COMPOSITE PANEL ASSOCIATION

Environmental Product Declaration

North American Medium Density Fiberboard

Composite Panel Association

ASTM INTERNATIONAL
Helping our world work better

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 Rules. Version: 8.0, Revised 04/29/20
DECLARATION OWNER	Composite Panel Association 19465 Deerfield Ave. Suite 303 Leesburg, Virginia 20176
DECLARATION NUMBER	EPD 639
DECLARED PRODUCT	North American Medium Density Fiberboard
DECLARED UNIT	1 m^3 of medium density fiberboard at facilities in North America and in use for 75 years
REFERENCE PCR AND VERSION NUMBER	ISO 21930:2017 Sustainability in Building and Civil Engineering works – Core Rules for environmental Product Declaration of Construction Products and Services. [10] 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 2018 [14] Part B: Structural and Architectural Wood Products EPD Requirements, v1.0 2020 [15]
DESCRIPTION OF PRODUCT'S INTENDED APPLICATION AND USE	Medium density fiberboard is wood composite panel used for making furniture, cabinets, flooring, door components, trim moulding, and millwork
MARKETS OF APPLICABILITY	Construction Sector, non-structural, laminators,
DATE OF ISSUE	April 2, 2024
PERIOD OF VALIDITY	5 years
EPD TYPE	Product-specific EPD
EPD SCOPE	Cradle to Grave
YEAR OF REPORTED MANUFACTURER PRIMARY DATA	2021
LCA SOFTWARE	SimaPro v9.5
LCI DATABASES	USLCI [12], Ecoinvent 3.9.1 [16], Datasmart [11]
LCIA METHODOLOGY	TRACI 2.1 v1.08 [3], CML-IA Baseline V3.08, CED, LHV 1.0

THE SUB-CATEGORY PCR REVIEW WAS CONDUCTED BY:	Dr. Thomas Gloria (chair) t.gloria@industrial-ecology.com
LCA AND EPD DEVELOPER This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by:	The Consortium for Research on Renewable Industrial Materials (CORRIM) PO Box 2432 Corvallis, OR 97330 541-231-2627 www.corrim.org CORRIM Consortium for Research on Renewable Industrial Materials

This declaration was independently verified in accordance with ISO 14025:2006.
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). Tim Brooke, ASTM International

☐ Internal ☒ External

INDEPENDENT VERIFIER This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Lindita Bushi, PhD, Athena Sustainable Materials Institute

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 for upstream or downstream of the life cycle stages declared.

DISCRIPTION OF INDUSTRY AND PRODUCT

DESCRIPTION OF NORTH AMERICAN MEDIUM DENSITY FIBERBOARD INDUSTRY

The North American composite panel industry is a major contributor to both the United States and Canada economies. Medium density fiberboard (MDF) is a composite panel that is valued for its consistency and ability to be engineered for specific applications. These properties have caused MDF to be widely used to manufacture door components, laminate flooring, cabinets, trim moulding, and furniture. MDF is also widely regarded as a sustainable material because it utilizes wood residues from other manufacturing processes that might otherwise be wasted. In 2021, total North American production capacity of MDF was over 5.00 million m^3, with 3.68 million m^3 from United States facilities and Canada producing an additional 1.32 million m^3.

The Composite Panel Association (CPA), Leesburg, Virginia, represents manufacturers of MDF in North America. Thirteen MDF facilities contributed production data from the United States and Canada (Table 1) for this EPD with a combined production capacity of 3.47 million m^3, or 69% of total industry production.

This EPD represents the cradle-to-grave energy and materials required for manufacturing MDF produced in the United States (U.S.) and Canada. MDF manufacturers represented in this EPD are in Arkansas, Montana, North Carolina, Oregon, Pennsylvania, of the U.S, and British Columbia, New Brunswick, Ontario, and Quebec in Canada. The 2021/2022 production data used in this EPD considers all MDF produced during these reporting years and is weighted based on material output.

TABLE 1 PARTICIPATING FACILITIES

Manufacturer	City, State/Province	Country
Arauco North America	St. Stephen, New Brunswick	Canada
Arauco North America	Sault Ste. Marie, Ontario	Canada
Arauco North America	Malvern, Arkansas	United States
Arauco North America	Moncure, North Carolina	United States
Georgia Pacific	Mt. Jewett, Pennsylvania	United States
Roseburg Forest Products	El Dorado, Arkansas	United States
Roseburg Forest Products	Pembroke, Ontario	Canada
Roseburg Forest Products	Medford, Oregon	United States
Uniboard Canada Inc	Mont-Laurier, Quebec	Canada
Unilin-US MDF	Mt Gilead, North Carolina	United States
West Fraser	Quesnel, British Columbia	Canada
West Fraser	Blue Ridge, Alberta	Canada
Weyerhaeuser	Columbia Fall, Montana	United States

MDF manufacturers, as members of CPA, can participate in the CPA 4-19 Eco-Certified Composite™ (ECC) Sustainability Standard. The (ECC) sustainability standard is a voluntary industry certification developed and administered by the CPA for manufacturers of composite wood or agrifiber-based panels, including particleboard, medium density fiberboard (MDF), hardboard, engineered wood siding, and engineered wood trim. ECC certified plants must comply with CARB and EPA formaldehyde emissions requirements for 100% of their panels 100% of the time, and meet at least three of the additional requirements below:

- **Carbon Footprint**
  Using CPA's proprietary Carbon Calculator, the plant must demonstrate that the panels they produce act as carbon sinks—that is, that they store enough carbon to offset their cradle-to-gate carbon footprint, as determined in kg-CO2 equivalents of greenhouse gas (GHG) emissions.

- **Use of Local and Renewable Resources**

At least 85 percent of the total wood fiber used annually must be sourced within 250 miles (402 km) of the manufacturing plant.

- **Made from Recycled/Recovered Materials**

Products must contain either:

1. A minimum of 75 percent recycled or recovered fiber; OR
2. At least 50 percent recycled or recovered fiber AND a minimum of 5 percent post-consumer fiber.

Percentages shall be calculated by weight, as measured in bone dry ton.

- **Sustainability**

The plant must have documentation to show that more than 97 percent of fiber furnish brought on-site is either converted into composite panels or other non-waste products.

- **Wood Sourcing**

The plant shall hold a valid certificate from a certifying agency recognized by CPA such as the Forest Stewardship Council® (FSC—Controlled Wood Standard or Chain of Custody Standard) or the Sustainable Forestry Initiative (SFI—Fiber Sourcing Standard).

DECRIPTION OF MEDIUM DENSITY FIBERBOARD PRODUCT

The product profile presented in this EPD is for a declared unit of 1 cubic meter(1 m^3) of MDF. MDF is manufactured from wood residues that are generated as a coproduct of lumber milling, and/or recovered fibers remaining after harvesting operations. One cubic meter of average North American MDF weighs 727.10 kg, excluding the variable moisture content (Table 2). MDF composition is presented in Table 2 and represents the weighted average of the various resin types that are used by different manufacturers.

