Boise Cascade COMMERCIAL SOLUTIONS

Boise Cascade
Environmental Product Declaration (EPD)
Cradle to Grave

Environmental Product Declaration (EPD)

CRADLE TO GRAVE

Cradle-to-Gate EPD for VersaWorks™ Veneer Laminated Timber (VLT) Mass Timber and Versa-Lam® Laminated Veneer Lumber (LVL) produced by Boise Cascade in White City, Oregon.

Summary Results – Average End of Life Treatment Full Results in Tables 3-7		Cradle-to-Gate Total
Global Warming Potential, Total	Kg CO_2e	-229.73
Global Warming Potential, Fossil	Kg CO_2e	304.25
Global Warming Potential, Biogenic	Kg CO_2e	-533.98
Ozone Depletion	Kg CFC11e	6.92E-06
Acidification	Kg SO_2e	2.62
Eutrophication	Kg Ne	0.66
SFP (Smog)	Kg O_3e	36.77
Non-renewable Energy	MJ, NCV	5,956

ASTM Certified Environmental Product Declaration

Program Operator	**ASTM International** 100 Barr Harbor Drive PO Box C700 West Conshohocken, PA, 19428-2959 USA **www.astm.org**
General Program Instructions and Version Number	ASTM Program Operator for Product Category Rules (PCR) and Environmental Product Declarations (EPDs) - General Program Instructions, version: 6.0
Declaration Owner	**Boise Cascade Wood Products, LLC** 1111 W Jefferson St Ste 300 Boise, ID 83728 www.bc.com
Declaration Number	EPD 230
Declared Product	Veneer Laminated Timber (VLT); Brand Name: VersaWorks™ Laminated Veneer Lumber (LVL); Brand Name: Versa-Lam®
Functional Unit	1 m3 of VersaWorks™ VLT and Versa-Lam® LVL produced at Boise Cascade's facility in White City, Oregon, installed in a building for 75 years.
Reference PCR and Version Number	**ISO 21930:2017** Sustainability in Building Construction — Environmental Declaration of Building Products. [7] **UL Environment:** Product Category Rules for Building-Related Products and Services **Part A:** Calculation Rules for the Life Cycle Assessment and Requirements on the Project Report, v3.2 [11] **Part B:** Structural and Architectural Wood Products EPD Requirements, v1.0 [12]
Description of Product's intended application and use	Boise Cascade VersaWorks™ VLT and Versa-Lam® LVL are engineered wood products with high structural strength and stability. They can be used as building material for structural floor slabs, walls, beams, ribs, and columns.
Markets of Applicability	Construction Sector, Mass Timber design
Date of Issue	June 21, 2021
Period of Validity	June 21, 2026
EPD Type	Product-specific EPD
EPD Scope	Cradle-to-Gate
Years of reported manufacturer primary data	2019
LCA Software	SimaPro v8.5
LCI Databases	USLCI [9], ecoinvent 3.5 [14], Datasmart [8]
LCIA Methodology	TRACI 2.1 [3]
The sub-category PCR review was conducted by:	Dr. Thomas Gloria (chair), Industrial Ecology Consultants; Dr. Indro Ganguly, University of Washington; Dr. Sahoo, University of Georgia

LCA and EPD Developer This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by:	**Athena Sustainable Materials Institute** 280 Albert Street, Suite 404 Ottawa, Ontario Canada K1P 5G8 www.athenasmi.org James Salazar

This declaration was independently verified in accordance with **ISO 14025:2006[4]**.
The **UL Environment "Part A: Calculation Rules for the Life Cycle Assessment and Requirements on the Project Report," v3.2** (December 2018), in conformance with **ISO 21930:2017**, serves as the core PCR,
with additional considerations from the **USGBC/UL Environment Part A Enhancement (2017)**.

☐ INTERNAL x EXTERNAL

Independent Verifier This life cycle assessment was independently verified in accordance with ISO 14044 [6] and the reference PCR by:	Dr. Thomas Gloria Industrial Ecology Consultants

Limitations

- Environmental declarations from different programs (ISO 14025) 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 different results upstream or downstream of the life cycle stages declared.

Company and Product Description

Boise Cascade

Boise Cascade® is a manufacturer of engineered wood products. Since our founding in 1957, we've grown to become a leading manufacturer and distributor of building materials in North America and beyond. Through conservation and sustainable practices, we are actively contributing to the responsible use and protection of the natural environment, which benefits our employees, our customers, and the communities we work and live in.

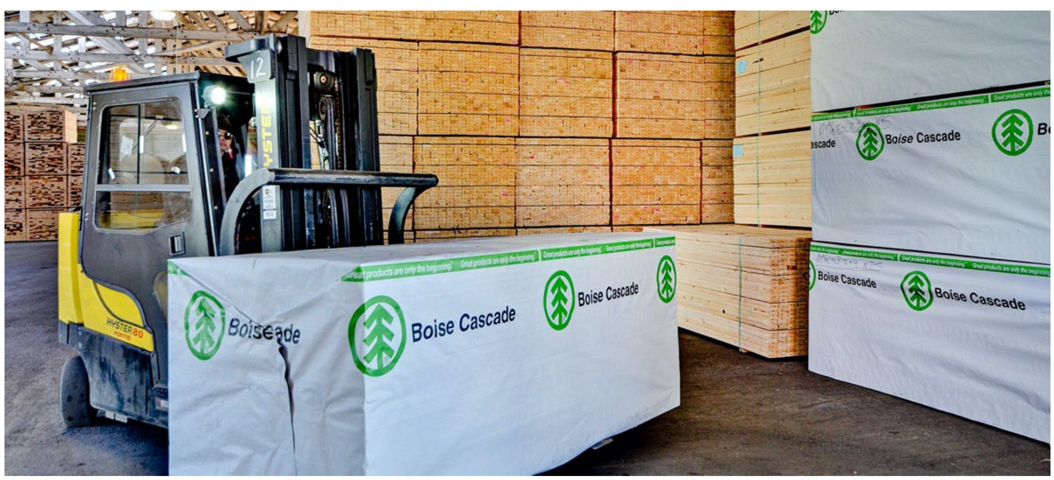
Product Description

VersaWorks™ Veneer Laminated Timber (VLT) and Versa-Lam® Laminated Veneer Lumber (LVL), are engineered wood products comprised of thin layers of wood called veneers that are laid up, glued, and pressed to produce structural sized members.

