CORRIM Report

Life Cycle Assessment of Engineered Wood I-Joist Production – United States

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Abbreviations

AP	Acidification Potential of Soil and Water Sources
CED	Cumulative Energy Demand
CFCs	Chlorofluorocarbons
CFC-11	Trichlorofluoromethane
EP	Eutrophication Potential
EPD	Environmental Product Declaration
Ft	Linear foot
FW	Consumption of Freshwater Resources
GWP	Global Warming Potential
GWP_{FOSSIL}	Global Warming Potential as an output from the TRACI impact methods. Does not include carbon dioxide released from biogenic sources
$GWP_{BIOGENIC}$	Global Warming Potential released from the combustion of biogenic materials (e.g., wood)
HLRW	High-level Radioactive Waste, Conditioned, to Final Repository
HWD	Hazardous waste Disposed
ILLRW	Intermediate- and Low-Level Radioactive Waste, Conditioned, to Final Repository
ISO	International Organization for Standardization
kg	Kilogram
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LHV	Low heat value (Net Caloric Value)
M	Linear meter
m^3	Cubic Meters
MC	Moisture Content
MJ	Megajoule
MBF	Thousand board foot
MSF	Thousand square foot
NCV	Net Caloric Value
NHWD	Non-Hazardous Waste Disposed
NRPRE	Non-Renewable Primary Energy Carrier Used as Energy
NRPRM	Non-Renewable Primary Energy Carrier Used as Material
O_3	Ozone
ODP	Depletion potential of the stratospheric ozone layer
OD	Oven-dry
PCR	Product Category Rules
RPRE	Renewable Primary Energy Carrier Used as Energy
RPRM	Renewable Primary Energy Carrier Used as Material
SFP	Formation Potential of Tropospheric Ozone
tkm	Metric-Tonne – Kilometers
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts

Glossary of Terms

Allocation – Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems (14040:2006/Amd1:2020)

Biogenic Carbon – Carbon derived from biomass ($CO_{2BIOGENIC}$) (ISO 21930:2017)

By-product – Any of two or more products coming from the same unit process or product system (ISO 14040:2006/Amd1:2020)

CO_2 eq/Carbon dioxide equivalent/CO_2 equivalent – Unit for comparing the radiative forcing of a greenhouse gas to that of carbon dioxide (ISO 14067)

Cradle-to-gate – Covers the mandatory production stage that includes the following information modules: extraction and upstream production (raw material supply), transport to factory and manufacturing (ISO 21930:2017)

Declared Unit – Quantity of a construction product for use as a reference unit in an EPD based on LCA, for the expression of environmental information needed in information modules. When the precise function of the product or scenarios at the construction works level is not stated, or is unknown, a declared unit may be used instead of the functional unit (ISO 21930:2017)

Embodied Carbon – Carbon emissions associated with materials and construction process throughout the whole life cycle of a building or infrastructure (World Green Building Council)

Life cycle assessment (LCA) – Compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle (14040:2006/Amd1:2020)

Life cycle inventory (LCI) – Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle (14040:2006/Amd1:2020)

Life cycle impact assessment (LCIA) – Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product (14040:2006/Amd1:2020)

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

System boundary – A set of criteria that specifies which unit processes are part of a product system (ISO 14044/Amd1:2017/Amd2:2020)

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Photo credit: Puettmann

1 Background

Producing all materials, renewable and non-renewable, has environmental impacts. Over the years, assessment of environmental burdens has evolved from not just considering site-specific impacts but to now including impacts of specific products' processes and use. The increased need for product-specific environmental information has progressed the use of environmental product declarations (EPDs) as one tool for product selection.

Historically, a preferred environmental building product was one that was made from renewable or recycled resources. Today, building materials are held to a higher standard of transparency that goes beyond their natural attributes. Builders, designers, politicians, and the public are asking for the full suite of a material's environmental impacts to meet "green building" standards as well as state and national emission reduction benchmarks, just to name a few. Building materials that have low embodied carbon and energy are sought out, and other functional aspects such as structural performance, ease of installation, and product durability are also desired. Users of building materials are increasingly relying on science-based quantitative life cycle assessment (LCA) studies and EPDs that offer assurance that the material has the environmental attributes they seek.

LCAs will become increasingly important as they are used by all industries to inform product and process design, as well as build system development, as they seek to minimize energy consumption and carbon release. Going forward, the need for credible, scientific, LCA-based information will be greater than ever.

This report describes the cradle-to-gate energy and materials required for producing engineered wood I-joist produced in the Pacific coast and Southern regions of the United States (U.S.) (Figure 1) and the subsequent releases into the environment. Facilities included in this LCA are members of the American Wood Council (AWC), Softwood Lumber Board (SLB), and/or APA – The Engineered Wood Association and voluntarily participated in AWC's online LCA survey, which collected primary data on each participating facility's material use and energy consumption for the 2023 calendar year. Inputs included softwood lumber, laminated veneer lumber (LVL), oriented strand board (OSB), adhesive, fuels, energy, ancillary materials, and packaging materials used for producing I-joist.

Data collection followed ISO 14040/10444 standards (ISO 2006a-c), ISO 21930 (ISO 2017), and the Product Category Rules (PCR) for North American Structural and Architectural Wood Products, Part B (UL 2020) and Part A: Life Cycle Assessment Calculations Rules and Report Requirements (UL 2018).

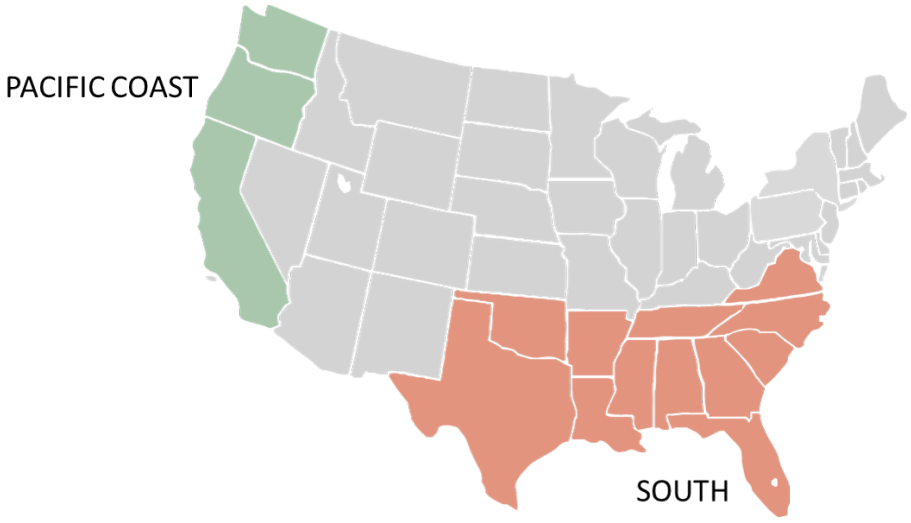


Figure 1. Geographical Regions of Wood I-Joist Production.