TABLE 2 AVERAGE PRODUCT COMPOSITION FOR 1 M³ MEDIUM DENSITY FIBERBOARD

Average Product Composition	Unit	Weighted Avg.	Representation
Mass, oven dry	kg	727.10	
Thickness	mm	19.05	
Density, oven dry	kg/m3	727.10	
Moisture Content	%	5.40%	
Wood Component	kg	654.37	
Resin Component	kg	72.63	
Wood portion	kg	654.37	90.01%
Urea Formaldehyde resin*	kg	45.77	6.30%
Melamine urea formaldehyde (MUF) resin*	kg	12.63	1.74%
Polymeric methylene diphenyl di-isocyanate (pMDI) resin*	kg	4.60	0.63%
Urea	kg	5.04	0.69%
Catalyst	kg	0.02	0.00%
Wax	kg	4.17	0.57%
Polybor, zinc borate, fire retardant	kg	0.41	0.06%

**Average MDF product. See underlying LCA report for high and low*

This EPD is based on LCA studies that considered the entire range of MDF product sizes and functions. The results are presented for the metric unit of measure, 1 cubic meter, 19.05 mm basis, which is equal to 565 square feet (3/4" thickness).

MDF is categorized as an engineered wood product under United Nations Standard Products and Services Code (UNSPSC) and Construction Specification Institute (CSI) for interior carpentry, architectural woodwork, and millwork (Table 3).

TABLE 3 UNITED NATIONS STANDARD PRODUCTS AND SERVICES CODE (UNSPSC) AND CONSTRUCTION SPECIFICATION INSTITUTE (CSI) MASTERFORMAT CODE FOR MEDIUM DENSITY FIBERBOARD

CLASSIFICATION STANDARD	CATEGORY	PRODUCT CODE
UNSPSC	Engineered Wood Products	11122002
CSI/CSC	Finish Carpentry	06 20 00
	Millwork	06 22 00
	Interior Architectural Woodwork	06 40 23
	Architectural Woodwork Casework	06 41 00

Wood residues used in MDF production are comprised of a very wide variety of species common to the western, Midwest, and southern US regions and western, central, and eastern Canada. Hardwood and softwood species were reported representing but not limited to Douglas-fir, hemlock, spruces, balsam fir, northern and southern pines, and a large variety of mixed hardwoods from the north, south, and western US, and central and eastern Canada.

MEDIUM DENSITY FIBERBOARD PRODUCTION

The MDF manufacturing process is a highly automated, process-controlled, and linear production process. Wood residue is delivered to the mill by truck; the residue, referred to in the industry as furnish, consists of shavings, sawdust, panel trim, and chips of various moisture contents; the residue is stored under cover; the moisture content of the residue can range from 10 to 100% on an oven-dry weight-basis. Sometimes a hog is used to reduce residue size. Sorted residue enter a digester where they are "cooked" under pressure then refined to separate the wood fibers. The fibers are blended with resins and then dried prior to distributed into a mat prior to pressing. The final steps are sanding, trimming, and sawing pressed panels to size before packaging and shipping (Figure 1).

Panels are protected during shipping with a waterproof wrapping material made from 100% recycled materials. Other packaging materials include plastic strapping, cardboard shrouds and corner protectors, and wood stickers. Packaging materials represent less than 1 percent (0.89%) of the mass of the main product.

Wood residue for MDF production can come from lumber and plywood facilities. The wood residue are coproducts generated and represent a mix of green or dry chips, sawdust, shavings, or trim. Data for these residues was generated in previous published LCA reports (www.corrim.org).

Wood residue attributes vary across the major production centers of the U.S and Canada. Wood residues include softwoods from the Southeast, Pacific Northwest, Northeast regions, and Inland Northwest and in western, central, and eastern Canada. A small quantity of hardwoods from the Midwest and southeast U.S. and Canada. Green residues represent 67% with the majority being green chips and sawdust. Other residues representing whole logs (19%), green shavings (1%), dry shavings (12%), and recycled MDF at 2%.

MDF was reported for this EPD to have densities ranging from 640-916 kg/m^3, consistent with the material standards listed in the American National Standard ANSI A208.2-2022 (ANSI 2022). Weighted average product moisture content is 5.40 percent (oven dry basis) at a density of 727.01 kg/m^3.

