysis was conducted to illustrate the consequences of replacing the St. Thomas, Ontario electricity grid (Electricity, medium voltage {ON}| market for | Cut-off, U) LCI profile for

CLT and Glulam manufacturing (foreground process only) with the Canadian electricity grid mix (Electricity, medium voltage {CA}| market group for | Cut-off, U).

The scenario analysis results are presented in detail in Table 12. The positive (+) or negative (-) signs of deviation (in %) depend on the mathematical signs (+/-) of both the value of base case and the deviation of the LCIA and energy indicators. For example, the influence of this scenario to GWP 100 of CLT compared to the base case is positive (+12%); indicating a 12% higher GWP 100 compared to the base case. *The scenario analysis indicates that replacing the Ontario LCI profile for electricity grid (for foreground process only) with the Canadian generic electricity grid would significantly influence the results for the GWP 100 for the Element5 CLT. Same findings are applicable for Glulam.*

Table 12 Analysis Results for 1 m^3 CLT

LCIA and energy indicators	Base case	Scenario case	Deviation-in absolute basis	Deviation-in %
GWP (kg CO_2 eq.)	122.0	136.5	14.5	12%
ODP (kg CFC-11 eq.)	1.3E-05	1.3E-05	4.1E-07	3%
SFP (kg O_3 eq.)	16.9	17.5	0.5	3%
AP (kg SO_2 eq.)	0.80	0.86	0.06	8%
EP (kg N eq.)	0.14	0.32	0.18	127%
ADP (MJ surplus)	279.4	287.4	8.0	3%
ADP fossil (MJ)	1,907	2,056	149	8%
RPR (MJ, LHV)	2,091	2,223	132	6%
NRPR (MJ, LHV)	3,312	2,673	-639	-19%

A *Monte Carlo uncertainty analysis* was also conducted to assess the combined uncertainty effect of the data variability on the GWP 100 results (see Annex C, Table C.1).

This uncertainty analysis assesses the combined uncertainty effect of the inventory data (foreground and background LCI datasets); see Annexes B and C. It should be noted that U.S. EPA TRACI version 2.1 methodology has not specified any uncertainty information of the characterization factors per impact category.

As a statistical method, Monte Carlo analysis is used to establish the uncertainty range, which expresses the variance between the upper and lower confidence limit [97.5%, 2.5%], in the calculated LCA results. Based on 1,000 runs, such information provides a quantitative indication of the range of GWP 100 results for the declared products.

8.3. Conclusions, limitations, and recommendations

Based on the goal and scope of this LCA, life cycle inventory, impact assessment, and interpretation phases, the following conclusions can be reached:

- Module A1 Extraction and upstream production contributes the largest share of the LCIA category indicator results, accounting for between 38% and 92% of the production stage (A1 to A3) potential environmental burdens. Module A3 Manufacturing is the second largest contributor to the overall potential environmental impacts of the CLT and Glulam manufacture.
- ***Natural gas*** consumption followed by ***electricity*** use significantly dominate the impact of Module A3 CLT and Glulam manufacturing. Module A3 typically accounts for 39% and 58% of the overall GWP 100 and $NRPR_E$ of CLT and Glulam production, respectively. Efforts to reduce natural gas and electricity use offer the most immediate opportunity to improve the environmental performance of the declared products.

Finally, "*LCA addresses potential environmental impacts and does not predict absolute or precise environmental impacts due to (a) the relative expression of potential environmental impacts to a reference unit, (b) the integration of environmental data over space and time, (c) the inherent uncertainty in modeling of environmental impacts, and (d) the fact that some possible environmental impacts are clearly future impacts"* (6).

9. Additional environmental information

- The Element5 St. Thomas facility is Forest Stewardship Council (FSC) certified. FSC certification ensures that products come from responsibly managed forests that provide environmental, social, and economic benefits.
- The St. Thomas, ON facility uses a dust collection system.