2 Life Cycle Assessment

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

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

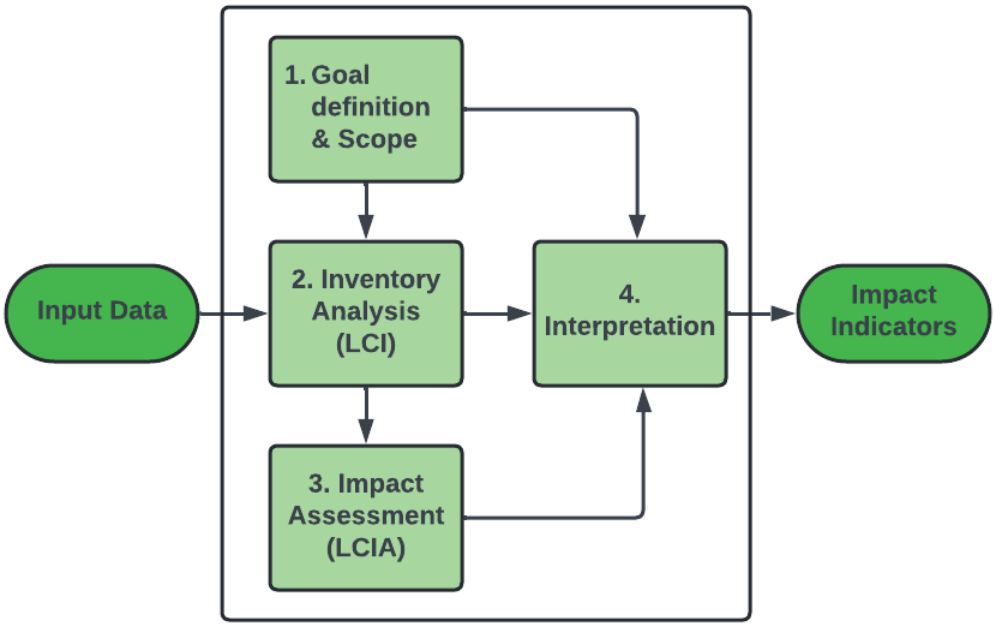


Figure 2. Steps Involved in a Life Cycle Assessment.

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

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

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

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

3 Goal and Scope

It is the goal and scope that provides the plan for conducting the LCI including data collection, compilation, and interpretation. The EPD developed from this LCA study is intended for use in Business to Business (B-to-B) communications.

3.1 Goals and Objectives

3.1.1 Goals

The primary goal is to generate a cradle-to-gate LCA of I-joist. The LCA will follow data and reporting requirements which provide guidance for preparation of a B-to-B EPD.

3.1.2 Intended Audience and Uses

The primary audience for the results of this LCA report is AWC/APA members and the participating facilities. The intended audience for the subsequent EPD includes AWC, APA, architectural and engineering professionals, government organizations, academia, policy makers, or other interested parties.

3.1.3 Comparative Assertions

The report does not include product use and end of life phases which are required for comparative assertions relative to substitute products. If comparative studies are intended and disclosed to the public, reporting will be consistent with the 14044:2006/Amd1:2017/Amd2:2020: guidelines and principles and ISO 21930:2017 core rules for EPDs (ISO 2006a-c, ISO 2017) and will follow the PCR for Building Products (Part A) and the PCR for Structural Wood Products (Part B) (UL 2018 and 2020). No comparative assertions are made in this LCA.

3.2 Scope of Considered System

This LCA follows the attributional approach as outlined in ISO 21930 Section 7.1.1.

3.2.1 System Boundary

Information modules included in the LCA are shown in Table 1. This LCA includes mandatory modules A1-A3 for a cradle-to-gate analysis. The cradle-to-gate system boundary is shown in Figure 3. The system boundary begins with regeneration of the forest and ends with I-joist product packaged at the plant gate. The system boundary includes forest operations (A_1), which may include growing seedlings in a nursery, planting the seedlings, managing the forest (which may include pre-commercial and commercial thinning), fertilization, and final harvesting, with the logs brought to a landing and loaded on the truck ready for transportation to the manufacturing facility; softwood lumber, LVL, and OSB production and adhesive production (A_1); transportation of all resources and materials (A_2); and I-joist production (A_3) (Figure 3).

Both human activity and capital equipment were excluded from the system boundary. The environmental effects of manufacturing and installing capital equipment and buildings have generally been shown to be minor relative to the throughput of materials and components over the useful lives of the buildings and equipment. Human activity involved in the manufacturing of I-joist products no doubt has a burden on the environment. However, the data collection required to properly quantify human involvement is particularly complicated, and allocating such flows to the production of materials as opposed to other societal activities was not feasible for a

study of this nature. Typically, human activity is only considered within the system boundary of an LCA when value-added judgements or substituting capital for labour decisions are within the study scope. These types of decisions are outside the current goal and scope of this study.

Table 1. Description of System Boundary Modules.

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
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

MND – Module Not Declared

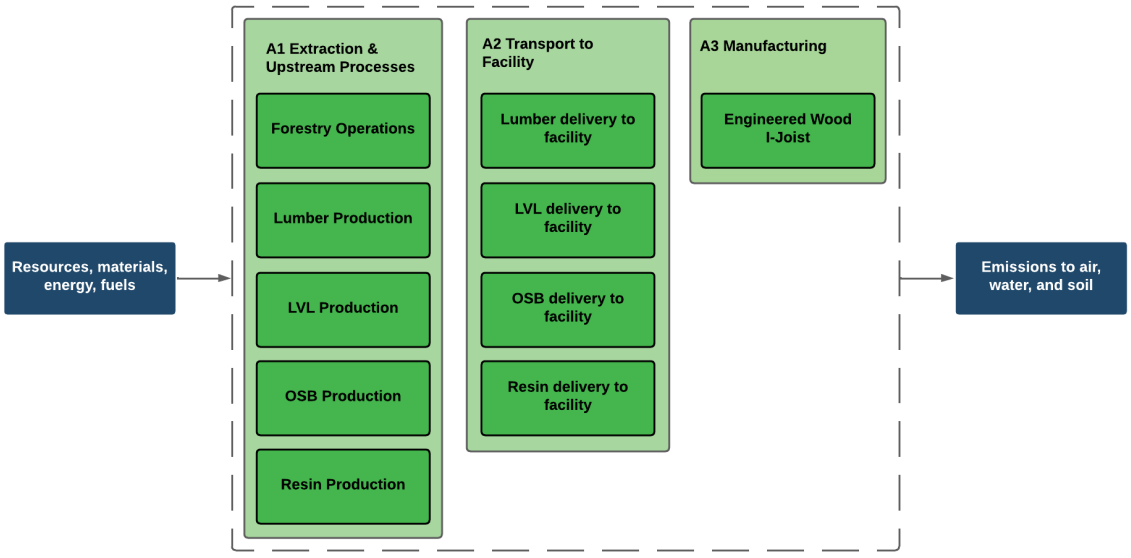


Figure 3. Cradle-to-Gate (A1-A3) System Boundary for Wood I-Joist Production.

3.2.2 Cut off Rules

The cut-off criteria for all activity stage flows considered within the system boundary conform with ISO 21930: 2017 Section 7.1.8. Specifically:

- 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 a) renewable and non-renewable primary energy consumption and b) the total mass of inputs within a unit process. The sum of the total neglected flows does not exceed 5 percent 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.

3.2.3 Data Collection

Primary data from each facility was collected via an online LCA survey portal developed and managed by AWC. These data were used to develop the LCI in accordance ISO 14044/Amd1:2017/Amd2:2020 standards. This study relied almost exclusively on 2023 production and emissions data provided by each facility, with upstream secondary data on fuels and electrical grid inputs from the US database (Datasmart 2023) and European datasets (Ecoinvent 3.8) (LTS 2023, Wernet et al. 2016). Eight facilities from the Pacific coast and Southern regions U.S. participated in the survey (Figure 1).

3.2.4 Calculation Rules

Wood I-joists were reported on a linear foot (ft) and converted to a linear meter (m). One ft of I-joist equals 0.305 m. All flow analyses of the product and by-products in the process were determined on an oven-dry weight basis. An overall wood mass balance was determined for material input to material output (Table 2).

The reported survey data was converted to a production basis: per m of I-joist. The values reported by each mill were combined into a production-weighted average for each input (see text box below). Thus, the value from a large mill had more weight. This approach resulted in an I-joist complex that represents a composite of the mills surveyed and maintains confidentiality. SimaPro, version 9.6 (Pré Consultants 2023) was used as an accounting program to track material flows.

Table 2. Mass Balance of Wood Inputs and Product and By-products Outputs in the Wood I-Joist Manufacturing Process per Linear Meter, Unallocated.