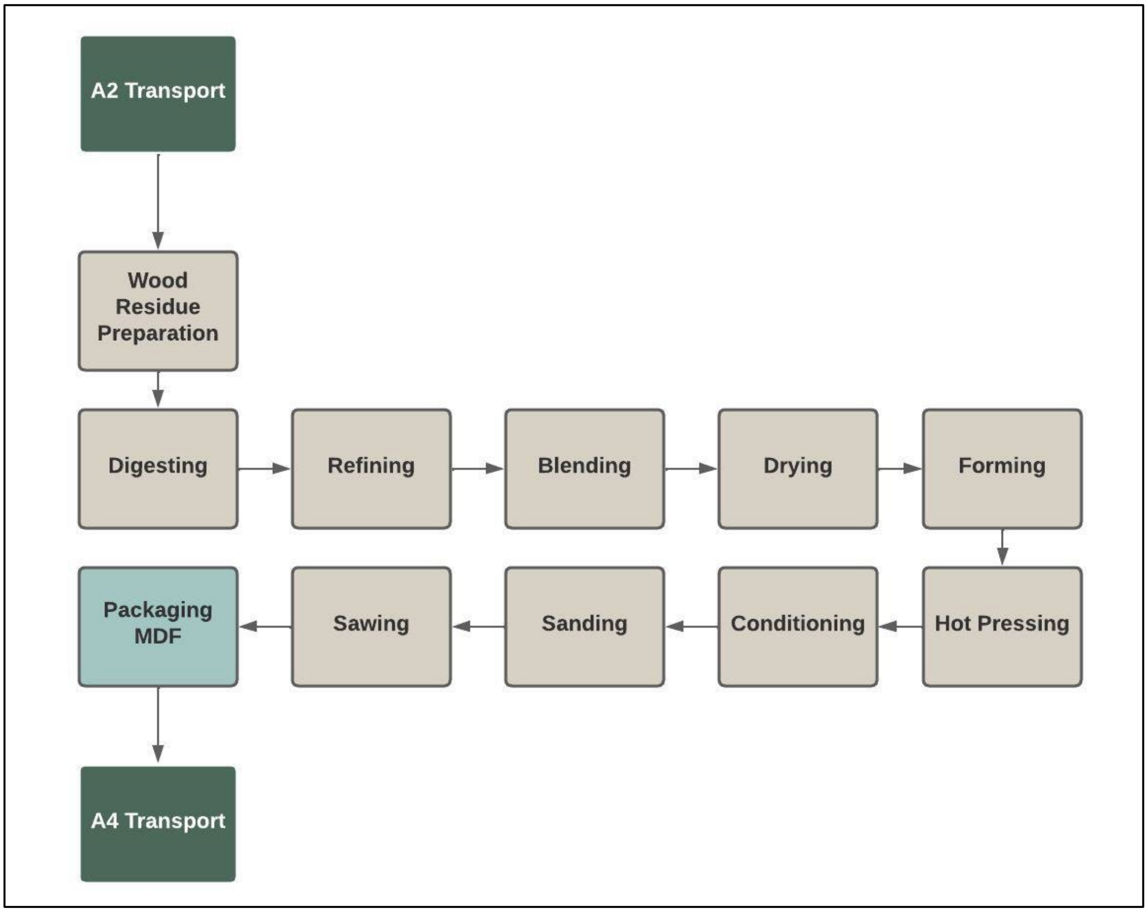

FIGURE 1 PROCESS FLOW FOR MEDIUM DENSITY FIBERBOARD MANUFACTURING

METHODOLOGICAL FRAMEWORK

TYPE OF EPD AND LIFE CYCLE STAGES

This EPD is intended to represent an industry wide life cycle assessment (LCA) for MDF. Thirteen CPA member facilities contributed production data, resource use, energy and fuel use, transportation distances, and onsite processing emissions. These data were weighted average based on production to produce the life cycle inventory data for the life cycle impact assessment (LCIA). The underlying LCA [4] investigates MDF production from cradle-to-grave. Information modules included in the LCA are shown in Table 4. This EPD includes mandatory modules A1-A3 for a cradle-to-gate analysis. Additional declared Modules include A4-Transportation to building site and A5 – Installation, Module B – Use, and End-of-Life (EoL) stages (C1 – C4) and additional benefits or reuse, energy recovery and recycling potential in Module D to complete a cradle-to-grave analysis (ISO 21090 5.2.2). Due to data gaps, the impact of deconstruction/demolition and waste processing (Module C1 and C3) are considered null for this LCA as well as Module B1 – B7 (Table 4).

TABLE 4 LIFE CYCLE STAGES & INFORMATION MODULES PER ISO 21930

	PRODUCTION STAGE			CONSTRUCTION STAGE		USE STAGE							END-OF-LIFE STAGE				OPTIONAL BENEFITS
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Extraction and up-stream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste	Disposal	Reuse, Recycle, & Recovery benefits
Module Included	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SYSTEM BOUNDARIES AND PRODUCT FLOW DIAGRAM

The product system described in Figure 2 includes the following information modules and unit processes:

A1 - RAW MATERIAL EXTRACTION	A1 includes the cradle-to-gate production of wood residues and resins for MDF. A1 would include all upstream processes for from resource extraction including removal of raw materials and processing.
A2 - RAW MATERIAL TRANSPORT	Average or specific transportation of raw materials (including secondary materials and fuels) from extraction site or source to manufacturing site (including any recovered materials from source to be recycled in the process).
A3 - MANUFACTURING	Manufacturing of MDF including energy consumption and fuel use, resource use, water use, emissions to air and water, waste disposal, and packaging. Packaging materials represent less than one percent (0.89%) of the mass of the main product. Common packaging materials are wrapping material, plastic strapping, steel strapping, wood stickers, corner protectors, and shrouds. The packaging is allocated 100 percent to MDF.
A4 - PRODUCT TRANSPORTATION	Average or specific transportation of product from manufacturing facility to construction site. This LCA product system includes actual product shipping distance to customers, secondary manufacturers retail, and distribution centers. Road and rail transportation modes were utilized.
A5 - CONSTRUCTION	The installation module covers installation of the construction product into any type of constructions and includes waste of construction product, waste from packaging material, energy for construction, and waste management at the site.
B1 – B7 - USE	Considered null for this EPD
C1- DEMOLITION	Considered null for this EPD
C2 - TRANSPORTATION TO EOL TREATMENT	Average or specific transportation of product from construction site to EoL processes.
C3 – WASTE	Considered null for this EPD
C4 - PROCESSING & DISPOSAL	Final deposition of wastes to be landfilled, incinerated, or reused/recycled.
D - BENEFITS BEYOND THE SYSTEM BOUNDARY	Optional information about the potential net benefits from reuse, recycling, and energy recovery.

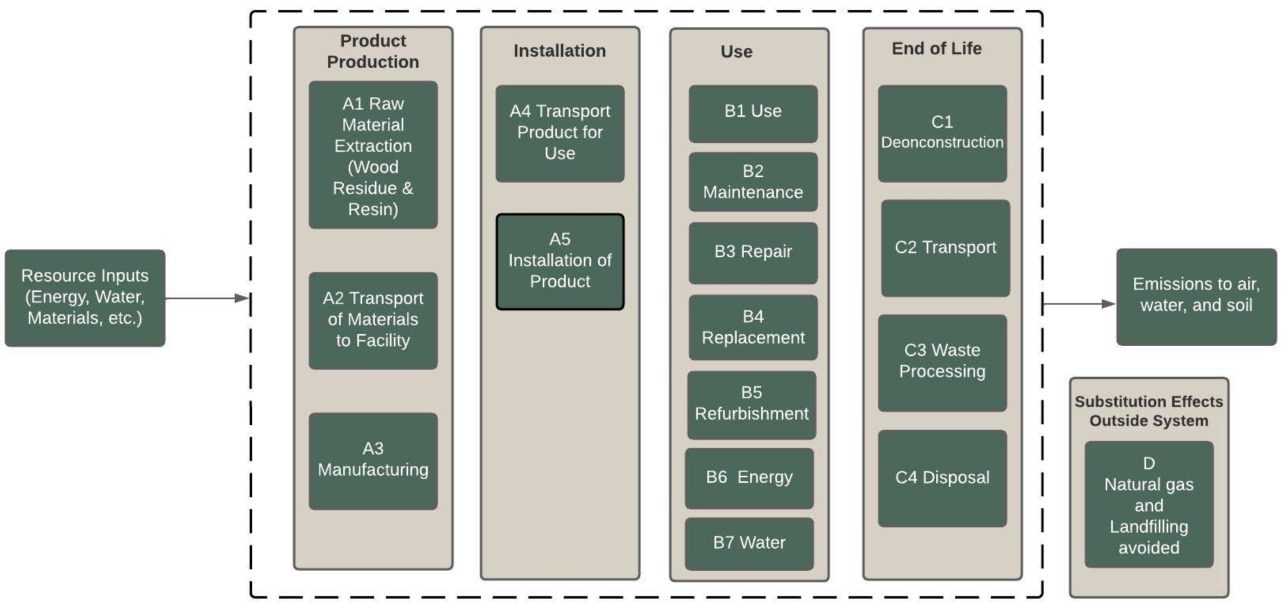

FIGURE 2 CRADLE TO GRAVE SYSTEM BOUNDARY FOR MEDIUM DENSITY FIBERBOARD PRODUCTION

DECLARED UNIT

Table 2 shows the declared unit and additional product information. In accordance with the PCR, the declared unit for MDF is one cubic meter (m^3), which represents the area of the panel multiplied by its thickness and installed in a building for 75 years [14]. This value is presented as 1.0 m^3, 19.05 mm basis.

ALLOCATION METHODS

Allocation is the method used to partition the environmental load of a process when several products or functions share the same process. Production of MDF produces no co-products that leave the system boundary, although some facilities reported production of other primary products that are sold; therefore, input materials, energy, and fuel use are allocated using a mass allocation. Allocation decisions are in accordance with UL PCR 2020 and ISO 21930:2017.

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 in accordance with UL PCR 2020.

Third party verified ISO [7,8,9] secondary LCI data sets contribute 78-100% of total impact to any of the required impact categories identified by the applicable PCR [14,15].

TREATMENT OF BIOGENIC CARBON

Biogenic carbon emissions and removals are reported in accordance with ISO 21930 7.2.7. and 7.2.12. Detailed information is provided in the underlying LCA in Section 3.3.

ISO 21930 requires a demonstration of forest sustainability to characterize carbon removals with a factor of -1 kg CO_2eq/kg CO_2. 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_2eq/kg CO_2.