Boise Cascade's mass timber VersaWorks VLT products are based on Versa-Lam LVL product components, produced using the same machinery and with the same composition, but assembled in larger product dimensions so that it may be used in mass timber designs. As the VLT and LVL products have identical composition and manufacturing processes, they can be considered identical in terms of their environmental impacts as calculated for this EPD.

Product Composition

Boise Cascade's VersaWorks™ VLT and Versa-Lam® LVL products are comprised of wood veneer (> 90%) and phenol formaldehyde resin (< 10%). See Table 1 for detailed product characteristics. The wood veneers used in the VLT and LVL production are produced by Boise Cascade and are procured from sustainably managed forests in the United States.



Methodological Framework

Type of EPD and Life Cycle Stages

The underlying LCA [5] investigates the product system from cradle-to-gate. This comprises the production stage including the information modules 'A1 Extraction and upstream production', 'A2 Transport to factory' and 'A3 Manufacturing' (Figure 1).

Figure 1: Life Cycle Stages and Information Modules per ISO 21930:2017.

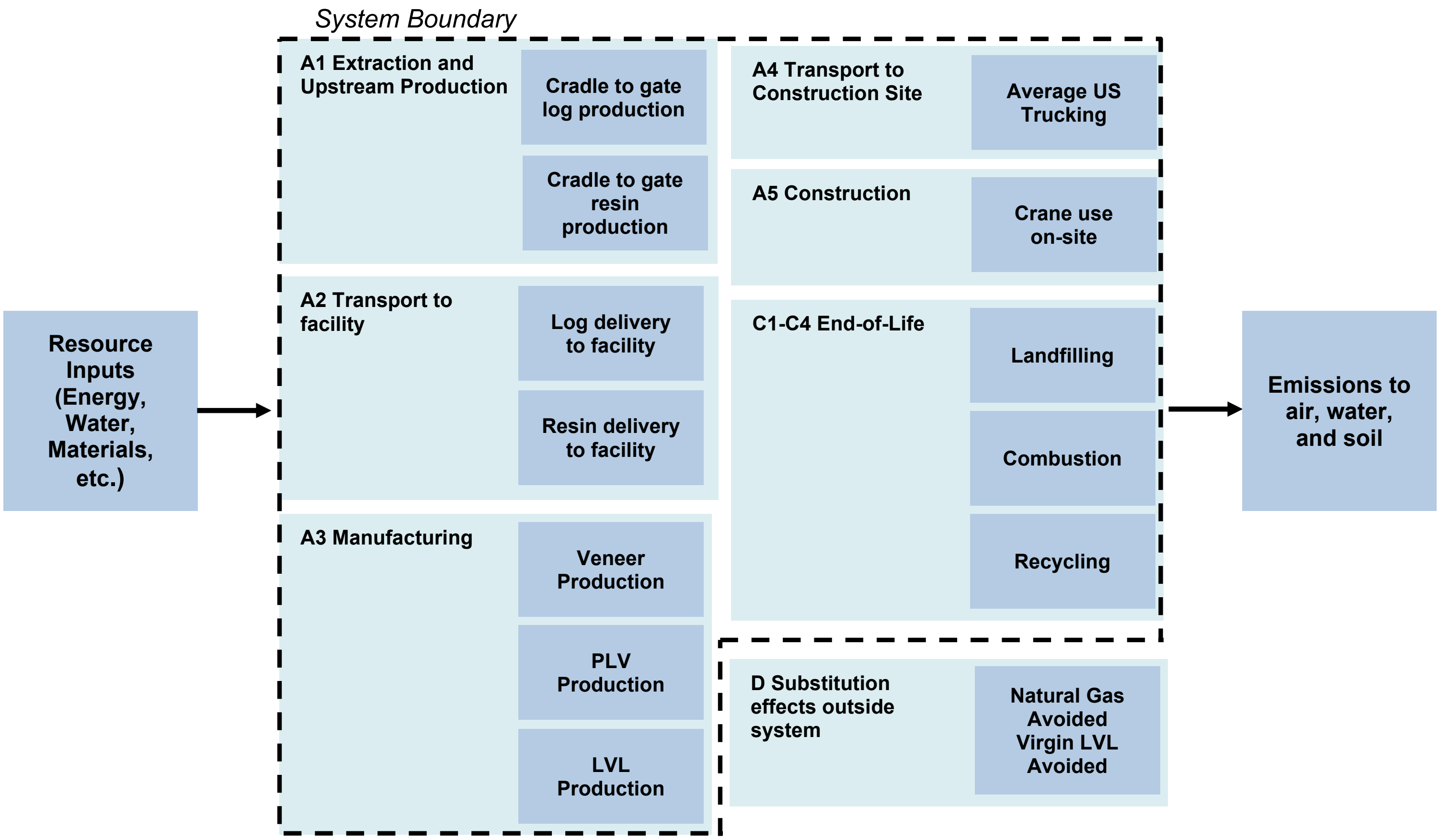
Building Lice Cycle Information Modules																
Production Stage			Construction Stage		Use Stage							End-of-Life Stage				Substitution Stage
Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	De-Construction/ Demolition	Transport to waste processing or disposal	Waste processing	Disposal	Benefits Outside System
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

X = Module Declared
MND = Module Not Declared

System Boundaries and Product Flow Diagram

The product system is presented in Figure 2 below and shows the information modules that are included in the system boundary.

