Measure, Report and Reduce: Using Comparative LCA to Highlight the Embodied Carbon Benefits of Wood Construction

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April 13, 2023
Carbon Benefits of Wood

» **Lower embodied carbon** as compared to other common building materials

» **Less fossil fuel** consumed during manufacture

» Extended **carbon storage** in products

» **Carbon sequestration** in forests and promote **forest health**
Life Cycle Assessment (LCA)

“Evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle”

» Systematic, scientific **quantification**

Used for:

» Single products or processes: e.g., a wood product

» Complex, integrated systems: e.g., an entire building (**WBLCA**)
Construction works life cycle information within the system boundary

A1 - A3
PRODUCTION Stage (Mandatory)
A1
Extraction and upstream production
A2
Transport to factory
A3
Manufacturing
A4
Transport to site
A5
Installation

A4 - A5
CONSTRUCTION Stage
B1 - B7
USE Stage
B1
Maintenance (incl. production, transport and disposal of necessary materials)
B2
Repair (incl. production, transport and disposal of necessary materials)
B3
Replacement (incl. production, transport and disposal of necessary materials)
B4
Refurbishment (incl. production, transport and disposal of necessary materials)
B5
Deconstruction / Demolition
B6
Operational energy use
B7
Operational water use
C1 - C4
END-OF-LIFE Stage
C1
Transport to waste processing or disposal
C2
Waste processing
C3
Disposal of waste
C4

Optional supplementary information beyond the system boundary

D
Potential net benefits from reuse, recycling and/or energy recovery beyond the system boundary

a Replacement information module (B4) not applicable at the product level.
What makes wood different?
Biogenic Carbon

“Carbon derived from... material of biological origin excluding material embedded in geological formations or transformed to fossilized material and excluding peat.”

Photosynthesis:

$$6 \text{CO}_2 + 6 \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 \text{ (stored)} + 6 \text{O}_2 \text{ (released)}$$

Source: ISO 21930:2017(E), 3.7
Carbon Storage

Wood ≈ 50% Carbon (dry weight)
Biogenic Carbon

“For wood, biogenic carbon may be characterized with a -1... when entering the product system only when the wood originates from sustainably managed forests.”

So...

What is a sustainably managed forest?

Source: ISO 21930:2017(E), 7.2.7
Sustainably Managed Forests

“... zero emissions associated with land use change”

Option 1:
Includes wood products *responsibly sourced and certified* to:

- **Standards** globally endorsed by PEFC and FSC
- FSC, SFI, CSA, ATFS, etc.

Option 2: (Note 2)
- “The concept of sustainably managed forests is linked but not limited to respective certification schemes”
- Evidence such as national reporting under UNFCCC to identify forests with stable or increasing forest carbon stocks

[https://www.woodworks.org/resources/when-to-include-biogenic-carbon-in-an-lca/](https://www.woodworks.org/resources/when-to-include-biogenic-carbon-in-an-lca/)

Source: ISO 21930:2017(E), 7.2.11
UNFCCC National Reporting

“... stable or increasing forest carbon stocks”
**U.S. Forest Land:**
Forest Area in the United States 1630 – 2017

Forest Area has been stable for more than 100 years

State of our Forests: US Timber Volume on Timberland

Volume of Trees has been growing for 60+ years!

Should I include biogenic carbon?

Yes! But how?
BIOCENIC CARBON FLOWS

START OF PRODUCT SYSTEM BOUNDARY
(Where human intervention first occurs)

A1 A2 A3 A4-A5 B1-B7 C1-C2 C3-C4

Life Cycle Information Module:

f Carbon stored in the wood for the life of the building

e Wood residues incinerated for energy

d Co-products (wood chips, shavings, sawdust) leave the product system

STORAGE PROFILES:

Natural environment outside product system boundary

Biogenic carbon sequestered by growing trees

Whole trees harvested; stored carbon enters the product system

Carbon remains stored in logs

Slash left in forest

Decomposition in landfill

Time (Not to scale)

NET ZERO BIOGENIC CARBON

Reuse, recycle, incineration; all result in net zero biogenic carbon flows

Reuse, recycle, or incineration with energy recovery; stored biogenic carbon leaves the product system for use in next system product

Permanent biogenic carbon storage in landfill

Note: The biogenic carbon balance over the life cycle is always zero or negative (indicating permanent biogenic carbon storage).

https://www.woodworks.org/resources/how-to-include-biogenic-carbon-in-an-lca/
Enters the system as (-) based on mass of carbon in harvested tree.
Carbon leaves the product system in the form of slash. Counted as (+) emission/export.
Carbon leaves the product system in the form of co-products. Counted as (+) export (but not a direct emission to the atmosphere).
Carbon leaves the product system in the form of wood residues incinerated for energy. Counted as (+) emission (but still carbon neutral).
Carbon stored in wood products when they leave the manufacturing gate. Still a (-) value.
No change in biogenic carbon
End-of-Life Fates for Wood Products

1. Landfill
2. Incineration (for energy recovery)
3. Recycle
4. Direct Reuse
Carbon leaves the product system for use in the next system Counted as (+) export (but not a direct emission to the atmosphere)

Reuse or Recycle
Hypothetical: Benefits get picked up by A1 of the next product system.
Carbon leaves the product system in the form of wood incinerated for energy. Counted as (+) emission (but still carbon neutral).
In all three cases, net biogenic carbon flows are zero.