10. Declaration type

This "Cradle-to-gate" EPD applies to Element5's CLT and Glulam. Production activities covered include the extraction and upstream production, transport to factory, and manufacturing (modules A1 to A3). The declaration is intended for use in Business-to-Business (B-to-B) communication.

The CLT and Glulam EPDs fall under the description:

- A product-specific EPD, from one manufacturer's facility.

11. Declaration comparability and other limitation statements

The following ISO 14025, ISO 21930 and UL PCR Part B statements indicate the EPD comparability limitations and intent to avoid any market distortions or misinterpretation of EPDs (4), (3), (2):

- *Environmental declarations from different programmes may not be comparable.*
- *Comparison of the environmental performance using EPD information shall consider all relevant information modules over the full life cycle of the products within the building.*
- *This PCR allows EPD comparability only when the same functional requirements between products are ensured and the requirements of ISO 21930:2017 §5.5 are met. It should be noted that different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.*
- *While this EPD does not address landscape level forest management impacts, potential impacts may be addressed through requirements put forth in regional regulatory frameworks, ASTM 7612-15 guidance, and ISO 21930 Section 7.2.11 including notes therein. These documents, combined with this EPD, may provide a more complete picture of environmental and social performance of wood products.*
- *While this EPD does not address all forest management activities that influence forest carbon, wildlife habitat, endangered species, and soil and water quality, these potential impacts may be addressed through other mechanisms such as regulatory frameworks and/or forest certification systems which, combined with this EPD, will give a more complete picture of environmental and social performance of wood products.*
- *EPDs can complement but cannot replace tools and certifications that are designed to address environmental impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, etc.*
- *National or regional life cycle averaged data for raw material extraction does not distinguish between extraction practices at specific sites and can greatly affect the resulting impacts.*
- *Accuracy of Results: EPDs regularly rely on estimations of impacts; the level of accuracy in estimation of effect differs for any particular product line and reported impact when averaging data. Variability was estimated in this EPD by Monte Carlo Uncertainty Analysis.*

12. EPD explanatory material

For any explanatory material, in regard to the Element5 EPDs based on this EPD project report, please contact the program operator:

ASTM International
Environmental Product Declarations
100 Barr Harbor Drive,
West Conshohocken, PA 19428-2959
www.astm.org

13. References

1. UL Environment 2018 Product Category Rule (PCR) Guidance for Building Related Products and Services, Part A Life Cycle Assessment Calculation Rules and Report requirement, v3.2.
2. UL Environment (2019) Product Category Rule (PCR) Guidance for Building-Related Products and Services, Part B: Structural and Architectural Wood Products EPD Requirements.
3. ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.
4. ISO 14025: 2006 Environmental labeling and declarations - Type III environmental declarations - Principles and procedures.
5. ISO 14040/Amd1:2020 Environmental Management – Life Cycle Assessment – Principles and Framework, International Organization for Standardization, 2006.
6. ISO 14044/Amd1:2017/Amd2:2020 Environmental Management – Life Cycle Assessment – Requirements and guidelines, International Organization for Standardization, 2006.
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13. LEED v4.1, MRc2: Building product disclosure and optimization, Environmental Product Declarations,. *https://leeduser.buildinggreen.com/credit/NC-v4.1/MRc2#tab-credit-language .*
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16. *PRé 2022. SimaPro LCA Software v9.4, 2022., https://simapro.com/.*
17. US EPA, ORD/NRMRL/Sustainable Technology Division, Systems Analysis Branch, SOP No. S-10637-OP-1-0- Tool. https://nepis.epa.gov/Adobe/PDF/P100HN53.pdf.
18. ACLCA 2019, Guidance to Calculating Non-LCIA Inventory Metrics in Accordance with ISO 21930:2017. The American Centre for Life Cycle Assessment. May, 2019.