A3 Production	Value	Unit/meter	Allocation
Inputs			
Oriented strand board	1.6845	kg	43.91%
Laminated veneer lumber	2.1421	kg	55.84%
Lumber	0.0097	kg	0.25%
Total	3.8363	kg	100%
Outputs			
I-Joists	3.7793	kg	98.51%
By-products, used onsite	0.0570	kg	1.49%
Total	3.8363	kg	100%

Averaging weighting factors for each I-Joist facility are calculated respectively as follows:

Example y_1, 8 facilities are represented

$$w_1 = y_1 / (y_1 + y_2 + y_3 \ldots y_8) = y_1 / Y_{total}$$

$$w_1 (\%) = (y_1 / Y_{total}) * 100$$

where:

Y_{total} **Total I-Joist production of all 8 facilities (m basis)**
y_1 **I-Joist production of facility 1 (m basis)**
y_2 **I-Joist production of facility 2 (m basis)**
y_3 **I-Joist production of facility 3 (m basis)**
$\ldots y_8$ **I-Joist production of facility 8 (m basis)**

Missing data is defined as data not reported in surveys. Whenever missing data occurred for survey items, they were checked with plant personnel to determine whether it was an unknown value or zero. Missing data were carefully noted so they were not averaged as zeros.

3.2.5 Functional and Declared Unit

In accordance with the PCR, the declared unit for I-joist is 1.0 m of product packaged for shipment. A declared unit is used in instances where the function and the reference scenario for the whole life cycle of a wood building cannot be stated (UL 2018). The inventory input data is presented as unallocated flows, with all input and output flows allocated to the main product. This analysis does not take the declared unit to the use stage; therefore, no service life is assigned.

3.2.6 Allocation Rules

Allocation is the method used to partition the environmental load of a process when several products or functions share the same process. The input material for producing I-joist can be lumber, LVL, and OSB. Following the PCR, Parts A and B, allocation is based on physical properties (e.g., mass or volume) (Table 2). For this study, a mass allocation was used for the primary product and subsequent by-products. A small amount of by-products generated were used internally for on-site energy generation. Packaging inputs are not related to the by-products and are allocated 100 percent to the final product.

3.2.7 Impact Categories / Impact Assessment

The life cycle impact assessment (LCIA) phase establishes links between the LCI results and potential environmental impacts. The LCIA calculates impact indicators (Table 3), such as global warming potential and smog. ***These impact indicators provide general, but quantifiable, indications of potential environmental impacts.*** The target impact indicator, the impact category, and means of characterizing the impacts are summarized in Table 2. **Note:** *Six impact indicators listed in Table 3, global warming potential, ozone depletion potential, acidification potential, eutrophication potential, smog formation potential, and abiotic resource depletion potential of non-renewable (fossil) energy resources, are globally deemed mature enough to be included in a Type III environmental declaration. Other categories are being developed and defined and LCA should continue making advances in their development. However, with the results from this LCA as they appear in the subsequent EPDs, users shall not use additional measures for comparative purposes.*

US Environmental Protection Agency's (EPA) TRACI 2.1 v1.08 (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts) (Bare 2012) environmental impacts are determined using several methods obtained with the SimaPro software package and include the North American TRACI method (Bare 2012). Additional impact indicators were generated using the European CML Baseline, and Cumulative Energy Demand (CED, LHV, v.1.0) as well as several indicators calculated from the LCI results. This LCIA does not make value judgments about the impact indicators, meaning a comparison of indicator values is not valid. Additionally, each impact indicator value is stated in units that are not comparable to others. For the same reasons, indicators should not be combined or added. Additionally, the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.

Cumulative Energy Demand is based on fuels' lower heating values (LHV). Cumulative Energy Demand is calculated from data published by Ecoinvent and expanded by PRé for energy resources available in the SimaPro database. Characterization factors are given for six impact categories: 1. Non-renewable, fossil, 2. Non-renewable, nuclear, 3. Non-renewable, biomass, 4. Renewable, biomass, 5. Renewable, wind, solar, geothermal, and 6. Renewable, water. The primary fuels are categorized into non-renewable (fossil and nuclear) and renewable (biomass, geothermal, solar, wind, and hydro). Table 3 summarizes the source and scope of each impact category reported in this report, as required to be in conformance with the PCR (UL 2018, 2020) and ISO 21930.

Table 3. Selected Impact Category Indicators and Inventory Parameters.

Impact Indicators per ISO 21930	Abbreviation	Units	Method
Core Mandatory Impact Indicator			
Global warming potential, Total	GWP_{TOTAL}	kg CO_2 eq	$GWP_{BIOGENIC}$ + GWP_{FOSSIL}
Global warming potential, Biogenic	$GWP_{BIOGENIC}$	kg CO_2 eq	TRACI 2.1 V1.08+ LCI Indicatory
Global warming potential, Fossil	GWP_{FOSSIL}	kg CO_2 eq	TRACI 2.1 V1.08
Depletion potential of the stratospheric ozone layer	ODP	kg CF-11 eq	TRACI 2.1 V1.08
Acidification potential of soil and water sources	AP	kg SO_2 eq	TRACI 2.1 V1.08
Eutrophication potential	EP	kg N eq	TRACI 2.1 V1.08
Formation potential of tropospheric ozone	SFP	kg O_3 eq	TRACI 2.1 V1.08
Abiotic depletion potential (ADP fossil) for fossil resources;	ADPf	MJ, LHV	CML-IA Baseline V3.08
Fossil fuel depletion	FFD	MJ Surplus	TRACI 2.1 V1.08
Use of Primary Resources			
Renewable primary energy carrier used as energy	RPRE	MJ, LHV [a/]	CED (LHV) V1.00
Renewable primary energy carrier used as material	RPRM	MJ, LHV	LCI Indicator
Non-renewable primary energy carrier used as energy	NRPRE	MJ, LHV	CED (LHV) V1.00
Renewable primary energy carrier used as material	NRPRM	MJ, LHV	LCI Indicator
Secondary material, secondary fuel and recovered energy			
Secondary material	SM	kg	LCI Indicator
Renewable secondary fuel	RSF	MJ, LHV	LCI Indicator
Non-renewable secondary fuel	NRSF	MJ, LHV	LCI Indicator
Recovered energy	RE	MJ, LHV	LCI Indicator
Mandatory Inventory Parameters			
Consumption of freshwater resources;	FW	m^3	LCI Indicator
Indicators Describing Waste			
Hazardous waste disposed	HWD	kg	LCI Indicator
Non-hazardous waste disposed	NHWD	kg	LCI Indicator
High-level radioactive waste, conditioned, to final repository	HLRW	m^3	LCI Indicator
Intermediate- and low-level radioactive waste, conditioned, to final repository	ILLRW	m^3	LCI Indicator
Components for re-use	CRU	kg	LCI Indicator
Materials for recycling	MR	kg	LCI Indicator
Materials for energy recovery	MER	kg	LCI Indicator
Recovered energy exported from the product system	EE	MJ, NCV	LCI Indicator
Additional Inventory Parameters for Transparency			
Biogenic Carbon Removal from Product	BCRP	kg CO2e	Manual
Biogenic Carbon Emission from Product	BCEP	kg CO2e	Manual
Biogenic Carbon Removal from Packaging	BCRK	kg CO2e	Manual
Biogenic Carbon Emission from Packaging	BCEK	kg CO2e	Manual
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	BCEW	kg CO2e	Manual

3.3 Biogenic Carbon

Wood is a biobased material and thus contains biogenic carbon. The accounting of biogenic carbon follows the requirements set out in ISO 21930:2017 section 7.2.7 and 7.2.12. Per ISO 21930, biogenic carbon enters the product system (removal) as primary or secondary material. Carbon removal is considered a negative emission. The biogenic carbon leaves the system (emission) as a product, by-products, and directly to the atmosphere when combusted. These mass flows of biogenic carbon from and to nature are listed in the LCI and are expressed in kg CO_2.

In the LCIA, the LCI flow of biogenic carbon removal is characterized by a factor of -1 kg CO_2e/kgCO_2 of biogenic carbon in the calculation of the GWP[1]. Likewise, the LCI flow of biogenic carbon emission is characterized by a factor of +1 kg CO_2e/kg CO_2 of biogenic carbon in the calculation of the GWP. Emissions other than CO_2 associated with biomass combustion (e.g., methane or nitrogen oxides) are characterized by their specific radiative forcing factors in the calculation of the GWP.