Figure 2: Cradle-to-Grave VLT and LVL Product System



Construction and Service Life Assumptions

The product system includes average assumptions as to the transportation of the product to the construction site, 167 miles [13] as well as construction energy use, 2.23 liters diesel [2]. The reference service life for the product is 75 years which is the default specified by the UL Part A PCR [11].

Declared Unit
The declared unit for VLT and LVL is "*one cubic meter (1 m^3) of laminated veneer lumber (LVL) produced at Boise Cascade's facility in White City, Oregon installed in a building for 75 years*". The product properties and composition associated with the functional unit are provided in Table 1.

Table 1: Product properties and composition of 1 cubic meter of veneer laminated timber (VLT) and laminated veneer lumber (LVL)

Product properties:	**Unit**	**Value**
Mass (including moisture)	kg	483.4
Moisture Content	%	7%
Product composition:	**Unit**	**Value**
Wood Veneer	%	> 90%
Resins	%	< 10%

Allocation Methods
Allocation is the method used to partition the environmental load of a process when several products or functions share the same process. VLT and LVL manufacturing includes veneer parallel laminated veneer production processes that are multiple output process, where the primary products are one of several valuable coproducts from a common process. In accordance with UL Wood PCR 2019, "mass" was selected as the parameter for allocation of the total inputs/outputs of the production system.

Cut-off Criteria
The cut-off criteria for all activity stage flows considered within the system boundary conform with ISO 21930: 2017 Section 7.1.8. Specifically, the cut-off criteria were applied as follows:

- All inputs and outputs for which data are available are included in the calculated effects and no collected core process data are excluded.
- A one percent cut-off is considered for renewable and non-renewable primary energy consumption and the total mass of inputs within a unit process. The sum of the total neglected flows does not exceed 5% of all energy consumption and mass of inputs.
- All flows known to contribute a significant impact or to uncertainty are included.
- The cut-off rules are not applied to hazardous and toxic material flows – all of which are included in the life cycle inventory.

No material or energy input or output was knowingly excluded from the system boundary.

Data Sources
Primary and secondary data sources, as well as the respective data quality assessment are documented in the underlying LCA project report [2] in accordance with UL PCR 2019. This EPD estimates the impacts of forest management using average data for Pacific Northwest log production. Third-party verified ISO 14040/44 secondary LCI data sets contribute more than 67% of total impact to any of the required impact categories identified by the applicable PCR.

Treatment of Biogenic Carbon and Sustainable Forest Management Certification
Biogenic carbon emissions and removals are reported in accordance with ISO 21930 7.2.7. and 7.2.12. Detailed information is provided in Section 5.1 of the underlying LCA [2]. Table 6 provides additional inventory parameters related to biogenic carbon removal and emissions.

ISO 21930 requires a demonstration of forest sustainability to characterize carbon removals with a factor of -1 kg CO2e/kg CO2. ISO 21930 Section 7.2.11 Note 2 states the following regarding demonstrating forest sustainability: "Other evidence 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." The United States 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 CO_2e/kg CO_2.

ENVIRONMENTAL PARAMETERS DERIVED FROM LCA

The impact categories and characterization factors (CF) for the LCIA were derived from the U.S. EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts -TRACI 2.1 [6].

The total primary energy consumption is tabulated from the LCI results based on the Cumulative Energy Demand Method published by ecoinvent [18]. Lower heating value of primary energy carriers is used to calculate the primary energy values reported in the study.

Other inventory parameters concerning material use, waste, water use, and biogenic carbon were drawn from the LCI results. ACLCA's Guidance to Calculating non-LCIA Inventory Metrics was followed in accordance with ISO 21930:2017 [1].

SimaPro v8.5 [10] was used to organize and accumulate the LCI data, and to calculate the LCIA results.

To consider the biogenic carbon dynamics that occur in landfills, UL Environment published an Appendix to the reference PCR that estimates the emissions from landfilling of wood products. The Landfill Modeling for Biogenic Carbon Appendix A is based on the United States EPA WARM model and aligns with the biogenic accounting rules in ISO 21930 Section 7.2.7 and Section 7.2.12.

The WARM model is documented by the EPA at https://www.epa.gov/warm/documentation-waste-reduction-model-warm. UL's wood product PCR adopted the WARM model estimations and published those assumptions under Appendix A of the PCR. These background accounting assumptions form the basis for landfill modeling that adjusts the carbon storage as a portion of the initial carbon while accounting for remaining carbon converted to landfill gas. It does not assign the percentage of the wood product sent to the landfill.

The U.S. Environmental Protection Agency has Materials Management Fact Sheet that assess trends in material recycling, composting, combustion with energy recovery and landfilling in the U.S. For durable wood products (such as construction materials) the 2017 estimates were 0% recycling, 0% composting, 18% combustion with energy recovery and 82% landfilling as a percentage of wood material generated by weight. This assessment can be adjusted for alternative end-of-life scenarios such as 100% landfill or 100% reuse.

The transparent presentation of LCA information allows the user to examine the relative difference between environmental impacts with and without biogenic carbon, with and without substitution effects, and with three different end-of-life scenarios. Table 8 provides a comprehensive list of the combinations of biogenic carbon, substitution effects and end-of-life scenarios for Global Warming Potential.

Detailed Biogenic Carbon Results

To ensure transparency, Table 2 shows 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, BCEK was reported in A5 and BCEP of the main product in C3/C4.