Annex A: Element5 CLT and Glulam specifications

Table A.1 Element5 CLT- Product Specifications (10)

Product Properties	Amount	Unit
CLT		
CLT	448.0	kg/m^3
Moisture Content	12.0+/-3%	%
Cross Laminated Timber (CLT) characteristics		
Stress grade	V2, E1	
Service Condition	Dry use	
Uses	Floor and roof slabs, Wall panels, Shearwalls, Stairwell & elevator cores, other applications	
Appearance grades	Industrial and architectural	
Species	Spruce-Pine-Fir (SPF), other species upon request	
Number of layers	3, 5, 7 and 9	
Thicknesses	Maximum Panel Thickness - 380 mm (15")	
Maximum width	3.2m visual, 3.5m non-visual	
Lengths	Various, up to a maximum of 16.0m (52 ft)	

Table A.2 Element5 Glulam- Product Specifications (11)

Product Properties	Amount	Unit
Glulam		
Glulam	448.0	kg/m^3
Moisture Content	12.0+/-3%	%
Glued Laminated Timber (Glulam) characteristics		
Stress grade	Spruce Pine 20f-EX, 20f-E, 12c-E, 14t-E to CSA-0122	
Service Condition	Dry use	
Uses	It can be used as a column, beam, rafter, purlin, or brace. It is suited for use in many diverse applications, including residential, commercial, institutional, and industrial buildings.	
Species	SPF (spruce-pine-fir), other species upon request	
Maximum width	79mm to 265mm (alternate sizes available upon request)	
Lengths	Any length required up to 16m long (+/- 2mm per CSA)	

Note to Tables A.1 to A.2:
[1)] Note that the scope of this LCA does not include any optional installation parts (e.g., screws and brackets) used for on-site product installation.

Table A.3 Element5 CLT- Calculated weighted average thickness (10)

CLT- Property	Average Thickness (in mm)	Total production (in %)
CLT- 3 layers	96	31%
CLT- 5 layers	157	61%
CLT-7 layers	218	3%
CLT-9 layers	315	5%
Weighted average thickness	**148**	**100%**

Table A.4 Element5 Glulam- Calculated weighted average thickness (11)

Glulam- Property	Thickness (in mm)	Total production (in %)
	79	32%
	80	13%
	130	39%
	139	8%
	171	0%
	175	5%
	178	1%
	180	1%
	265	1%
Weighted average thickness	**112**	**100%**

Annex B: LCI data for Element5 CLT and Glulam manufacturing

Table B.1 LCI data for Element5 CLT manufacturing

Inputs/Outputs	1 m³ CLT		Source of data
	Quantity	Units	
Input Materials			
Softwood lumber (19%MC)	1.12	m³	D
PUR Adhesives (100% solids) [1)]	4.3	kg	D
MF Hardener (100% solids) [1)]	0.8	kg	D
MF Adhesive (100% solids) [1)]	0.8	kg	D
Packaging materials			
Plastic lumber wrap	1.4	kg	D
Ancillary Materials			
Hydraulic fluid, lubricants, motor oil, and greases	0.03	kg	D
KP-12 moisture protection coating material [1)]	2.1E-04	kg	D
Energy Input			
Purchased Electricity	122.8	kWh	D
Natural gas	17.6	m³	D
Propane	0.070	liter	D
Water Consumption			
Freshwater	194.8	liter	D
Product and Co-product			
CLT (12%MC)	1.0	m³	D
Sawdust	29.1	kg	D
Emissions to Air-n/a			
Emissions to Water-n/a			
Emissions to Industrial Soil-n/a			
Solid Waste			
Wood Waste (stockpiled; picked up for disposal)	22.4	kg	E
Wastewater and Other Liquid Waste			
Wastewater (to sewage)	194.8	liter	D

Note:
[1)] The chemical weights are given at 100% non-volatile solids content or active substance/solution strength. The solids content of the PUR adhesive, MF hardener and MF adhesive were reported 100%, between 42.5 and 45.5%, and between 65% and 68%, respectively.