The UL PCR 2020 specifies TRACI as the default LCIA method for GWP (GWP_{FOSSIL}). The TRACI method does not account for the removals or emissions of biogenic CO_2. We have thus manually calculated the component of the global warming potential related to biogenic carbon separately. We have reported the GWP indicator both with and without the biogenic CO_2 component for maximum transparency.

The results for global warming potential (GWP) and biogenic CO_2 are as follows:

- GWP_{FOSSIL} includes greenhouse gases (GHG) emissions from the combustion of fossil resources, and GHG emissions other than CO_2 from the combustion of biogenic resources (TRACI method)
- $GWP_{BIOGENIC}$ adds the net emissions of biogenic carbon to the GWP (TRACI method + net biogenic carbon = GWP_{TOTAL})
- LCI flows of biogenic carbon emissions and removals (Section 7.2; Table 22)

[1] ISO 21930 requires a demonstration of forest sustainability to characterize carbon removals with a factor of -1 kg CO_2e/kg CO_2. ISO 21930 Section 7.2.1 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.” Canada’s UNFCCC annual report Table 6-1 provides annual net GHG Flux Estimates for different land use categories. This reporting indicates non-decreasing forest carbon stocks and thus the source forests meet the conditions for characterization of removals with a factor of -1 kg CO_2e/kg CO_2.

4 Description of Industry

The wood I-joist industry plays a critical role in modern residential and light commercial construction, offering a high-performance alternative to traditional solid-sawn lumber for floor and roof framing.

The I-joist design results in a lightweight yet strong member that resists warping, shrinkage, and twisting, while allowing for longer spans and more open floor plans. The industry has grown steadily over the past few decades, driven by increasing demand for resource-efficient, cost-effective, and dimensionally stable framing solutions. Major manufacturers operate large-scale automated facilities and rely on sustainably sourced wood, often backed by third-party certification and environmental product declarations (EPDs), to meet stringent building codes and sustainability goals.

The UNSPSC (United Nations Standard Products and Services Code) code for I-joists is 301036 07, which falls under the category of "Structural products/ Wood joists" and Construction Specifications Institute (CSI) code for engineered wood products 06 11 13 and wood I-joist 06 17 33 (Table 4).

Table 4. United Nations Standard Products and Services Code (UNSPSC) and Construction Specification Institute (CSI) MasterFormat Code for Wood I-Joist.

Classification Standard	Category	Subcategory	Product Code
UNSPSC	Structural products	Wood joist	301036 07
CSI / CSC	Wood I-Joist / Prefabricated Wood I-Joist	Engineered Wood Products	06 11 13
		Wood I-Joist	06 17 33

4.1 Description of Product

As the name implies, I-joist have an “I” shaped cross-section with the top and bottom flanges separated by a narrow webbing material. I-joists flanges are made from LVL and to a lesser extent machine stress-rated lumber (Figure 4). The web material is made with OSB. There are many different dimensions of I-joists, but the most common are dimensions that directly replace 2 x 10 and 2 x 12-inch structural lumber. The I-joists are usually made in continuous length and then cut to 60-foot lengths for shipping.

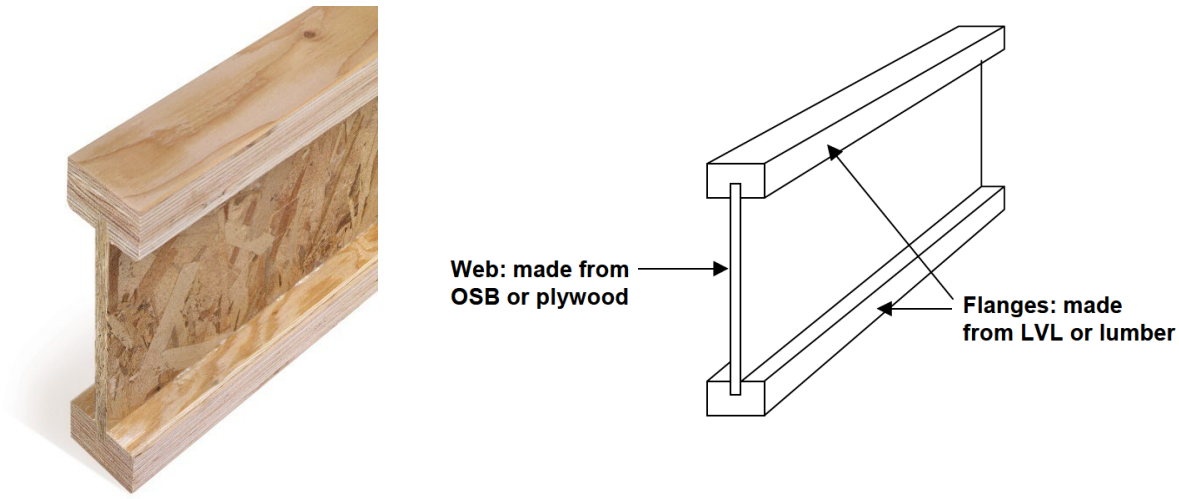


Figure 4. Typical I-joist Made with Laminated Veneer Lumber Flanges and an Oriented Strand Board Web (Photo credit, APA-The Engineered Wood Association (Left), Wilson and Dancer 2004 (Right)

4.2 Categories of Products and By-products

The primary product from I-Joist facilities is I-Joist. Some of the facilities in this LCA also produce LVL using the LVL as the flanges in their I-joist production. Very little by-products are generated during the I-joist production process (1.5%). These by-products could include trimmings and sawdust. One of the I-joist facilities reported that 100 percent of the by-products produced are used for on-site energy and heat generation.

4.3 Annual Operating and Production Statistics of the Industry

In this LCA, participating I-joist facilities (n=8) accounted for 94 percent of the 403 million linear feet (LF) (123 million linear meters) of I-joist capacity in 2023 (FEA 2024). Of the reporting facilities, the annual production ranged from 3 to 115 million LF, with a weighted average based on production of 69.81 million LF (21.28 million meters).

4.4 Typical Emission Control Measures

Baghouses are the primary collectors of particulate matter with all surveyed plants using this emission control device. Emissions to air for each facility were provided by the National Council for Air and Stream Improvement (NCASI).

All waterborne emissions occurred off site for gate-to-gate I-joist production. I-joist plants are zero-discharge facilities. Solid emissions were dominated by LVL and OSB production stages. No dangerous substances were reported by industry that fall under ISO 21930 (ISO 2017).

4.5 General Types of Wastes and Emissions

Emissions to air for each facility were provided by the National Council for Air and Stream Improvement (NCASI). All waterborne emissions occurred off site for gate-to-gate I-joist production. I-joist plants are zero-discharge facilities.

No dangerous substances were reported that fall under ISO 21930 (ISO 2017). Mills classified as major sources under EPA rules are required to report methanol, formaldehyde, phenol, acetaldehyde, propionaldehyde, and acrolein, which are on the US Environmental Agency (EPA) Toxics Release Inventory. These emissions are reported in this LCA.

Most mills reported mill waste going to landfills and or recycling. Most common waste types reported were wood and municipal solid waste destined for landfill.

4.6 Wood Species

Southern pine dominated the species mix for both OSB and LVL used in I-joist manufacturing (Table 5) (Puettmann 2025a-b). Weighted average production of I-joist facilities in this LCA represented 51 percent from the Southern region and 49 percent from the Pacific Coast (Figure 1).

Table 5. Species and Representation for Wood Inputs in I-Joist Production.