Table 2: Biogenic carbon inventory parameters

Additional Inventory Parameters		**A1 All Scenarios**	**A3 All Scenarios**	**C4 Landfill Scenario**	**C4 Incin. Scenario**	**C4 Reuse Scenario**	**D Incin. Scenario**
Biogenic Carbon Removal from Product	kg CO_2	-1767.33	-	-	-		
Biogenic Carbon Emission from Product	kg CO_2	-	784.35	124.80	777.59	777.59	-566.02
Biogenic Carbon Removal from Packaging	kg CO_2	-	-	-	-		
Biogenic Carbon Emission from Packaging	kg CO_2	-	-	-	-		
Biogenic Carbon Emission from Combustion of Waste from Ren. Sources Used in Production	kg CO_2	-	205.39	-	-		
Total Biogenic CO2 Removals & Emissions							
Net biogenic carbon emission landfill scenario	kg CO_2	-652.79					
Net biogenic carbon emission incineration scenario	kg CO_2	0.00					
Net biogenic carbon emission reuse scenario	kg CO_2	0.00					
Average end-of-life treatment	**kg CO_2**	**-533.98**					

RESULTS

Table 3 shows the results for the *cradle-to-gate* (A1-A3) VLT and LVL product system. The cradle-to-gate results align with the North American industry average EPD for LVL developed by the American Wood Council and Canadian Wood Council in 2020. The cradle-to-gate results are identical to the A1-A3 results that are presented in Section 4.3 as a part of the cradle-to-gate plus end-of-life system boundaries except for the accounting of biogenic carbon. In the cradle-to-gate results, the biogenic carbon stored in the primary product is conservatively accounted as an emission in module A3 as the end-of-life modules (C1-C4) are not considered.

Tables 4-7 present the LCIA and LCI parameter results for the functional unit of 1 m^3 of VLT and LVL over a service life of 75 years. The *cradle-to-grave* results includes the delivery of the product to the construction site, construction, use, and the end-of-life. Table 4 presents the weighted average results for the typical waste treatment in the United States for durable wood products, 82% landfill and 18% incineration [14]. As per the PCR and ISO 21930 Section 7.1.7, the results for each of the individual options are also separately reported. These options also include 100% landfilling (Table 5), 100% incineration (Table 6) and 100% reuse (Table 7).

Table 3: Results Summary for 1 m^3 of VLT and LVL – Cradle-to-Gate Scope

Core Mandatory Impact Indicator			**A1-A3**	**A1**	**A2**	**A3**
Global warming potential – TRACI 2.1	GWP_{TRACI}	kg CO_2e	**239.47**	136.70	6.79	95.98
Global warming potential – w/ biogenic CO_2	GWP_{BIO}	kg CO_2e	**239.47**	-1,630.63	6.79	1,863.31
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11e	**6.19E-06**	9.21E-08	2.79E-10	6.10E-06
Acidification potential of soil and water sources	AP	kg SO_2e	**2.13**	1.53	0.08	0.51
Eutrophication potential	EP	kg Ne	**0.63**	0.03	0.00	0.59
Formation potential of tropospheric ozone	SFP	kg O_3e	**23.13**	12.10	2.08	8.94
Abiotic depletion potential for fossil resources	ADPf	MJ, NCV	**4,836.90**	3,525.67	95.87	1,215.35
Fossil fuel depletion	FFD	MJ Surplus	**634.27**	496.70	14.01	123.56
Use of Primary Resources						
Renewable primary energy carrier used as energy	RPRE	MJ, NCV	**2,532.87**	0.61	0.00	2,532.26
Renewable primary energy carrier used as material	RPRM	MJ, NCV	**8,864.53**	8,864.53	0.00	0.00
Non-renewable primary energy carrier used as energy	NRPRE	MJ, NCV	**5,417.91**	3,799.85	101.58	1,516.48
Non-renewable primary energy carrier used as material	NRPRM	MJ, NCV	**0.00**	0.00	0.00	0.00
Secondary Material, Secondary Fuel						
Secondary material	SM	kg	**0.00**	0.00	0.00	0.00
Renewable secondary fuel	RSF	MJ, NCV	**0.00**	0.00	0.00	0.00
Non-renewable secondary fuel	NRSF	MJ, NCV	**0.00**	0.00	0.00	0.00
Recovered energy	RE	MJ, NCV	**0.00**	0.00	0.00	0.00
Mandatory Inventory Parameters						

Consumption of freshwater resources	FW	m^3	**0.58**	0.00	0.00	0.58
Indicators Describing Waste						
Hazardous waste disposed	HWD	kg	**0.00**	0.00	0.00	0.00
Non-hazardous waste disposed	NHWD	kg	**0.01**	0.00	0.00	0.01
High-level radioactive waste, conditioned, to final repository	HLRW	m^3	**1.01E-07**	1.40E-09	0.00E+00	9.93E-08
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m^3	**9.27E-07**	7.84E-09	0.00E+00	9.20E-07
Components for re-use	CRU	kg	**0.00**	0.00	0.00	0.00
Materials for recycling	MR	kg	**0.00**	0.00	0.00	0.00
Materials for energy recovery	MER	kg	**0.00**	0.00	0.00	0.00
Recovered energy exported from the	EE	MJ, NCV	**0.00**	0.00	0.00	0.00

Table 4: LCIA Results Summary for VLT and LVL – Average End-of-Life Treatment, 82% Landfill / 18% Combustion with Energy Recovery