Table B.2 LCI data for Element5 Glulam manufacturing

Inputs/Outputs	1 m³ Glulam		Source of data
	Quantity	Units	
Input Materials			
Softwood lumber (19%MC)	1.12	m³	D
PUR Adhesives (100% solids) [1)]	4.3	kg	D
MF Hardener (100% solids) [1)]	0.8	kg	D
MF Adhesive (100% solids) [1)]	0.8	kg	D
Packaging materials			
Plastic lumber wrap	1.4	kg	D
Ancillary Materials			
Hydraulic fluid, lubricants, motor oil, and greases	0.03	kg	D
KP-12 moisture protection coating material [1)]	2.1E-04	kg	D
Energy Input			
Purchased Electricity	122.8	kWh	D
Natural gas	17.6	m³	D
Propane	0.070	liter	D
Water Consumption			
Freshwater	194.8	liter	D
Product and Co-product			
Glulam (12%MC)	1.0	m³	D
Sawdust	29.1	kg	D
Emissions to Air-n/a			
Emissions to Water-n/a			
Emissions to Industrial Soil-n/a			
Solid Waste			
Wood Waste (stockpiled; pick up for disposal)	22.4	kg	E
Wastewater and Other Liquid Waste			
Wastewater (to sewage)	194.8	liter	D

Note:
[1)] The chemical weights are given at 100% non-volatile solids content or active substance/solution strength. The solids content of the PUR adhesive, MF hardener and MF adhesive were reported 100%, between 42.5 and 45.5%, and between 65% and 68%, respectively.

Table B.3 Inbound transportation data for 1m³ CLT

Transportation data	Per 1 m³ CLT			
	Truck t.km	Rail t.km	Ship t.km	Barge t.km
All material inputs (see Table B.1)	85.1	0	0	0
Combination truck, diesel, short haul <200 mi	81.2			
Single unit truck, diesel, long haul > 200 mi	3.9			
All ancillary and packaging inputs (see Table B.1)	0.2	0	0	0
Combination truck, diesel, short haul <200 mi	0.2			
Combination truck, diesel, long haul >200 mi	2.5E-04			
All waste outputs (see Table B.1)	1.1	0	0	0
Single unit truck, diesel, short haul < 200 mi	1.1			

Table B.4 Inbound transportation data for 1m³ Glulam

Transportation data	Per 1 m³ Glulam			
	Truck t.km	Rail t.km	Ship t.km	Barge t.km
All material inputs (see Table B.2)	85.1	0	0	0
Combination truck, diesel, short haul <200 mi	81.2			
Single unit truck, diesel, long haul > 200 mi	3.9			
All ancillary and packaging inputs (see Table B.2)	0.2	0	0	0
Combination truck, diesel, short haul <200 mi	0.2			
Combination truck, diesel, long haul >200 mi	2.5E-04			
All waste outputs (see Table B.2)	1.1	0	0	0
Single unit truck, diesel, short haul < 200 mi	1.1			