Species Grouping	Scientific Name	Survey Composition
Laminated Veneer Lumber		
Southern Pine	*Pinus spp.*	65.53%
Douglas-fir	*Pseudotsuga menziesii*	34.47%
		100%
Oriented Strand Board		
Southern pine	*Pinus spp.*	82.95%
Maple	*Acer spp.*	9.53%
Aspen/Balsam poplar	*Populus spp.*	6.01%
Eastern pines	*Pinus spp.*	0.67%
Birch	*Betula spp.*	0.45%
Tamarack	*Larix spp.*	0.33%
Basswood	*Tilia spp.*	0.06%
		100.00%

4.7 Moisture Content

The weighted average moisture content of the I-joist ready for shipment was 5.7 percent. Surveys reported a range of moisture contents for finished I-joist from 4.9 – 6.0 percent. All wood moisture content values are reported on an oven-dry basis.

5 Life Cycle Inventory Analysis

The life cycle inventory (LCI) in this section presents the unit process flows for 1 linear m of finished I-joist. The LCI was calculated based on 2023 production and the corresponding flows of materials during that period. No data gaps were recorded.

5.1 A1- Wood Inputs

LVL and OSB are the primary wood input in I-joist manufacturing. A small amount of lumber was used for flanges (Puettmann 2024). Upstream impacts from forestry operations are accounted for in the manufacturing of OSB and LVL (Puettmann 2025a, 2025b). Included are activities associated with establishment, growth, and harvest of trees specific to the Pacific Northwest and Southeast regions (Oneil and Puettmann 2017; Oneil 2021). This group of activities is collectively referred to as forest resource extraction. The forest resource extraction life cycle stage includes the efforts required to establish a forest stand, to treat that stand to maturity, and to harvest the merchantable logs from the stand (Table 6).

Table 6. Wood Input Representation for Wood I-Joist Production, U.S.

Wood Input Category	Survey Composition, by mass	Survey Composition, by volume
Laminated Veneer Lumber	55.84%	59.47%
Oriented Strand Board	43.91%	40.22%
Lumber	0.25%	0.31%
	100%	100%

5.2 A1 – Adhesive

Facilities reported the use of phenol resorcinol formaldehyde (PRF), polymer emulsion polyurethane (PEP), phenol formaldehyde (PF), and melamine formaldehyde resins and hardeners (Table 7). Production of adhesives was obtained from published LCA data (Athena 2022). Phenol and formaldehyde are listed on the EPA Toxics Release Inventory[2].

[2] US Environmental Protection Agency, Toxics Release Inventory. http://www.epa.gov/toxics-release-inventory-tri-program/tri-listedchemicals. Accessed February 2025.

Table 7. Weighted Average Resin and Additive Inputs per Linear Meter of Wood I-Joist, Unallocated.

Adhesive and Sealant Components	Component mass (kg)	Component Percent
	per meter of I-Joist	
PRF	1.84E-02	69.77%
PEP	6.47E-03	24.51%
PF	1.17E-03	4.43%
MF	8.22E-05	0.31%
Hardeners	2.59E-04	0.98%
Total	2.64E-02	100.00%

A2 – Transport

The A2 module includes the transportation of resources and materials used in the production of I-joist (Table 8). The distances are weighted averages based on I-joist production surveys.

Table 8. Weighted Average Delivery Distance and Mode of Transport for Wood I-Joists.

Input Material	Mode of Transportation	Distance	
		km	Miles
Laminated veneer lumber	Road	161.22	100.18
Oriented Strand Board	Road	250.74	155.80
Lumber	Road	75.22	46.74
Adhesive	Road	274.61	170.64
Oriented Strand Board	Rail	1,428.98	887.92
Adhesive	Rail	39.84	24.76

5.3 A3 –I-Joist Manufacturing

Routing and shaping of web and flanges are the first step in producing I-joists. This process requires machining of the OSB web pieces so they fit together at the ends as well as tapering them on the top and bottom edges so that they can be fitted into the flanges. Flanges are made primarily from LVL and to a lesser extent lumber. The flanges are machined their entire length to accept the inserted tapered OSB web material. The coproduct created during this process is dry sawdust.

Adhesive application and pressing of the I-joist web and flanges members is the next step. Adhesive is applied in web-to-web and web-to-flange joints. Assembly is done mechanically, pressing web sections end-to-end and into the top and bottom flange, which are also pressed end-to-end; the result is a continuous ribbon of I-joist that can be of infinite length. The final step before packaging is sawing the I-joists to length and allowing the joints to cure. In some cases, the I-joist may be heated in a convection or radio-frequency oven to accelerate resin cure time and allow handling.

Survey respondents provided data from 2023 on the material and resource inputs to I-joist manufacturing at the mill and outputs such as product, by-products and energy use (Table 9). The data were production-weight averaged and are reported below per linear m of finished I-joist produced. Under materials, wood feedstocks include OSB, LVL, and lumber. Emissions to air for each facility were provided by NCASI.

Table 9. Process Inputs/Outputs Wood I-Joist Manufacturing to Produce 1 Linear Meter, Unallocated.

A3 Production	Value	Unit/m	Allocation
A3-Wood I joist, at mill, US	1.00E+00	m	98.51%
A3-By-product, I joist, at mill, US	5.70E-02	kg	1.49%
Resources			
Water, process, municipal	9.90E-02	L	
Materials / Fuels			
Total Wood Inputs	6.40E-03	m3	
Adhesive System	2.64E-02	kg	
Transportation	3.14E+00	tkm	
Diesel	3.37E-03	l	
Gasoline	1.78E-05	l	
Natural gas	4.00E-02	m3	
Propane	3.11E-03	l	
Lubricating oil	4.78E-02	kg	
Oil and grease	1.72E-03	kg	
Process Waste, recycling	1.65E-04	kg	
Process Waste, Landfill	1.35E-02	kg	
Packaging materials	4.99E-02	kg	100%
Electricity/heat			
Electricity, WECC	2.16E-01	kWh	
Electricity, SERC	2.28E-01	kWh	
Emissions to air			
Particulates, < 2.5 um	3.43E-07	kg	
Particulates, unspecified	3.13E-04	kg	
Particulates, < 10 um	2.40E-06	kg	
Particulates, unspecified	7.78E-05	kg	
VOC, volatile organic compounds, unspecified origin	8.16E-04	kg	
Methanol	2.18E-04	kg	
Formaldehyde	9.96E-06	kg	
Acetaldehyde	1.99E-05	kg	
Acrolein	1.03E-05	kg	
Phenol	2.37E-05	kg	
Propanol	1.45E-05	kg	

5.3.1 Equipment: Type and Fuel Consumption

Diesel-powered loaders are typically used for moving materials and product. Electrically driven motors in the mill are used for material conveyors and trims saws. Electricity is also used for running fans and pumps, and for operating emissions control equipment. Lifts for transporting products and materials in the mill are typically powered by electricity and liquefied propane gas. Natural gas and wood by-products are used for boiler fuel and emission control equipment, and propane fuel is used in forklifts.

5.3.2 Onsite Energy Production

Heat energy is used for curing resins. Heat energy can be generated either by natural gas or wood waste. Of the wood fuel burned, 100 percent is produced on site. The combustion of wood and its emissions is factored into this LCA (Puettmann and Milota 2017).

5.3.3 Packaging

Packing materials represent 1.26 percent of the mass of the main product. The packaging wrap makes up the bulk of the mass of the total materials representing 99.5 percent of the total packaging (Table 9).

Table 10. Materials Used in Packaging and Shipping per Linear Meter Wood I-Joists.

Material	Unit / m	Value / meter	Percent of Total Packaging
Wrapping Material	kg	4.96E-02	99.46%
Plastic strapping	kg	2.70E-04	0.54%
TOTAL	kg	4.99E-02	100.00%

5.4 Secondary Data Sources

Secondary data is necessary for creating the full cradle-to-gate analysis. Tables 11, 12, and 13, list the secondary LCI data sources, geographical origin, age, and quality of the data used in this LCA study.

Table 11. Raw Material Supply Processes.