ENVIRONMENTAL PARAMETERS DERIVED FROM LCA

The impact categories and characterization factors 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 v1.08 [3]. The total primary energy consumption is tabulated from the LCI results based on the Cumulative Energy Demand Method (CED, LHV, V1.0) published by ecoinvent [16]. 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. We followed the ACLCA's Guidance to Calculating non-LCIA Inventory Metrics in accordance with ISO 21930:2017 [1]. SimaPro 9.5 [13] was used to organize and accumulate the LCI data, and to calculate the LCIA results. The reporting of landfill emission factors used are 0.0035 metric tons of methane (CH_4) / metric ton of product and 0.2060 metric tons of carbon dioxide, CO_2 / metric ton of product.

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 is based on the United States EPA WARM model [5] 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. These background accounting assumptions (Appendix A of the PCR) [14] 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. In 2017, the average U.S. EoL treatments for durable wood products were estimated to be 0% recycling, 0% composting, 18% combustion with energy recovery and 82% landfilling as a percentage of wood material generated by weight. In this EPD it is reported as the "Average" EoL Scenario. Other scenarios adjusted the allocation for 100% landfill and 100% reuse.

BIOGENIC CARBON RESULTS

Table 5 shows additional inventory parameters related to biogenic carbon removal and emissions. The carbon dioxide flows are presented unallocated to consider any coproducts leaving the product system in information Module A3 (242 kg CO_2eq). The biogenic CO_2 component for MDF shows that the landfill scenario causes a net removal of biogenic carbon from the atmosphere equivalent to 846.68 kg CO_2eq. This is caused by the permanent storage of 84% of the biogenic carbon that enters the landfill; only 16% of the wood decomposes as estimated by the US EPA [5]. The net incineration and reuse are zero because of the assumption 100% of product is either completely combusted or reused. The net average uses the U.S. EPA Materials Management Fact Sheet for durable wood products assuming 0% recycling, 0% composting, 18% incineration, and 82% landfilling [6].

TABLE 5 BIOGENIC CARBON INVENTORY PARAMETERS FOR MEDIUM DENSITY FIBERBOARD

Additional Inventory Parameters		**A1 All Scenarios**	**A3 All Scenarios**	**C4 Landfill Scenario**	**C4 Incineration Scenario**	**C4 Reuse Scenario**	**C4 AVG**
Biogenic Carbon Removal from Product	kg CO_2	-1,447.69	-	-	-		
Biogenic Carbon Emission from Product	kg CO_2	-	51.00	353.01	1,199.69	1,199.69	507.10
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	-	197.00	-	-		
Total Biogenic CO_2 Removals & Emissions							
Net biogenic carbon emission landfill scenario	kg CO_2	-846.68					
Net biogenic carbon emission incineration scenario	kg CO_2	0.00					
Net biogenic carbon emission recycling scenario	kg CO_2	0.00					
Average end-of-life treatment	**kg CO_2**	**-692.59**					

LCIA RESULTS

A1 – A3 -PRODUCT MANUFACTURING

Table 6 presents the cradle-to-gate (A1-A3) LCIA and LCI parameter results for the functional unit of 1 m^3 of MDF. No permanent carbon storage is included in the cradle-to-gate (A1-A3) results. As a result, the biogenic carbon balance for the cradle-to-gate portion of the life cycle is net neutral. Cradle-to-gate results for MDF on a relative basis are presented in Figure 4.

TABLE 6 LCIA RESULTS SUMMARY FOR 1 M3 OF MEDIUM DENSITY FIBERBOARD – CRADLE-TO-GATE SCOPE

Core Mandatory Impact Indicator	Indicator	Unit	A1-A3	A1	A2	A3
Global warming potential – Total	GWP_{TOTAL}	kg CO_2eq	469.36	-1,290.94	15.78	1,744.51
Global warming potential - Biogenic	$GWP_{BIOGENIC}$	kg CO_2eq	0.00	-1,447.69	0.00	1,447.69
Global warming potential - Fossil	GWP_{FOSSIL}	kg CO_2eq	469.36	156.76	15.78	296.82
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11eq	2.03E-05	0.00	0.00	0.00
Acidification potential of soil and water sources	AP	kg SO_2eq	3.69	0.85	0.10	2.75
Eutrophication potential	EP	kg Neq	0.61	0.19	0.01	0.41
Formation potential of tropospheric ozone	SFP	kg O_3eq	62.13	16.76	2.76	42.61
Abiotic depletion potential (ADP_{FOSSIL}) for fossil resources	ADPf	MJ, NCV	7,593.05	3,264.61	197.76	4,130.68
Fossil fuel depletion	FFD	MJ Surplus	962.06	499.39	29.71	432.96
Use of Primary Resources						
Renewable primary energy used as energy	RPRE	MJ, NCV	3,485.60	512.00	0.43	2,973.18
Renewable primary energy used as material	RPRM	MJ, NCV	16,188.71	16,188.71	0.00	0.00
Non-renewable primary energy used as energy	NRPRE	MJ, NCV	8,472.96	3,436.59	200.61	4,835.76
Non-renewable primary energy used as material	NRPRM	MJ, NCV	2,577.90	2,577.90	0.00	0.00
Secondary Material, Secondary Fuel and Recovered Energy						
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	m3	2.67	0.72	0.00	1.95
Indicators Describing Waste						
Hazardous waste disposed	HWD	kg	0.00	6.05E-04	0.00	1.42E-03
Non-hazardous waste disposed	NHWD	kg	48.55	0.00E+00	0.00	4.85E+01
High-level radioactive waste, conditioned, to final repository	HLRW	m3	2.52E-06	1.10E-07	1.47E-09	2.40E-06
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m3	4.37E-06	1.13E-06	2.62E-08	3.22E-06
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	EE	MJ, NCV	0.00	0.00	0.00	0.00