Annex C: Data quality assessment

Table C.1 Element5 CLT and Glulam Production stage LCI datasets

LCI datasets	Comments
Source: *SimaPro LCA Software, v9.4, 2022,* *ecoinvent 3.8, Allocation, Cut-off by classification, Nov 2021;* *US LCI database, Sept 2015.*	Geography: U.S. or adjusted to U.S. Technology: Industry average or conventional Timeline: Not older than 10 years.
Element5 CLT and Glulam	**Modules A1-A3**
Eastern Canadian Surfaced Dry Softwood Lumber {ON/CA} Cut-off (14)	A1, Upstream manufacturing Source: http://www.athenasmi.org/wp-content/uploads/2018/07/CtG-LCA-of-E
Melamine formaldehyde adhesive {US/CA} Cut-off (15)	A1, Upstream manufacturing Source: https://www.fs.usda.gov/treesearch/pubs/64106
Melamine formaldehyde hardener {CA} Cut-off	A1, Upstream manufacturing; Based on SDS[3)]
Polyurethane, rigid foam {CA/RER}| market for polyurethane, rigid foam | Cut-off, U[1)]	A1, Upstream manufacturing
Transport, combination truck, long-haul, diesel powered/tkm/RNA[2)]	A2, Transportation
Transport, combination truck, short-haul, diesel powered/tkm/RNA	A2, Transportation
Transport, single unit truck, long-haul, diesel powered/tkm/RNA	A2, Transportation
Transport, single unit truck, short-haul, diesel powered/tkm/RNA	A2, Transportation
Electricity, medium voltage {CA/ON}| market for | Cut-off, U	A3, On-site fabrication
Electricity, medium voltage {CA}| market for | Cut-off, U	A3, On-site fabrication
Heat production, natural gas, at industrial furnace low-NOx >100kW, CA-ON	A3, On-site fabrication
Propane, burned in building machine {GLO}| propane, burned in building machine | Cut-off, U	A3, On-site fabrication
Lubricating oil {RoW}| market for lubricating oil | Cut-off, U	A3, On-site fabrication
KP-12 moisture protection coating material {CA}| Cut-off, U	A3, On-site fabrication; Based on SDS
Plastic Lumber wrap {CA/ON}| production | Cut-off	A3, Packaging material; Based on SDS
Tap water {CA-ON}| tap water production, conventional treatment | Cut-off, U	A3, On-site fabrication
Wastewater, average {RoW}| treatment of, capacity 1E9l/year | Cut-off, U	A3, On-site fabrication

Notes to Table C.1:

[1)] Source of the LCI datasets with the tag "Cut-off, U" is ecoinvent 3.8, Allocation, Cut-off by classification, Nov 2021.

[2)] Source of the LCI datasets with the tag "/RNA" is US LCI Database, Sept 2015.

[3)] Any data gaps in the SDS are filled in with two generic LCI datasets, as appropriate (conservative assumptions): Chemical, organic {GLO}\| production \| Cut-off, U; Chemical, inorganic {GLO}\| production \| Cut-off, U.

Table C.2 Module A5 product packaging waste and biogenic carbon renewals (BCR) per 1 m³ CLT and Glulam

Inputs/Outputs	1 m³ CLT	1 m³ Glulam	Units
Packaging materials- in kg			
Plastic lumber wrap	1.45	1.45	kg
Biogenic carbon removals packaging (BCRK)- in kg CO_2 biogenic			
Plastic lumber wrap	0	0	kg
Total BCRK (in kg CO_2 biogenic)	**0**	**0**	kg

Notes to Table C.2:

[1)] Per ISO 21930, 7.2.7, when entering the product system (i.e., a flow to the technosphere from nature), this biogenic carbon flow shall be characterized in the LCIA with −1 kg CO_2e/kg CO_2 of biogenic carbon in the calculation of the GWP.

[2)] The plastic lumber wrap does not contain any biogenic material.

Annex D: Monte Carlo uncertainty results

As discussed in Section 8.2, a Monte Carlo uncertainty analysis was also conducted to assess the uncertainty effect of the data variability on the GWP 100 results.

With a confidence level of 95%, the confidence interval of cradle-to-gate GWP 100 of the CLT and Glulam are presented in Table D1. Based on 1,000 runs, such information provides a quantitative indication of the range of GWP 100 results that are likely for CLT and Glulam. In addition, Table D1 shows the summary results of the uncertainty analysis (mean; median; standard deviation, SD; coefficient of variation, CV; 2.5%, 97.5%; and standard error of median values, SEM) for "cradle-to-gate" GWP results of both CLT and Glulam.

Table D1 Monte Carlo uncertainty analysis: Cradle-to-gate GWP 100 results of CLT and Glulam (confidence interval: 95%, 1,000 runs, exported from SimaPro LCA software 9.4, 2022)

CLT and Glulam	Indicator	Unit	Mean	Median	SD	CV	2.5%	97.5%	SEM	Confidence interval in %	
										High	Low
CLT	GWP 100a	kg CO_2 eq	122.1	121.3	8.1	6.6	108.6	139.2	0.3	14.7%	-10.5%
Glulam	GWP 100a	kg CO_2 eq	122.1	121.3	8.1	6.6	108.6	139.2	0.3	14.7%	-10.5%