Core Mandatory potential Impact Indicator	Indicator	Unit	Total A-C	Total w/D	A1	A2	A3	A4	A5	B	C1	C2	C4	D
Global warming potential – Total Fossil & Biogenic	GWPTOTAL	$kgCO_2e$	-229.73	-332.74	-1630.63	6.79	1,085.72	21.27	7.14	0.00	16.80	12.03	251.15	-103.02
Global warming potential – Fossil	GWPFOSSIL	$kgCO_2e$	304.25	201.24	136.70	6.79	95.98	21.27	7.14	0.00	16.80	12.03	7.54	-103.02
Global warming potential – Biogenic	GWPBIOGENIC	$kgCO_2e$	-533.98	-533.98	-1,767.33	0.00	989.74	0.00	0.00	0.00	0.00	0.00	243.61	0.00
Depletion potential of the stratospheric ozone layer	ODP	kgCFC11e	7.05E-06	2.53E-06	9.21E-08	2.79E-10	6.10E-06	8.98E-10	1.34E-07	0.00E+00	3.16E-07	6.02E-10	4.08E-07	-4.52E-06
Acidification potential of soil and water sources	AP	$kgSO_2e$	2.96	2.10	1.53	0.08	0.51	0.25	0.10	0.00	0.23	0.13	0.13	-0.87
Eutrophication potential	EP	kg Ne	0.68	0.66	0.03	0.00	0.59	0.01	0.01	0.00	0.01	0.01	0.01	-0.01
Formation potential of tropospheric ozone	SFP	$kgSO_3e$	46.14	43.80	12.10	2.08	8.94	6.28	3.09	0.00	7.27	3.17	3.20	-2.34
Abiotic depletion potential (ADPfossil)	ADPf	MJ, NCV	5,748.87	4,123.86	3,525.67	95.87	1,215.35	305.25	98.57	0.00	232.02	170.68	105.45	-1,625.02
Fossil fuel depletion	FFD	MJ Surplus	763.26	496.03	496.70	14.01	1.563	45.11	14.67	0.00	34.53	25.22	9.46	-267.23
Use of Primary Resources														
Renewable primary energy used as energy	RPRE	MJ, NCV	4,080.23	4,079.28	0.61	0.00	2,532.26	0.00	0.12	0.00	0.29	0.00	1,546.95	-0.95
Renewable primary energy used as material	RPRM	MJ, NCV	8,864.53	8,864.53	8,864.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-renewable primary energy used as energy	NRPRE	MJ, NCV	6,384.97	4,581.79	3,799.85	101.58	1,516.48	323.57	104.64	0.00	246.31	180.93	111.61	-1,803.19
Non-renewable primary energy used as material	NRPRM	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Secondary Material, Secondary Fuel and Secondary Recovered Energy														
Secondary material	SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewable secondary fuel	RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-renewable secondary fuel	NRSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy	RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mandatory Inventory Parameters														
Consumption of freshwater resources	FW	m^3	0.62	0.62	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Indicators Describing Waste														
Hazardous waste disposal	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous disposal	NHWD	kg	395.41	395.41	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	395.40	0.00
High-level radioactive waste	HLRW	m^3	1.02E-07	1.01E-07	1.40E-09	0.00E+00	9.93E-08	0.00E+00	4.35E-11	0.00E+00	1.02E-10	0.00E+00	8.87E-10	-1.15E-09
Intermediate and Low-level radioactive waste	ILLRW	m^3	9.98E-07	9.92E-07	7.84E-09	0.00E+00	9.20E-07	0.00E+00	2.08E-10	0.00E+00	4.90E-10	0.00E+00	6.96E-08	-5.52E-09
Components for re-use	CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for recycling	MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for energy recovery	MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy exported	EE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5: LCIA Results Summary for VLT and LVL – 100% Landfilling at End-of-Life

Core Mandatory potential Impact Indicator	Indicator	Unit	Total A-C	A1	A2	A3	A4	A5	B	C1	C2	C4
Global warming potential – Total Fossil & Biogenic	GWPTOTAL	kgCO$_2$e	-353.55	-1,630.63	6.79	1,08.72	21.27	7.14	0.00	16.80	12.03	127.32
Global warming potential – Fossil	GWPFOSSIL	kgCO$_2$e	299.24	136.70	6.79	95.98	21.27	7.14	0.00	16.80	12.03	2.52
Global warming potential – Biogenic	GWPBIOGENIC	kgCO$_2$e	-652.79	-1767.33	0.00	989.74	0.00	0.00	0.00	0.00	0.00	1.25E+02
Depletion potential of the stratospheric ozone layer	ODP	kgCFC11e	7.14E-06	9.21E-08	2.79E-10	6.10E-06	8.98E-10	1.34E-07	0.00E+00	3.16E-07	5.02E-10	4.98E-07
Acidification potential of soil and water sources	AP	kgSO$_2$e	2.85	1.53	0.08	0.51	0.25	0.10	0.00	0.23	0.13	0.02
Eutrophication potential	EP	kgSO$_3$e	0.67	0.03	0.00	0.59	0.01	0.01	0.00	0.01	0.01	0.00
Formation potential of tropospheric ozone	SFP	kgO$_3$e	43.57	12.10	2.08	8.94	6.28	3.09	0.00	7.27	3.17	0.63
Abiotic depletion potential (ADPfossil)	ADPf	MJ, NCV	5,676.48	3,525.67	95.87	1,215.35	305.25	98.57	0.00	232.02	170.68	33.06
Fossil fuel depletion	FFD	MJ Surplus	763.26	496.70	14.01	123.56	45.11	14.67	0.00	34.53	25.22	4.50
Use of Primary Resources												
Renewable primary energy used as energy	RPRE	MJ, NCV	2,534.07	0.61	0.00	2,532.26	0.00	0.12	0.00	0.29	0.00	0.79
Renewable primary energy used as material	RPRM	MJ, NCV	8,864.53	8,864.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-renewable primary energy used as energy	NRPRE	MJ, NCV	3,799.85	3,799.85	101.58	1,516.48	323.57	104.64	0.00	246.31	180.93	36.56
Non-renewable primary energy used as material	NRPRM	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Secondary Material, Secondary Fuel and Secondary Recovered Energy												
Secondary material	SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewable secondary fuel	RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-renewable secondary fuel	NRSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy	RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mandatory Inventory Parameters												
Consumption of freshwater resources	FW	m^3	0.58	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00
Indicators Describing Waste												
Hazardous waste disposal	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous disposal	NHWD	kg	483.38	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	483.37
High-level radioactive waste	HLRW	m^3	1.02E-07	1.40E-09	0.00E+00	9.93E-08	0.00E+00	4.33E-11	0.00E+00	1.02E-10	0.00E+00	1.08E-09
Intermediate and Low-level radioactive waste	ILLRW	m^3	9.98E-07	7.84E-09	0.00E+00	9.20E-07	0.00E+00	2.08E-10	0.00E+00	4.90E-10	0.00E+00	8.51E-08
Components for re-use	CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for recycling	MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for energy recovery	MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy exported	EE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6: LCIA Results Summary for VLT and LVL – 100% Incineration with Energy Recovery at End-of-Life