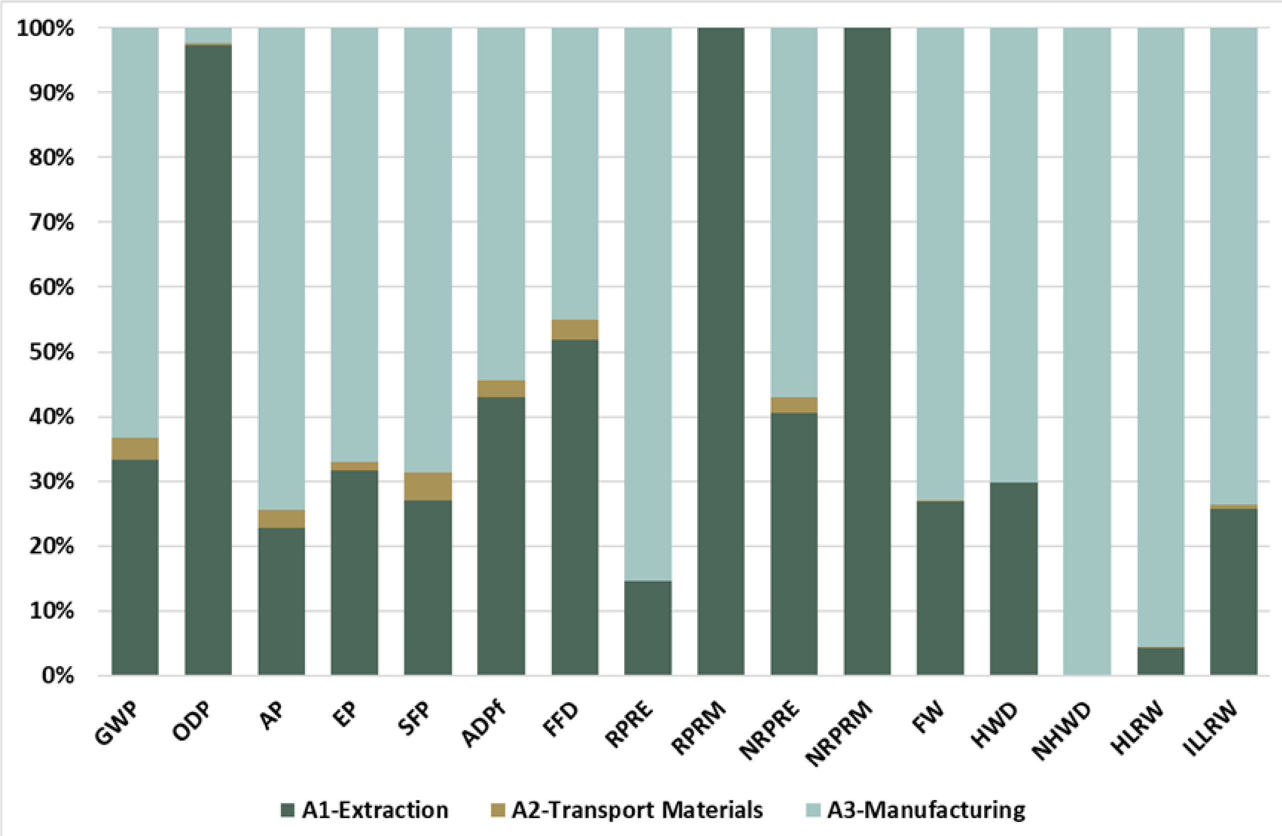

FIGURE 3 CRADLE-TO-GATE LCIA RESULTS FOR THE PRODUCTION MEDIUM DENSITY FIBERBOARD–RELATIVE BASIS

GWP	Global warming potential
ODP	Depletion potential of the stratospheric ozone layer
AP	Acidification potential of soil and water sources
EP	Eutrophication potential
SFP	Formation potential of tropospheric ozone
ADPf	Abiotic depletion potential (ADP fossil) for fossil resource
FFD	Fossil fuel depletion
RPRM	Renewable primary energy carrier used as energy
RPRM	Renewable primary energy carrier used as material
NRPE	Non-renewable primary energy carrier used as energy
NRPRM	Renewable primary energy carrier used as material
FW	Consumption of freshwater resources
HWD	Hazardous waste disposed
NHWD	Non-hazardous waste disposed
HLRW	High-level radioactive waste, conditioned, to final repository
ILLRW	Intermediate- and low-level radioactive waste, conditioned, to final repository

A4 -PRODUCT TRANSPORTATION

The A4 module includes transportation of the final product to customers or distribution center/resale center). MDF was transported mostly by road (61%) and 39 percent by rail. MDF is shipped throughout the United States and Canada to secondary manufactures, e.g., laminators)(3%), retail (6%), distribution centers (30%), or direct to customers (61%) (CPA 2021). Product shipping distances were distributed over a weighted average of 1,044 km by road and 1,874 km by rail.

A5 – INSTALLATION

The installation module A5 covers installation of the construction product into any type of constructions and includes waste of construction product, waste from packaging material, energy for construction, and waste management at the site. For this LCA, Module A5 was calculated using the ACLA ISO 21930 Guidance by calculating 5% of the A1-A4 burden and adding the waste disposal from packaging. The reference service life (RSL) for the product is 75 years which is the default specified by the UL Part B PCR (UL 2020). Total non-renewable energy use for A5 is conservatively estimated at 456 MJ/m³ of MDF.

B1-B7 – USE

The use phase of a product includes seven information modules, B1 - B7. This product does not require any inputs including energy and water during the use phases (B1-B7) and is declared null.

C2 TO C4 – END OF LIFE

This product system includes the end-of-life (EoL) modules C1-C4. For the purpose of this LCA, C1 and C3 are null. For EoL processing, we applied the weighted average of the typical waste treatment in the United States for durable wood products: 82% landfill and 18% incineration (EPA 2019). As per the PCR, the results for each of the individual options are also separately reported, as required by ISO 21930 Section 7.1.7. Table 7 lists the assumptions for C1-C4 and the net values.

TABLE 7 MEDIUM DENSITY FIBERBOARD END OF LIFE (C1-C4) ASSUMPTIONS FOR SCENARIO DEVELOPMENT (DESCRIPTION OF DECONSTRUCTION, COLLECTION, RECOVERY, DISPOSAL METHOD, AND TRANSPORTATION)

C1-C4 Description of Processes	Description	Value	Unit
Collection Process	Collected separately	NA	Dry kg
Collection Process	Collected with mixed construction waste	654.37	Dry kg
Recovery	Reuse	-	Dry kg
Recovery	Recycling	-	Dry kg
Recovery	Landfill	535.28	Dry kg
Recovery	Incineration		Dry kg
Recovery	Incineration with energy recovery/	119.10	Dry kg
Recovery	Product or material for final deposition	535.28	Dry kg
Removal of biogenic carbon (excluding packaging)		(692.59)	kg CO_2eq

Note: C1 - Building demolition is considered null

[1]/ Waste was collected as construction waste using dump truck to the disposal site with 81% of the total product mass was landfilled

[3]/Remaining 19% of the product mass was incinerated with energy recovery

D – SUBSTITUTION EFFECTS OUTSIDE SYSTEM

Per ISO 21930 Section 7.1.7.6, the net output flow for all products for reuse, secondary materials, secondary fuels and/or recovered energy leaving a product system is calculated by adding all output flows of the secondary material or fuel or recovered energy and subtracting any input flows of this secondary material or fuel or recovered energy from each information module (A1 to A5, B1 to B7, C1 to C4) thus arriving at the net output flow of secondary material or fuel or re-covered energy from the product system. Table 8 lists the assumptions for module D substitution benefits and the net values.

Incineration with energy recovery causes the potential displacement of fossil fuels with an equivalent heat content. To estimate the natural gas displacement, we first calculated the potential fuel heating value of MDF on a lower heating value (LHV) of 20.9 MJ/kg (oven dry) and 35.7 MJ/kg for resin, which equates to 16,254 MJ/m^3. The energy equivalent amount of natural gas was calculated based on a lower heating value of 36.6 MJ/m^3.

Wood Panel energy content = (20.9MJ/kg x 654.37 kg/m^3) + (35.7 MJ/kg x 72.21 kg/m^3) = 16,254 MJ/m^3

Substitution with Natural gas = $\frac{16{,}254\ MJ/m3}{36.6\frac{MJ}{m3}} = 444.11\ m3/m3$

Displacing 444.11 cubic meters of natural gas for every cubic meter of MDF combusted for energy.