A1: Raw Material Inputs				
Inputs	**LCI Data Source**	**Geography**	**Year**	**Data Quality Assessment**
Resources	Database: CORRIM LVL, OSB, and Lumber	US Pacific Coast and Southern regions	2024-2025	- Technology: Good - Process models product specific technology - Time: Good update in the last 5 years - Geography: Good, Data specific to product
Resins	Database: Athena Processes: Wood Resins 2021	United States	2021	- Technology: Good - Process models product specific technology - Time: Fair, updated in the last 2 years - Geography: Good, Data specific to product

Table 12. Transportation Processes.

A2: Raw Material Transportation				
Inputs	LCI Data Source	Geography	Year	Data Quality Assessment
Road	Database: Datasmart v. 2023 Process: Transport, combination truck, Diesel powered NREL/US U	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 2 years old - Geography: good
Rail	Database: Datasmart v. 2023 Process: Transport, train, diesel powered NREL/US U	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 2 years old - Geography: good

Table 13. Manufacturing Processes.

A3 Manufacturing				
Inputs	LCI Data Source	Geography	Year	Data Quality Assessment
Electricity	Database: Ecoinvent 3.9 Processes: Electricity, low voltage {WECC, US only} | market for electricity, low voltage | Cut-off, U Processes: Electricity, low voltage {SERC, US only} | market for electricity, low voltage | Cut-off, U	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 2 years old - Geography: Good
Natural gas	Database: Datasmart v. 2023 Process: Natural gas, combusted in industrial boiler NREL/US U	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 2 years old - Geography: Good
Diesel	Database: Datasmart v. 2023 Process: Diesel, combusted in industrial equipment NREL/US U	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 2 years old - Geography: Good
LPG	Database: Datasmart v. 2023 Process: Liquefied petroleum gas, combusted in industrial boiler NREL/US U	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 5 years old - Geography: Good
Wood Fuel	CORRIM Database	United States	2020	- Technology: Good, process models average North American technology - Time: Good, Data is less than 5 years old - Data is less than 5 years old - Geography: Good
Wrapping Materials	Database: Datasmart v. 2023 Processes: High density polyethylene resin, at plant NREL/RNA U Low density polyethylene resin, at plant NREL/RNA U	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 2 years old - Geography: Good
Strapping	Database: Datasmart v. 2023 Processes: Polyethylene, HDPE, granulate, at plant/US- US-EI U.	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 5 years old - Geography: Good
Waste	Database: Ecoinvent 3.9 Processes: Process-specific burdens, sanitary landfill {RoW} | market for process-specific burdens, sanitary landfill | Cut-off, U;	North America	2023	- Technology: Good, process models average North American technology - Time: Good, Data is less than 2 years old Data is less than 5 years old - Geography: Good

6 Life Cycle Impact Assessment Results

6.1 A1-A3 - Cradle-to-Gate

This section discusses the cradle-to-gate results for the declared unit, one linear meter of I-joist. The TRACI, CML, and CED LCIA methods were used to characterize the flows to and from the environment. Allocation of environmental burdens to siding and its by-products is done according to mass allocation principles (ISO 2006 a, b). The cradle-to-gate (A1-A3) LCIA results for I-joist are presented for one linear meter (Tables 14-20).

The contribution impact results are in tables 17-19. Module A1 has the greatest contribution to the overall impact in nearly every impact category (except waste). The higher contribution on the A1 module comes from the upstream impacts of OSB and LVL production (Puettmann 2025a-b) and resins. Transportation accounted for a maximum of 18 percent and as low as 0.1 percent. While manufacturing I-joist (A3) impact contribution was as low as 7.7 percent in renewable energy use (NPRE), it was as high as 53 percent for waste (Tables 18-20, Figure 5).

Table 14. Cradle-to-Gate LCIA Results for 1 Linear Meter of Wood I-Joist – Absolute Basis.

Core Mandatory Impact Indicator	Total	A1	A2	A3
GWP_{TOTAL} [kg CO_2 eq]	2.15E+00	-5.46E+00	1.26E-01	7.49E+00
$GWP_{BIOGENIC}$ [kg CO_2 eq]	0.00E+00	-7.03E+00	0.00E+00	7.03E+00
GWP_{FOSSIL} [kg CO_2 eq]	2.15E+00	1.57E+00	1.26E-01	4.61E-01
ODP [kg CF-11 eq]	2.22E-07	1.77E-07	2.22E-10	4.48E-08
AP [kg SO_2 eq]	9.72E-03	6.89E-03	1.31E-03	1.51E-03
EP [kg N eq]	4.70E-03	3.42E-03	9.51E-05	1.18E-03
SFP [kg O_3 eq]	2.31E-01	1.63E-01	4.19E-02	2.56E-02
FFD [MJ, surplus]	5.11E+00	3.32E+00	2.37E-01	1.55E+00
ADP_{FOSSIL} [MJ, LHV]	3.67E+01	2.42E+01	1.58E+00	1.09E+01

Table 15. Cradle-to-Gate Resource use Results for 1 Linear Meter of Wood I-Joist – Absolute Basis.

Use of Primary Resources	Total	A1	A2	A3
RPRE [MJ, LHV]	2.63E+01	2.43E+01	3.62E-03	2.02E+00
RPRM [MJ, LHV]	8.00E+01	8.00E+01	0.00E+00	0.00E+00
NRPRE [MJ, LHV]	4.12E+01	2.75E+01	1.60E+00	1.21E+01
NRPRM [MJ, LHV]	9.42E-01	9.42E-01	0.00E+00	0.00E+00
SM [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RE [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW [m^3]	6.64E-03	5.68E-03	3.09E-06	9.64E-04

Table 16. Cradle-to-Gate Output Flows for 1 Linear Meter of Wood I-Joist – Absolute Basis.

Indicators Describing Waste	Total	A1	A2	A3
HWD [kg]	8.08E-04	6.80E-04	1.01E-06	1.27E-04
NHWD [kg]	2.17E-01	9.01E-02	1.14E-02	1.16E-01
HLRW [m^3]	4.14E-09	2.91E-09	1.25E-11	1.22E-09
ILLRW [m^3]	5.12E-08	2.69E-08	1.10E-10	2.42E-08
CRU [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MR [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EE [MJ, LHV]	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 17. Cradle-to-Gate LCIA Results for 1 Linear Meter of Wood I-Joist – Relative Basis.

Core Mandatory Impact Indicator	Total	A1	A2	A3
GWP_{FOSSIL} [kg CO_2 eq]	100%	72.8%	5.8%	21.4%
ODP [kg CF-11eq]	100%	79.7%	0.1%	20.2%
AP [kg SO_2 eq]	100%	70.9%	13.5%	15.6%
EP [kg N eq]	100%	72.8%	2.0%	25.2%
SFP [kg O_3 eq]	100%	70.8%	18.2%	11.1%
FFD [MJ, surplus]	100%	66.0%	4.3%	29.7%
ADP_{FOSSIL} [MJ, LHV]	100%	65.0%	4.6%	30.4%