Core Mandatory potential Impact Indicator	Indicator	Unit	Total A-C	Total w/D	A1	A2	A3	A4	A5	B	C1	C2	C4	D
Global warming potential – Total Fossil & Biogenic	GWPTOTAL	$kgCO_2e$	326.81	-239.21	-1,630.63	6.79	1,085.72	21.27	7.14	0.00	16.80	12.03	807.68	-566.02
Global warming potential – Fossil	GWPFOSSIL	$kgCO_2e$	326.81	-239.21	136.70	6.79	95.89	21.27	7.14	0.00	16.80	12.03	30.09	-566.02
Global warming potential – Biogenic	GWPBIOGENIC	$kgCO_2e$	0.00	0.00	-1,767.33	0.00	989.74	0.00	0.00	0.00	0.00	0.00	777.59	0.00
Depletion potential of the stratospheric ozone layer	ODP	kgCFC11e	0.00	0.00	9.21E-08	2.79E-10	6.10E-06	8.98E-10	1.34E-07	0.00E+00	3.16E-07	5.02E-10	4.95E-10	0.00
Acidification potential of soil and water sources	AP	$kgSO_2e$	3.46	-1.30	1.53	0.08	0.51	0.25	0.10	0.00	0.23	0.13	0.63	-4.76
Eutrophication potential	EP	kg Ne	0.69	0.62	0.03	0.00	0.59	0.01	0.01	0.00	0.01	0.01	0.03	-0.08
Formation potential of tropospheric ozone	SFP	$kgSO_3e$	57.71	44.84	12.10	2.08	8.94	6.28	3.09	0.00	7.27	3.17	14.76	-12.86
Abiotic depletion potential (ADPfossil)	ADPf	MJ, NCV	6,074.26	-2,854.40	3,626.67	85.87	1,215.35	305.25	98.57	0.00	232.02	170.68	480.83	-8,928.66
Fossil fuel depletion	FFD	MJ Surplus	785.51	-682.79	496.70	14.01	123.56	45.11	14.67	0.00	34.53	25.22	31.71	-1,468.30
Use of Primary Resources														
Renewable primary energy used as energy	RPRE	MJ, NCV	11,029.48	11,024.25	0.61	0.00	2,532.26	0.00	0.12	0.00	0.29	0.00	8,496.19	-5.23
Renewable primary energy used as material	RPRM	MJ, NCV	8,864.53	8,864.53	8,864.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-renewable primary energy used as energy	NRPRE	MJ, NCV	6,722.31	-3,185.32	3,799.85	101.58	1,516.48	323.57	104.64	0.00	246.31	180.93	448.95	-9,907.63
Non-renewable primary energy used as material	NRPRM	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Secondary Material, Secondary Fuel and Secondary Recovered Energy														
Secondary material	SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewable secondary fuel	RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-renewable secondary fuel	NRSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy	RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mandatory Inventory Parameters														
Consumption of freshwater resources	FW	m^3	0.78	0.78	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.20	-0.01
Indicators Describing Waste														
Hazardous waste disposal	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous disposal	NHWD	kg	483.38	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	483.37
High-level radioactive waste	HLRW	m^3	1.01E-07	9.45E-08	1.40E-09	0.00E+00	9.93E-08	0.00E+00	4.33E-11	0.00E+00	1.02E-10	0.00E+00	0.00E+00	-6.30E-09
Intermediate and Low-level radioactive waste	ILLRW	m^3	9.28E-07	8.98E-07	7.84E-09	0.00E+00	9.20E-07	0.00E+00	2.08E-10	0.00E+00	4.90E-10	0.00E+00	0.00E+00	-3.03E-08
Components for re-use	CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for recycling	MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for energy recovery	MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy exported	EE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7: LCIA Results Summary for VLT and LVL – 100% Reuse at End-of-Life