TABLE 8 USE, RECOVERY AND/OR RECYCLING POTENTIALS (D), RELEVANT SCENARIO INFORMATION

C1-C4 DESCRIPTION OF PROCESSES	VALUE	UNIT
Net energy benefit from energy recovery from waste treatment declared as exported energy in C3 (R>0.6)	NA	MJ
Net energy benefit from thermal energy due to treatment of waste declared as exported energy in C4 (R <0.6)	13,816.2	MJ
Net energy benefit from material flow declared in C3 for energy recovery	NA	MJ
Process and conversion efficiencies (thermal efficiency)	85.0	%
Further assumptions for scenario development (e.g., further processing technologies, assumptions on correction factors)	NA	

Tables 5 and 6 show the mandatory cradle-to-gate results (A1-A3) for 1 cubic meter MDF. Tables 9 to 12 present the cradle-to-grave results includes the delivery of the product to the construction site (A4), construction (A5), the use phase (B1-B7) and the EoL (C1-C4). Table 9 presents the weighted average results for the average waste treatment in the United States for durable wood products, 82% landfill and 18% incineration [5]. As per the PCR and ISO 21930 Section 7.1.7, the results for each of the individual options are also separately reported and include 100% landfilling (Table 10), 100% incineration (Table 11) and 100% reuse (Table 12).

TABLE 9 LCIA RESULTS SUMMARY FOR 1 M3 OF MEDIUM DENSITY FIBERBOARD – AVERAGE END-OF-LIFE, TREATMENT, 82% LANDFILL/18% COMBUSTION WITH ENERGY RECOVERY – CRADLE-TO-GRAVE SCOPE

Core Mandatory Impact Indicator	**Indicator**	**Unit**	**A1-C4**	**A1-A3**	**A4**	**A5**	**B1-B7**	**C1**	**C2**	**C3**	**C4**	**D**
Global warming potential – Total	GWP_{TOTAL}	kg CO_2eq	-123.28	-730.33	51.23	26.03	0.00	0.00	8.55	0.00	521.23	-196.32
Global warming potential - Biogenic	$GWP_{BIOGENIC}$	kg CO_2eq	-692.59	-1,199.69	0.00	0.00	0.00	0.00	0.00	0.00	507.10	0.00
Global warming potential - Fossil	GWP_{FOSSIL}	kg CO_2eq	569.31	469.36	51.23	26.03	0.00	0.00	8.55	0.00	14.13	-196.32
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11eq	2.22E-05	2.03E-05	8.55E-08	1.02E-06	0.00	0.00	3.61E-10	0.00	8.65E-07	-4.44E-12
Acidification potential of soil and water sources	AP	kg SO_2eq	4.72	3.69	0.52	0.21	0.00	0.00	0.10	0.00	0.20	-0.05
Eutrophication potential	EP	kg Neq	0.70	0.61	0.04	0.03	0.00	0.00	0.01	0.00	0.02	0.00
Formation potential of tropospheric ozone	SFP	kg O_3eq	89.54	62.13	16.35	3.92	0.00	0.00	2.53	0.00	4.61	-0.12
Abiotic depletion potential (ADP_{FOSSIL}) for fossil resources	ADPf	MJ, NCV	11,312.40	7,593.05	641.75	411.74	1.00	0.00	62.06	1.00	194.92	-2,857.72
Fossil fuel depletion	FFD	MJ Surplus	1,527.73	962.06	96.39	52.92	2.00	0.00	9.32	2.00	27.24	-474.20
Use of Primary Resources												
Renewable primary energy used as energy	RPRE	MJ, NCV	6,048.86	3,485.60	1.39	174.35	0.00	0.00	0.00	0.00	2,387.53	0.00
Renewable primary energy used as material	RPRM	MJ, NCV	16,188.71	16,188.71	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	9,902.44	8,472.96	651.08	456.20	0.00	0.00	130.10	0.00	192.10	-97.56
Non-renewable primary energy used as material	NRPRM	MJ, NCV	2,706.79	2,577.90	0.00	128.89	0.00	0.00	0.00	0.00	0.00	0.00
Secondary Material, Secondary Fuel and 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	m3	3.51	2.67	0.72	0.00	0.00	0.00	0.00	0.00	0.12	0.00
Indicators Describing Waste												
Hazardous waste disposed	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous waste disposed	NHWD	kg	5.84E+02	4.85E+01	0.00	0.00	1.00	0.00	0.00	1.00	5.35E+02	0.00E+00
High-level radioactive waste, conditioned, to final repository	HLRW	m3	8.18E-01	2.52E-06	1.10E-07	1.47E-09	1.00E+00	0.00	0.00	8.18E-01	1.00E-09	0.00E+00
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m3	1.64E+00	4.37E-06	1.13E-06	2.62E-08	2.00E+00	0.00E+00	0.00E+00	1.64E+00	1.46E-07	0.00E+00
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 10 LCIA RESULTS SUMMARY FOR 1 M³ OF MEDIUM DENSITY FIBERBOARD – 100% LANDFILLING AT END-OF-LIFE – CRADLE-TO-GRAVE SCOPE

Core Mandatory Impact Indicator	Indicator	Unit	A1-C4	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	D
Global warming potential – Total	GWP_{TOTAL}	kg CO_2eq	-284.56	-730.33	51.23	26.03	0.00	0.00	8.55	0.00	359.95	0.00
Global warming potential - Biogenic	$GWP_{BIOGENIC}$	kg CO_2eq	-846.68	-1,199.69	0.00	0.00	0.00	0.00	0.00	0.00	353.01	0.00
Global warming potential - Fossil	GWP_{FOSSIL}	kg CO_2eq	562.12	469.36	51.23	26.03	0.00	0.00	8.55	0.00	6.94	0.00
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11eq	2.24E-05	2.03E-05	8.55E-08	1.02E-06	0.00	0.00	3.61E-10	0.00	1.06E-06	0.00E+00
Acidification potential of soil and water sources	AP	kg SO_2eq	4.54	3.69	0.52	0.21	0.00	0.00	0.10	0.00	0.02	0.00
Eutrophication potential	EP	kg Neq	0.69	0.61	0.04	0.03	0.00	0.00	0.01	0.00	0.01	0.00
Formation potential of tropospheric ozone	SFP	kg O_3eq	85.50	62.13	16.35	3.92	0.00	0.00	2.53	0.00	0.57	0.00
Abiotic depletion potential (ADP_{FOSSIL}) for fossil resources	ADPf	MJ, NCV	11,355.77	7,593.05	3,264.61	197.76	0.00	0.00	62.06	0.00	238.29	0.00
Fossil fuel depletion	FFD	MJ Surplus	1,533.79	962.06	499.39	29.71	0.00	0.00	9.32	0.00	33.31	0.00
Use of Primary Resources												
Renewable primary energy used as energy	RPRE	MJ, NCV	3,663.59	3,485.60	1.39	174.35	0.00	0.00	0.00	0.00	2.26	0.00
Renewable primary energy used as material	RPRM	MJ, NCV	16,188.71	16,188.71	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	9,791.07	8,472.96	651.08	456.20	0.00	0.00	130.10	0.00	80.73	0.00
Non-renewable primary energy used as material	NRPRM	MJ, NCV	2,706.79	2,577.90	0.00	128.89	0.00	0.00	0.00	0.00	0.00	0.00
Secondary Material, Secondary Fuel and 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	m3	3.47	2.67	0.72	0.00	0.00	0.00	0.00	0.00	0.08	0.00
Indicators Describing Waste												
Hazardous waste disposed	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous waste disposed	NHWD	kg	702.92	48.55	0.00	0.00	0.00	0.00	0.00	0.00	654.37	0.00
High-level radioactive waste, conditioned, to final repository	HLRW	m3	1.00E+00	2.52E-06	1.10E-07	1.47E-09	0.00	0.00	0.00	1.00	1.23E-09	0.00
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m3	2.00E+00	4.37E-06	1.13E-06	2.62E-08	0.00	0.00	0.00	2.00	1.78E-07	0.00
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 11 LCIA RESULTS SUMMARY FOR 1 M3 OF MEDIUM DENSITY FIBERBOARD – 100% INCINERATION WITH ENERGY RECOVERY AT END-OF-LIFE – CRADLE-TO-GRAVE