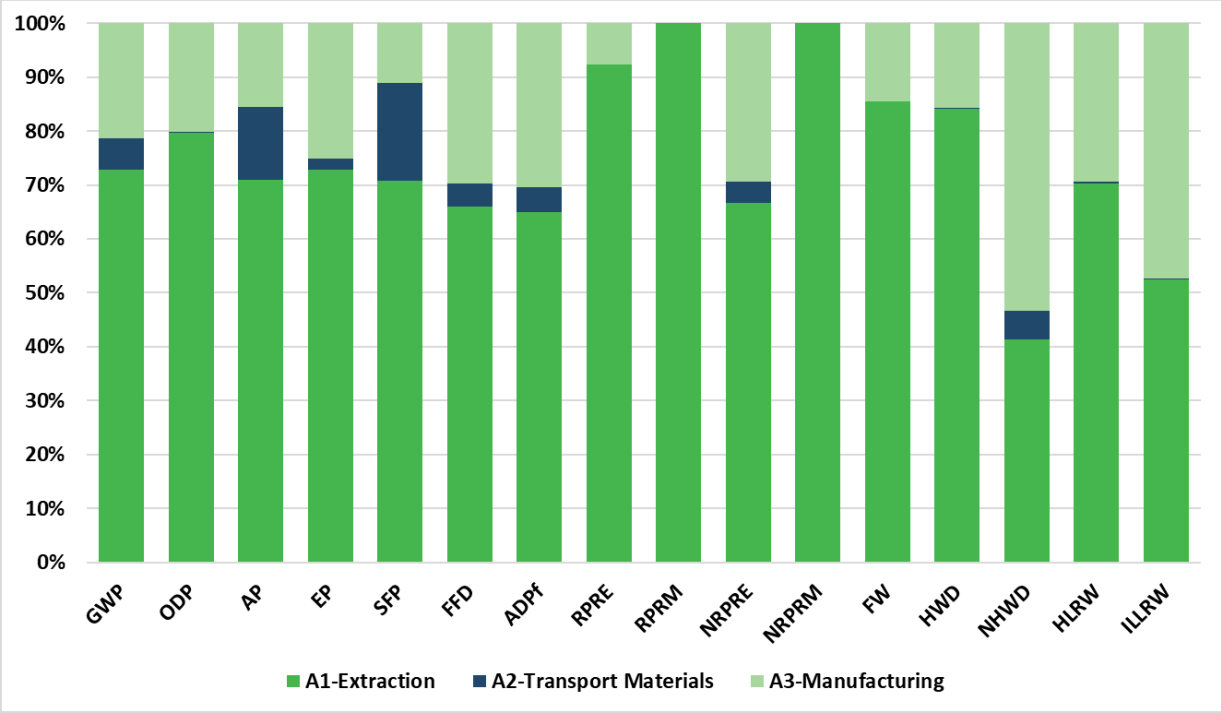
Table 18. Cradle-to-Gate LCIA Results for 1 Linear Meter of Wood I-Joist – Relative Basis.

Use of Primary Resources	Total	A1	A2	A3
RPRE [MJ, LHV]	100%	92.3%	0.0%	7.7%
RPRM [MJ, LHV]	100%	100.0%	0.0%	0.0%
NRPRE [MJ, LHV]	100%	66.7%	3.9%	29.4%
NRPRM [MJ, LHV]	100%	100.0%	0.0%	0.0%
FW [m^3]	100%	85.4%	0.0%	14.5%

Table 19. Cradle-to-Gate LCIA Results for 1 Linear Meter of Wood I-Joist – Relative Basis.

Indicators Describing Waste	Total	A1	A2	A3
HWD [kg]	100%	84.2%	0.1%	15.7%
NHWD [kg]	100%	41.4%	5.2%	53.3%
HLRW [m^3]	100%	70.3%	0.3%	29.4%
ILLRW [m^3]	100%	52.5%	0.2%	47.3%

Most of the renewable fuels were used in the A1 life-cycle stage (Table 20-23). Renewable fuels represented 39 percent energy consumption cradle-to-gate (A1-A3) (Table 23) with 92 percent from the A1 module (Table 23). Renewable energy used in A1 module comes from the production of OSB and LVL (Puettmann 2025a-b) (Table 22). Non-renewable fuel consumption represented 61 percent over all modules (A1-A3) (53 percent within A1 and 86 percent in A3). In summary, cradle-to-gate total energy for producing I-joist, which includes fuel for heat energy and equipment and electricity, comes from 54 percent fossil fuels, 7 percent nuclear, 37 percent renewable biomass fuel, and 2 percent other renewable (Table 20).



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

Figure 5. Cradle-to-Gate LCIA Results for 1 Linear Meter of Wood I-Joist – Relative Basis.

Table 20. Cradle-to-Gate Cumulative Energy Demand (CED) Results for 1 Linear Meter of Wood I-Joist – Absolute Basis.

Impact category	A1-A3	A1	A2	A3
Nonrenewable, fossil	3.67E+01	2.42E+01	1.58E+00	1.09E+01
Non-renewable, nuclear	4.51E+00	3.24E+00	2.31E-02	1.25E+00
Non-renewable, biomass	2.13E-04	1.40E-04	1.18E-08	7.35E-05
Renewable, biomass	2.49E+01	2.34E+01	7.38E-04	1.51E+00
Renewable, wind, solar, geothermal	6.38E-01	3.99E-01	7.95E-04	2.38E-01
Renewable, water	7.40E-01	4.68E-01	2.08E-03	2.70E-01
Total	6.75E+01	5.18E+01	1.60E+00	1.41E+01

Table 21. Cradle-to-Gate Renewable and Non-Renewable Energy Use Results for 1 Linear Meter of Wood I-Joist – Absolute Basis.

Impact category	A1-A3	A1	A2	A3
Renewable Energy	2.63E+01	2.43E+01	3.62E-03	2.02E+00
Non-renewable Energy	4.12E+01	2.75E+01	1.60E+00	1.21E+01
Total	6.75E+01	5.18E+01	1.60E+00	1.41E+01

Table 22. Contribution Analysis for Cradle-to-Gate Renewable and Non-Renewable Energy Use Results for 1 Linear Meter of Wood I-Joist, by A1-A3 Total, Relative Basis.

Impact category	A1-A3	A1	A2	A3
Renewable Energy	100%	92.31%	0.01%	7.68%
Non-renewable Energy	100%	66.68%	3.88%	29.43%
Total	100%	76.67%	2.38%	20.95%

Table 23. Contribution Analysis for Cradle-to-Gate Renewable and Non-Renewable Energy Use Results for 1 Linear Meter of Wood I-Joist by Module Total, Relative Basis.

Impact category	A1-A3	A1	A2	A3
Renewable Energy	39.0%	46.91%	0.23%	14.27%
Non-renewable Energy	61.0%	53.09%	99.77%	85.73%
Total	100.0%	100.00%	100.00%	100.00%

6.2 Biogenic carbon

Table 24 shows additional inventory parameters related to biogenic carbon removal and emissions. All carbon dioxide flows (kg CO_2e) presented in Table 24 are unallocated to include by-products leaving the system boundary in module A3. Even though the system boundary for this LCA only includes modules A1-A3, in accordance with ISO 21930, emission from packaging (BCEK) is reported in A5-Construction and emission from the main product (BCEP) is reported in C3/C4-End-of-Life[3]. The net biogenic carbon emission across the cradle-to-gate life cycle is zero. It is assumed that all carbon removed from the atmosphere is eventually emitted to the atmosphere as CO_2.

Total $GWP_{BIOGENIC}$ includes biogenic carbon emissions and removals from the information modules A1-A3, A5, and C3/C4, leading to a net zero contribution of biogenic carbon to $GWP_{BIOGENIC}$. Therefore, in Table 14, results from Total GWP_{FOSSIL} and Total GWP_{TOTAL} are equal.

Using the method described earlier in this report, -7.03 kg CO_2 (reported in A1-Extraction) were removed in the production of 1 m of I-joist (unallocated). One linear meter of I-joist stores 1.89 kg of carbon or 6.92 kg CO_2 eq (reported in C3/C4-End-of-Life). No by-products left the system boundary (reported in A3-Manufacturing). The combustion of wood fuel emitted 0.11 kg of CO_2. Packaging resulted in removal of -0.09 kg CO_2 and an emission of +0.09 kg CO_2. In summary, total removals was -7.12 kg CO_2 and total “emissions” was +7.12 kg CO_2 from cradle-to-gate (A1-A3 of the LCA system boundary).

Table 24. Biogenic Carbon Inventory Parameters for 1 Linear Meter of Wood I-Joist, Unallocated.