Core Mandatory potential Impact Indicator	Indicator	Unit	Total A-C	Total w/D	A1	A2	A3	A4	A5	B	C1	C2	C4	D
Global warming potential – Total Fossil & Biogenic	GWPTOTAL	kgCO_2e	296.72	57.25	-1630.63	6.79	1,085.72	21.27	7.14	0.00	16.80	12.03	777.59	-239.47
Global warming potential – Fossil	GWPFOSSIL	kgCO_2e	296.72	57.25	136.70	6.79	95.98	21.27	7.14	0.00	16.80	12.03	0.00	-239.47
Global warming potential – Biogenic	GWPBIOGENIC	kgCO_2e	0.00	0.00	-1,767.33	0.00	989.74	0.00	0.00	0.00	0.00	0.00	243.61	0.00
Depletion potential of the stratospheric ozone layer	ODP	kgCFC11e	0.00	0.00	9.21E-08	2.79E-10	6.10E-06	8.98E-10	1.34E-07	0.00E+00	3.16E-07	5.02E-10	0.00	-6.19E-06
Acidification potential of soil and water sources	AP	kgSO_2e	2.83	0.70	1.53	0.08	0.51	0.25	0.10	0.00	0.23	0.13	0.00	-2.13
Eutrophication potential	EP	kg Ne	0.67	0.04	0.03	0.00	0.59	0.01	0.01	0.00	0.01	0.01	0.00	-0.63
Formation potential of tropospheric ozone	SFP	kgSO_3e	42.94	19.82	12.10	2.08	8.94	6.28	3.09	0.00	7.27	3.17	0.00	-23.13
Abiotic depletion potential (ADPfossil)	ADPf	MJ, NCV	5,643.42	806.53	3,525.67	95.87	1,215.35	305.25	98.57	0.00	232.02	170.68	0.00	-4836.90
Fossil fuel depletion	FFD	MJ Surplus	753.80	119.53	496.70	14.01	1.563	45.11	14.67	0.00	34.53	25.22	0.00	-534.27
Use of Primary Resources														
Renewable primary energy used as energy	RPRE	MJ, NCV	2,533.28	0.41	0.61	0.00	2,532.26	0.00	0.12	0.00	0.29	0.00	0.00	-2,532.87
Renewable primary energy used as material	RPRM	MJ, NCV	8,864.53	0.00	8,864.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-8,864.53
Non-renewable primary energy used as energy	NRPRE	MJ, NCV	6,273.36	855.45	3,799.85	101.58	1,516.48	323.57	104.64	0.00	246.31	180.93	0.00	-5,417.91
Non-renewable primary energy used as material	NRPRM	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Secondary Material, Secondary Fuel and Secondary Recovered Energy														
Secondary material	SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewable secondary fuel	RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-renewable secondary fuel	NRSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy	RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mandatory Inventory Parameters														
Consumption of freshwater resources	FW	m^3	0.58	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.04	-0.58
Indicators Describing Waste														
Hazardous waste disposal	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous disposal	NHWD	kg	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
High-level radioactive waste	HLRW	m^3	1.01E-07	1.45E-07	1.40E-09	0.00E+00	9.93E-08	0.00E+00	4.33E-11	0.00E+00	1.02E-10	0.00E+00	0.00E+00	-1.01E-07
Intermediate and Low-level radioactive waste	ILLRW	m^3	9.28E-07	6.99E-07	7.84E-09	0.00E+00	9.20E-07	0.00E+00	2.08E-10	0.00E+00	4.90E-10	0.00E+00	0.00E+00	-9.27E-07
Components for re-use	CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for recycling	MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Materials for energy recovery	MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recovered energy exported	EE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

INTERPRETATION

The primary sources of impacts across the life cycle are the manufacturing of the product itself (Modules A1-A3) and the net flows of biogenic carbon. Table 2 shows that the flows of biogenic carbon out of the system in Module A3 (combustion emissions and the export of coproducts to other product systems) and Module C4 (landfill gas and incineration emissions) are significantly less than the flows of biogenic carbon into the system in Module A1 (removal of biomass from a net neutral sustainable forest). The permanent biogenic carbon storage is so significant (534 kg CO2eq.) that this net benefit is larger than the total fossil emissions from all other modules and causes the total global warming potential to be negative. The total global warming potential of -258 kg CO2eq. means the product system removes more greenhouse gases from the atmosphere than are emitted in its production and disposal combined.

Table 8 provides a comparison of the global warming potential of the various results based on three variables: whether the biogenic carbon emissions are included, whether substitution effects (Module D) are included, and what assumptions are made as to the end-of-life treatment.

Global warming potential **Result 1** (239.47) in Table 8 references the *cradle-to-gate* GWP result shown in Table 3. The end-of-life modules (C1-C4), construction (A4, A5) and use (B1-B7) are outside the scope while the biogenic carbon is conservatively assumed to be completely emitted. Thus, in GWP **Result 1**, the results with and without biogenic carbon are identical.

This *cradle-to-gate* result serves as the baseline for the other *cradle-to-grave* scenarios that include end-of-life modules, which are presented in Tables 4 through 7. They include:

- Table 4 – Average end-of-life treatment assumed to be 82% landfill and 18% combustion with energy recovery
- Table 5 - End-of-life treatment assumed to be 100% landfill
- Table 6 - End-of-life treatment assumed to be 100% incineration with energy recovery
- Table 7 - End-of-life treatment assumed to be 100% reuse

The choice between use of Table 4, 5, 6 or 7 depends on the intended method of disposal or reuse. For this EPD, Table 4 is the most common representation of mass timber based on the average end-of-life treatment for wood products. Regardless of the *cradle-to-grave* table chosen, there is an additional GWP impact, relative to *cradle-to-gate* Table 1, caused by the combustion of fossil fuels in demolition, transportation to waste treatment, and landfill operations (where applicable).

Once the *cradle-to-grave* table is selected, then the next selection is whether to include biogenic carbon or substitution effects. Each table is broken down to disclose the combined impact of including or excluding biogenic carbon and/or substitution effects. Table 8 serves to tabulate the GWP impact for each assumption. For example, Table 4 – average end-of-life treatment assumed to be 82% landfill and 18% combustion with energy recovery, which is represented in Table 8 by **Result 2, 6 and 10**.

- **Result 2** (304.25) excludes the biogenic carbon impacts on GWP as well as the substitution effects. This result is closely related to the cradle-to-gate **Result 1** (239.47).
- **Result 6** (-229.73) includes the biogenic carbon impacts and excludes the substitution effects.
- **Result 10** (-332.74) includes both biogenic carbon impacts and the substitution effects of reusing the product at end of life as well as fossil fuel substitution caused by the recovery of energy for the portion of the material that is burned at end-of-life.

Summarizing the GWP impacts presented in Table 4, the cradle-to-gate 239.47 increases to 304.25 when end-of-life modules are added without biogenic carbon or substitution effects. When biogenic carbon is added, there is a dramatic drop in GWP to -229.73. When substitution effects are also added to biogenic carbon, the GWP impact drops further to -332.74.

Using the same methodology, there are other *cradle-to-grave* scenarios in Tables 5, 6 and 7 to consider for end-of-life treatments for mass timber. They are provided as a basis of comparison when considering different methods of disposal or reuse.