Core Mandatory Impact Indicator	**Indicator**	**Unit**	**A1-C4**	**A1-A3**	**A4**	**A5**	**B1-B7**	**C1**	**C2**	**C3**	**C4**	**D**
Global warming potential – Total	GWP_{TOTAL}	kg CO_2eq	601.60	-730.33	51.23	26.03	0.00	0.00	8.55	0.00	1,246.11	-1,078.65
Global warming potential - Biogenic	$GWP_{BIOGENIC}$	kg CO_2eq	0.00	-1,199.69	0.00	0.00	0.00	0.00	0.00	0.00	1,199.69	0.00
Global warming potential - Fossil	GWP_{FOSSIL}	kg CO_2eq	601.60	469.36	51.23	26.03	0.00	0.00	8.55	0.00	46.43	-1,078.65
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11eq	2.14E-05	2.03E-05	8.55E-08	1.02E-06	0.00	0.00	3.61E-10	0.00	7.64E-10	-2.44E-11
Acidification potential of soil and water sources	AP	kg SO_2eq	5.49	3.69	0.52	0.21	0.00	0.00	0.10	0.00	0.97	-0.26
Eutrophication potential	EP	kg Neq	0.72	0.61	0.04	0.03	0.00	0.00	0.01	0.00	0.04	0.00
Formation potential of tropospheric ozone	SFP	kg O_3eq	107.71	62.13	16.35	3.92	0.00	0.00	2.53	0.00	22.78	-0.65
Abiotic depletion potential (ADP_{FOSSIL}) for fossil resources	ADPf	MJ, NCV	11,117.49	7,593.05	3,,264.61	197.76	0.00	0.00	62.06	0.00	0.00	-15701.75
Fossil fuel depletion	FFD	MJ Surplus	1,500.48	962.06	499.39	29.71	0.00	0.00	9.32	0.00	0.00	-2,605.52
Use of Primary Resources												
Renewable primary energy used as energy	RPRE	MJ, NCV	16,769.48	3,485.60	1.39	174.35	0.00	0.00	0.00	0.00	13,108.15	0.00
Renewable primary energy used as material	RPRM	MJ, NCV	16,188.71	16,188.71	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	10,403.00	8,472.96	651.08	456.20	0.00	0.00	130.10	0.00	692.65	-536.02
Non-renewable primary energy used as material	NRPRM	MJ, NCV	2,706.79	2,577.90	0.00	128.89	0.00	0.00	0.00	0.00	0.00	0.00
Secondary Material, Secondary Fuel and 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	m3	3.70	2.67	0.72	0.00	0.00	0.00	0.00	0.00	0.31	0.00
Indicators Describing Waste												
Hazardous waste disposed	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous waste disposed	NHWD	kg	48.55	48.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
High-level radioactive waste, conditioned, to final repository	HLRW	m3	2.63E-06	2.52E-06	1.10E-07	1.47E-09	0.00	0.00	0.00	0.00	0.00	0.00
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m3	5.52E-06	4.37E-06	1.13E-06	2.62E-08	0.00	0.00	0.00	0.00	0.00	0.00
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 12 LCIA RESULTS SUMMARY FOR 1 M3 OF MEDIUM DENSITY FIBERBOARD – 100% REUSE AT END-OF-LIFE – CRADLE-TO-GRAVE

Core Mandatory Impact Indicator	Indicator	Unit	A1-C4	A1-A3	A4	A5	B1-B7	C1	C2	C3	C4	D
Global warming potential – Total	GWP_{TOTAL}	kg CO_2eq	555.17	-730.33	51.23	26.03	0.00	0.00	8.55	0.00	1,199.69	-469.36
Global warming potential - Biogenic	$GWP_{BIOGENIC}$	kg CO_2eq	0.00	-1,199.69	0.00	0.00	0.00	0.00	0.00	0.00	1,199.69	0.00
Global warming potential - Fossil	GWP_{FOSSIL}	kg CO_2eq	555.18	469.36	51.23	26.03	0.00	0.00	8.55	0.00	0.00	-469.36
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11eq	2.14E-05	2.03E-05	0.00	0.00	0.00	0.00	3.61E-10	0.00	0.00	-2.03E-05
Acidification potential of soil and water sources	AP	kg SO_2eq	4.52	3.69	0.52	0.21	0.00	0.00	0.10	0.00	0.00	-3.69
Eutrophication potential	EP	kg Neq	0.68	0.61	0.04	0.03	0.00	0.00	0.01	0.00	0.00	-0.61
Formation potential of tropospheric ozone	SFP	kg O_3eq	84.93	62.13	16.35	3.92	0.00	0.00	2.53	0.00	0.00	-62.13
Abiotic depletion potential (ADP_{FOSSIL}) for fossil resources	ADPf	MJ, NCV	11,117.49	7,593.05	3,264.61	197.76	0.00	0.00	62.06	0.00	0.00	-7,593.05
Fossil fuel depletion	FFD	MJ Surplus	1,500.48	962.06	499.39	29.71	0.00	0.00	9.32	0.00	0.00	-962.06
Use of Primary Resources												
Renewable primary energy used as energy	RPRE	MJ, NCV	3,661.33	3,485.60	1.39	174.35	0.00	0.00	0.00	0.00	0.00	-3,661.33
Renewable primary energy used as material	RPRM	MJ, NCV	16,188.71	16,188.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-16,188.71
Non-renewable primary energy used as energy	NRPRE	MJ, NCV	9,710.35	8,472.96	651.08	456.20	0.00	0.00	130.10	0.00	0.00	-9,580.25
Non-renewable primary energy used as material	NRPRM	MJ, NCV	2,706.79	2,577.90	0.00	128.89	0.00	0.00	0.00	0.00	0.00	-2,706.79
Secondary Material, Secondary Fuel and 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	m3	3.39	2.67	0.72	0.00	0.00	0.00	0.00	0.00	0.00	-2.67
Indicators Describing Waste												
Hazardous waste disposed	HWD	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-hazardous waste disposed	NHWD	kg	48.55	48.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-51.31
High-level radioactive waste, conditioned, to final repository	HLRW	m3	2.63E-06	2.52E-06	1.10E-07	1.47E-09	0.00	0.00	0.00	0.00	0.00	-2.64E-06
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m3	5.52E-06	4.37E-06	1.13E-06	2.62E-08	0.00	0.00	0.00	0.00	0.00	-4.71E-06
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

INTERPRETATION

The primary sources of impacts across the life cycle are the manufacturing of MDF (Modules A1-A3) and the net flows of biogenic carbon. Table 5 shows the flows of biogenic carbon out of the system in Module A3 from the combustion of biomass and the export of coproducts out of the system boundary. In 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 (847 kg CO_2eq.) (Table 5) 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 (GWP_{TOTAL}) of -123.28 kg CO_2eq. (Table 9 (A1-C4)) means the product system removes more greenhouse gases from the atmosphere than are emitted in its production and disposal combined.