	A1	A2	A3	A5	C3/C4	Total
BCRP [kg CO_2]	(7.03E+00)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	(7.03E+00)
BCEP [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.92E+00	6.92E+00
BCRK [kg CO_2]	0.00E+00	0.00E+00	(8.71E-02)	0.00E+00	0.00E+00	(8.71E-02)
BCEK [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	8.71E-02	0.00E+00	8.71E-02
BCEW [kg CO_2]	0.00E+00	0.00E+00	1.11E-01	0.00E+00	0.00E+00	1.11E-01

I-joist production facilities obtain their wood fiber from sources that are legally and sustainably sourced. The carbon that is part of the molecular composition of wood is derived from the carbon dioxide removed from the atmosphere by the growing of trees that produce wood. The carbon content of wood, in general, is 50 percent. The GWP_{FOSSIL} accounts for the green house gas emissions released through manufacturing (embodied carbon). In this LCA, an I-joist stores more carbon than is released during manufacturing (A1-A3) by containing 6.92 kg CO_2e in the final product while emitting 2.15 kg CO_2e from cradle-to-gate (A1-A3) (Table 13). In summary, the carbon balance of I-Joist is 4.76 kg CO_2e/m^3.

[3] These products are reported in modules outside the scope of this LCA system boundary to provide reference for EoL waste and emissions if a full cradle-to-grave LCA were to be performed.

7 Interpretation

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

7.1 Uncertainty Analysis

The uncertainty and sensitivity analysis aims to assess the reliability of the final results. The uncertainty analysis investigates input data variations within the sample production facilities. Some degree of uncertainty is present in the results due to the variation amongst different data providers. Table 25 provides statistics for electricity, natural gas, adhesive, and wood input.

Table 25. Summary of Selected Survey Data Statistics for 1 Linear Meter of Wood I-Joist

Parameter	Unit per meter	Weighted Average	Max	Min.	Std. Dev.	Median
Electricity	kwh	0.4439	2.3840	0.1728	0.6641	0.5192
Natural gas	m3	0.0400	0.4284	0.0000	0.1365	0.0222
Adhesive	kg	0.0264	0.0354	0.0080	0.0079	0.0193
Wood Input	kg	3.8363	5.3502	2.9664	0.8992	3.5930

7.2 Completeness and Consistency Checks

Life cycle assessment reports must be reviewed for completeness, consistency, and data sensitivity. Evaluation helps to establish and enhance confidence in, and the reliability of, the results of the LCA study, including the significant issues identified in the interpretation. The energy use (MJ/m) of I-joist in this LCA was compared to the previous LCA on Southeast and Pacific Northwest I-joist (Bergman and Alanya-Rosenbaum 2020a-b), and the North American Composite I-Joist EPD (2020) (Table 26).

Table 26. Energy Consumption of Wood I-Joist – Comparison of this LCA to Other Similar LCAs.

Product	Total	A1	A2	A3	Reference
	MJ / linear meter				
I-Joist 2023 data	67.52	51.77	1.60	14.15	This LCA
Southeast I-Joist, 2012 data	86.92	75.12	1.28	10.52	Bergman and Alanya-Rosenbaum 2020a
Pacific Northwest I-Joist, 2012 data	77.04	63.99	2.43	10.62	Bergman and Alanya-Rosenbaum 2020b
North American EPD, 2012 data	63.04	53.30	1.75	7.99	I-Joist EPD, North American, AWC 2020

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

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

8 Additional Information

Engineered I-joist production facilities in the U.S. obtain their wood fiber from sources that are legally and sustainably sourced. Participating facilities reported Fiber Sourcing data for the three sourcing categories established in ASTM-D7612: Standard Practice for Categorizing Wood and Wood-Based Products According to Their Fiber Sources (ASTM 2021). The standard provides criteria for differentiating wood products into three categories:

1. Non-controversial Sources of Forest Products,
2. Responsible Sources of Forest Products, and
3. Certified Sources of Forest Products.

Fiber from non-controversial, or legal, sources are from geographic areas with a low risk of illegal activity and are compliant with legal or other proprietary standards. Products from responsible sources are produced with wood fiber acquired according to an independently certified procurement standard or are from jurisdictions with regulatory or quasi-regulatory programs to implement best management practices. Independently certified procurement standards include FSC Controlled Wood and SFI Fiber Sourcing. To qualify for either standard, an I-joist mill must have a system in place that verifies their logs (or the logs used to produce their input veneer or PLV) are coming from areas in compliance with forestry best management practices to protect air and water quality and ensure all fiber comes from known and legal sources. Products from certified sources are independently certified to an internationally recognized forest management certification standard, such as those from the Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC), American Tree Farm System (ATFS), or the Canadian Standards Association (CSA).

The eight facilities represented in this regional LCA reported on average, 100% of the fiber entering their mills to be non-controversial (legal), 100% to be responsible (following a certified procurement standard), and 13.6% from independently certified forests.

9 Discussion

This LCA is an update to the previous published US regional LCAs for I-joist production (Bergman and Alanya-Rosenbaum 2020a-b). Reported in the 2020 LCA, three Pacific Northwest and two southeast facilities participated. In this LCA eight facilities participated representing the Pacific coast region (62.5%) and the Southern region (37.5%) of the US. Participating facilities represented 94 percent of the US production while for the 2020 report participating facilities represented only 27 percent from the southeast and 31 percent from the Pacific Northwest. US I-joist production in 2012 was reported at 109 million meters (Bergman and Alanya-Rosenbaum 2020a-b), while reported in this LCA, the industry production is 123 million meters (FEA 2024). Table 27 shows selected LCIA parameter differences between the previous regional LCA reports and this current LCA.

Table 27. Selected LCIA Results Comparison Between 2012 data LCAs and This LCA (based on 2023 industry data) on Wood I-joist production.

	Unit / linear meter	This LCA	SE[1/]	PNW[2/]	Difference from SE	Difference from PNW
Global warming potential, fossil	kg CO_2 eq	2.155	3.068	2.347	-30%	-8%
Depletion potential of the stratospheric ozone layer	kg CFC11 eq	2.22E-07	1.15E-07	8.32E-08	93%	167%
Acidification potential of soil and water sources	kg SO_2 eq	0.010	0.059	0.033	-84%	-71%
Eutrophication potential	kg N eq	0.005	0.014	0.009	-66%	-48%
Formation potential of tropospheric ozone	kg O_3 eq	0.231	1.918	1.058	-88%	-78%
Renewable primary energy carrier used as energy	MJ, NCV	26.309	18.212	26.187	44%	0%
Non-renewable primary energy carrier used as energy	MJ, NCV	41.210	68.705	50.852	-40%	-19%
Consumption of freshwater resources;	m^3	0.007	0.018	0.014	-63%	-51%
Wood Inputs	kg	3.836	4.383	4.373	-12%	-12%
Adhesive system	kg	0.026	0.033	0.023	-20%	15%

[1/] Bergman and Alanya-Rosenbaum 2020a
[2/] Bergman and Alanya-Rosenbaum 2020b

10 Conclusions

This study provides a comprehensive cradle-to-gate LCA of the production engineered I-joist produced and sourced in the Pacific coast and Southern regions of the United States. The primary goal of this LCA was to develop life cycle inventory data and impact assessment results for I-joist that could be used to develop a product Environmental Product Declaration (EPD). In addition to the impact assessment results, the life cycle inventory elements are also provided. Including the LCI elements enables the resource use inventory elements and waste flows as required by the Product Category Rule (PCR) to be included in the EPD. This cradle-to-gate LCA does incorporate the necessary scope to develop a “business-to-business” EPD in accordance with the PCR Guidance for Building-Related Products and Services, Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL 2018) and Part B: Structural and Architectural Wood Products EPD Requirements (UL 2020).

11 Critical Review

11.1 Internal Review

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

- Anna Ostrander, Manager, Sustainability Data, American Wood Council
- Tyler Congleton, Product Engineering Technical Manager, Boise Cascade Company

11.2 External Review

The external review process is intended to ensure consistency between the completed LCA and the principals and requirements of the International Standards on LCA (ISO 2006a) and ISO 21930 – Sustainability in Buildings and Civil Engineering Works - Core Rules for Environmental Product Declarations of Construction Products and Services (ISO 2017), the Product Category Rules for North American Structural and Architectural Wood Products Part B (UL 2020) and Part A: Life Cycle Assessment Calculations Rules and Report Requirements (UL 2018).

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

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