The lowest global warming potential is realized in Table 5 - end-of-life treatment assumed to be 100% landfill, which is represented in Table 8, Result 7 (-353.55) where biogenic carbon is added. There are no substitution effects with a landfill scenario. This scenario maximizes the permanent sequestration of carbon in the landfill which, strictly in terms of the global warming potential, is the most beneficial treatment for wood at end-of-life under the study's assumptions.

The highest global warming potential result is realized in Table 6 - end-of-life treatment assumed to be 100% incineration with energy recovery, which is represented in Table 8, **result 4 and 8** (326.81) that excludes the beneficial fossil fuel substitution effects. This scenario assumes the worst-case carbon storage and fossil fuel combustion. However, when the substitution effect is added, **result 11** (-239.21) shows a significant GWP reduction, meaning the potential energy recovery value of the product is greater than the fossil fuel combusted in the rest of the life cycle.

Clearly, the broad range of GWP impact between 326.81 and -353.55 illustrates the importance of making the correct assumptions in life-cycle analysis based upon the intended use. The user is responsible for determining the intended use of the product. Boise Cascade offers this information to help the user make an informed decision.

Table 8: End-of-Life Considerations: Impact on Global Warming Potential (GWP)

GWP Result #	Source of Result	Cradle-to-Gate; A1-A3 Impacts	A4, A5, B1-B7 Impacts	C1-C4 Impacts	Biogenic Carbon Impacts(1)	Substitution Module D Impacts(2)	End-of-Life Percent Assigned to Landfill	End-of-Life Percent Assigned to Combustion with Energy Recovery (Incineration)	End-of-Life Percent Assigned to Reuse	GWP (kg CO_2e)
1	Table 3(3)	Declared	Not Declared	Not Declared	Either Declared or Not(5) Declared	Not Declared	N/A	N/A	N/A	239.47
2	Table 4	Declared	Declared	Declared	Not Declared	Not Declared	82%	18%	N/A	304.25(4)
3	Table 5	Declared	Declared	Declared	Not Declared	Not Declared	100%	N/A	N/A	299.24
4	Table 6	Declared	Declared	Declared	Not Declared	Not Declared	N/A	100%	N/A	326.81
5	Table 7	Declared	Declared	Declared	Not Declared	Not Declared	N/A	N/A	100%	296.72
6	Table 4	Declared	Declared	Declared	Declared	Not Declared	82%	18%	N/A	-229.73(4)
7	Table 5	Declared	Declared	Declared	Declared	Not Declared	100%	N/A	N/A	-353.55
8	Table 6	Declared	Declared	Declared	Declared	Not Declared	N/A	100%	N/A	326.81
9	Table 7	Declared	Declared	Declared	Declared	Not Declared	N/A	N/A	100%	296.72
10	Table 4	Declared	Declared	Declared	Declared	Declared	82%	18%	N/A	-332.74
11	Table 6	Declared	Declared	Declared	Declared	Declared	N/A	100%	N/A	-239.21
12	Table 7	Declared	Declared	Declared	Declared	Declared	N/A	N/A	100%	57.25

1- Biogenic carbon emissions and removals are reported in accordance with ISO 21930 7.2.7 and 7.2.12.

2 - The substitution effects from energy and material recovery were estimated based on secondary data for biomass combustion relative to natural gas combustion, as well as primary data for virgin LVL/mass timber production.

3- Useful when comparing to other mass timber Cradle-to-Gate EPDs.

4- The Table 4 difference between -229.73 and 304.25 (with and without biogenic carbon) is -533.98 found in Table 2.

5- GWP remains the same whether or not biogenic carbon is declared.

LIMITATIONS

Comparability

Environmental declarations from different programs (ISO 14025) 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. In addition, to be compared EPDs must comply with the same core and sub-category PCRs (Part A and B) and include all relevant information modules. 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.

Forest Management

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.

Scope of the EPD

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.

Data

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 product line and reported impact when averaging data.

REFERENCES

1. American Center for Life Cycle Assessment (2019) ACLCA Guidance to Calculating Non-LCIA Inventory Metrics in Accordance with ISO 21930:2017

2. Athena Sustainable Materials Institute (2020) A Life Cycle Assessment of LVL and Mass Timber (VLT) Manufactured by Boise Cascade, v1.0,

3. Bare, J. (2012) Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) - Version 2.1.

4. International Organization for Standardization (2006) ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations – Principles and procedures

5. International Organization for Standardization (2006) International Standard ISO 14040:2006 - Life cycle assessment – Principles and framework

6. International Organization for Standardization (2006) International Standard ISO 14044:2006, Life cycle assessment Requirements and guidelines

7. International Organization for Standardization (2017) International Standard ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.

8. LTS (2019) DataSmart: http://ltsexperts.com/services/software/datasmart-life-cycle-inventory/

9. National Renewable Energy Laboratory (2019) U.S. Life Cycle Inventory Database http://www.nrel.gov/lci/

10. PRé Consultants BV (2018) SimaPro v8.5 LCA Software

11. UL Environment (2018) Product Category Rule (PCR) Guidance for Building-Related Products and Services, Part A Life Cycle Assessment Calculation Rules and Report Requirements V 3.2.

12. UL Environment (2020) Product Category Rule (PCR) Guidance for Building-Related Products and Services, Part B: Structural and Architectural Wood Products EPD Requirement.

13. U.S. Department of Transportation, Bureau of Transportation Statistics; and, U.S. Department of Commerce, U.S. Census Bureau. (2020). 2017 Commodity Flow Survey Final Tables. [CF1700A21].

14. U.S. Environmental Protection Agency (2019) Advancing Sustainable Materials Management: 2017 Fact Sheet (Table 4 values for Durable Goods).

15. Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016) The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, 21, 1218–1230.