BIOGENIC CARBON NOT DECLARED (A1-C4):

Table 9 - Cradle-to-grave GWP_{FOSSIL} = 569.31, average EoL treatment assuming 82% landfill and 18% incineration with energy recovery

Table 10 - Cradle-to-grave GWP_{FOSSIL} = 562.12, EoL treatment assumed to be 100% landfill

Table 11 - Cradle-to-grave GWP_{FOSSIL} = 601.60, EoL treatment assumed to be 100% incineration with energy recovery

Table 12 - Cradle-to-grave GWP_{FOSSIL} = 555.18, EoL treatment assumed to be 100% reuse

BIOGENIC CARBON DECLARED (A1-C4):

Table 9 – Cradle-to-grave GWP_{TOTAL} = -123.28 average EoL treatment assuming 82% landfill and 18% incineration with energy recovery

Table 10 - Cradle-to-grave GWP_{TOTAL} = -284.56 EoL treatment assumed to be 100% landfill

Table 11 - Cradle-to-grave GWP_{TOTAL} = 601.60, EoL treatment assumed to be 100% incineration with energy recovery

Table 12 - Cradle-to-grave GWP_{TOTAL} = 555.18 EoL treatment assumed to be 100% reuse

Summarizing the GWP_{FOSSIL} from Table 9, the most common representation of EoL treatment for wood products, the cradle-to-gate 469.36 kg CO_2eq/m^3 increases to 569.31 kg CO_2eq/m^3 when EoL modules are added without biogenic carbon or substitution effects. When biogenic carbon is added, there is a dramatic drop in GWP_{TOTAL} to -123.28 kg CO_2eq/m^3. This further drops to -196 kg CO_2eq/m^3 when substitution effects are included.

The lowest GWP_{TOTAL} occurs in the EoL 100% landfill treatment where the result is -284.56 kg CO_2eq/m^3 when biogenic carbon is added (A1-C4, Table 10). This scenario maximizes the permanent carbon storage in the landfill which, ***strictly in terms of the GWP only***, is the most beneficial treatment for wood at EoL.

The highest GWP_{TOTAL} (601 kg CO_2eq/m^3) is in the 100% incineration EoL treatment which excludes the substitution benefits of fossil fuel (A1-C4, Table 11). This scenario assumes the worst-case carbon storage and fossil fuel combustion. When the substitution effects are added, there is a significant reduction in the GWP (-1,078 kg CO_2eq/m^3) meaning that the potential energy value of the product is greater than fossil fuels combusted from cradle-to-grave.

In this cradle-to-grave EPD there is a wide range of GWP_{TOTAL} results 601.60 to -123.28 kg CO_2eq/m^3 illustrating the importance of making correct assumptions for the LCA and the intended use. CPA offers this information in this EPD to help users make informed decisions. The user is responsible for determining the intended use of the product.

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. 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 different results for upstream or downstream of the life cycle stages declared.

This LCA was created using manufacturer average data for upstream materials. Variation can result from differences in supplier locations, manufacturing processes, manufacturing efficiency and fuel type used. This LCA does not report all of the environmental impacts due to manufacturing of the product, but rather reports the environmental impacts for those categories with established LCA-based methods to track and report. Unreported environmental impacts include (but are not limited to) factors attributable to human health, land use change, and habitat destruction. In order to assess the local impacts of product manufacturing, additional analysis is required.

Although this LCA is cradle-to-grave in scope, it assumes the use and maintenance stages of the products are null (B1-B7). The RSL refers to the declared technical and functional performance of the product within a construction works. RSL is indicated by the manufacturer. RSL is dependent on the properties of the product and reference in-use conditions [14]. This LCA acknowledges the limitation making the use phase null as one could conclude that a shorter lifespan is just as good as a life span of 75 plus years. The functional unit declared in this LCA assumes the default RSL of 75 years [14].

ADDITIONAL ENVIRONMENTAL INFORMATION

Pressing and drying processes contribute the most emissions in wood production facilities. These are caused by the thermal energy production and by the use of emission control devices. All facilities reported the use of ECDs throughout their facility. Types of ECDs include electrostatic precipitators (ESP), wet electrostatic precipitators (WESP), regenerative thermal oxidizers (RTO), regenerative catalytic oxidizers (RCO), cyclones, and baghouses. Most ECDs use electricity or natural gas. Hence, the additional energy requirement for ECDs can potentially result in an overall increase of other greenhouse gases such as CO_2, SO_2, NOx, and CH_4. The pMDI emission from using pMDI resin is listed on the US Environmental Agency (EPA) Toxics Release Inventory.

For CPA member facilities producing MDF, 81.9% of producers in North America reported having their panel products “Certified for Formaldehyde Emissions,” 18.1% were ”Exempt” (NAF or ULEF) and none were classified as “Not certified for Formaldehyde Emissions.”

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. Bare, J. 2012. Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) - Version 2.1.
3. Puettmann, M.E. 2024. Cradle to Grave Life Cycle Assessment of Medium Density Fiberboard. March 2024. 57 pp.
4. Composite Panel Association (CPA). 2021. Shipments and Downstream Market Report. 30pp.
5. EPA. 2021. 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 Addendum 1 as a part of the PCR. (Accessed November 2023).
6. EPA 2019. Advancing sustainable materials management: 2017 Fact Sheet. https://www.epa.gov/sites/default/files/2019-11/documents/2017_facts_and_figures_fact_sheet_final.pdf. (Table 4 values for Durable Goods). 22 pp. (Accessed November 2023).
7. International Organization for Standardization. 2006. ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations – Principles and procedures.
8. International Organization for Standardization ISO. 2006b. Environmental management—Life-cycle assessment—Principles and framework. ISO 14040. International Organization for Standardization, Geneva, Switzerland. 14040:2006/Amd1:2020. 20 pp/8 pp.
9. International Organization for Standardization ISO. 2006a. Environmental management—Life-cycle assessment—Requirements and guidelines. ISO 14044:2006/Amd1:2017/Amd:2:2020. International Organization for Standardization, Geneva, Switzerland. 46 pp/8 pp/12 pp/.
10. 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.
11. LTS. 2021. DataSmart: http://ltsexperts.com/services/software/datasmart-life-cycle-inventory/. (Accessed November 2023).
12. National Renewable Energy Laboratory. 2023. U.S. Life Cycle Inventory Database http://www.nrel.gov/lci/. (Accessed November 2023).
13. PRé Consultants BV. 2022. SimaPro v9.5 LCA Software.
14. UL Environment. 2018. Product Category Rule (PCR) Guidance for Building-Related Products and Services, Part A Life Cycle Assessment Calculation Rules and Report Requirements, UL 10010, v.3.2.
15. UL Environment. 2020. Product Category Rule (PCR) Guidance for Building-Related Products and Services, Part B: Structural and Architectural Wood Products EPD Requirements, UL 10010-9 v.1.0.
16. 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.