Reuse, Recycle or Incineration
A portion of the carbon leaves the product system through decomposition in the landfill. Counted as (+) emission (but still carbon neutral).
The remaining amount is permanently stored in the landfill and is never emitted, resulting in net negative biogenic carbon (net storage).
What end-of-life option should I use?
Some combination of these four scenarios...
Athena IE

80% Landfill
23% decompose
77% stored
10% Incineration
10% Recycle

= 38.4% emit/export

OneClick

100% emitted/exported (reuse, recycle, incineration)

A Note About Tools:

In addition to differences in end-of-life scenarios:

» Where end-of-life effects are reported (C3-C4 vs Module D)
» Methodology (ISO compliance)
» LCI Databases (background data)
» User interface, workflow

https://www.woodworks.org/resources/calculating-the-embodied-carbon-of-different-structural-systems/
Resources from WoodWorks

**Whole Building Life Cycle Assessment (WBLCA)**
- Introduction to Whole Building Life Cycle Assessment: The Basics

**Biogenic Carbon and Carbon Storage**
- When to Include Biogenic Carbon in an LCA
- How to Include Biogenic Carbon in an LCA
- Biogenic Carbon Accounting in WBLCA Tools
- Long-Term Biogenic Carbon Storage
- Calculating the Carbon Stored in Wood Products

**Environmental Product Declarations (EPDs)**
- Current EPDs for Wood Products
- How to Use Environmental Product Declarations
MEASURE, REPORT, AND REDUCE:
USING COMPARATIVE LCA TO HIGHLIGHT THE EMBODIED
CARBON BENEFITS OF WOOD CONSTRUCTION

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Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
OUTLINE

• PLATTE FIFTEEN LCA CASE STUDY
• RETURN TO FORM LCA CASE STUDY
• CASE STUDY TRENDS
### Life Cycle Stages & Study Scope

<table>
<thead>
<tr>
<th>Product</th>
<th>Construction</th>
<th>Use</th>
<th>End-of-Life</th>
<th>Module D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A2</td>
<td>A3</td>
<td>A4</td>
<td>A5</td>
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<tr>
<td>Raw material supply</td>
<td>Transport</td>
<td>Manufacturing</td>
<td>Transport</td>
<td>Construction/Installation</td>
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<tr>
<td>Use</td>
<td>Maintenance</td>
<td>Repair</td>
<td>Replacement</td>
<td>Refurbishment</td>
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<tr>
<td>B1</td>
<td>B2</td>
<td>B3</td>
<td>B4</td>
<td>B5</td>
</tr>
<tr>
<td>Operational Energy Use</td>
<td>Operational Water Use</td>
<td>Deconstruction</td>
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<td>B6</td>
<td>B7</td>
<td>C1</td>
<td>C2</td>
<td>C3</td>
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<tr>
<td>D1</td>
<td>D2</td>
<td>D3</td>
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</tbody>
</table>

![Tally Logo](logo.png)

Figure 3. Life Cycle Stages as defined by EN 15978. Processes included in Tally modeling scope are shown in bold. Italics indicate optional processes.
Office / Retail
Type III-B over IA Construction, IBC 2015
P2: Concrete Mat Slab Foundation
P1, L1: Concrete Slabs
L2: Concrete Podium Slab
L3: Roof: Mass Timber
Concrete Cores
30’ x 30’ Grid
Office / Retail
Type III-B over IA Construction, IBC 2015
P2: Concrete Mat Slab Foundation
P1, L1: Concrete Slabs
L2: Concrete Podium Slab
L3- Roof: Mass Timber

Concrete Cores
30’ x 30’ Grid

PLATTE FIFTEEN
Denver, Colorado
The GWP is overwhelmingly dominated by this piece.

Floor assembly, (including topping) framing, columns.
Total GWP/M² Per Building System

- Mass Timber
- Steel
- Concrete

Materials:
- Wood
- Metals
- Concrete
- Masonry

Total GWP/M² Above Podium Slab Per Building System

- Mass Timber
- Steel
- Concrete

Materials:
- Wood
- Metals
- Concrete
- Masonry
Total GWP/M^2 Per Life Cycle Stage

Building Systems
- Mass Timber
- Steel
- Concrete
3490 km (2200 miles) from Quebec to Denver
Mix Assumptions for Wood:
- 63.5% Landfill
- 22.0% Incineration
- 14.5% Recycle
DOLLAR COST

VS

TIME COST

VS

CARBON COST
MATERIAL COST

Steel: Lowest = Baseline
Concrete: Middle
Mass Timber: Highest

DOLLAR COST

Cost Premium Over Steel (%)

<table>
<thead>
<tr>
<th>Material Installed</th>
<th>Concrete System</th>
<th>Mass Timber System</th>
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<tbody>
<tr>
<td>Raw Material Installed</td>
<td>3.27%</td>
<td>8.37%</td>
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</tbody>
</table>
MT CONSTRUCTION SPEED:
2,000 SF / DAY
6-8 WORKERS
Mass Timber: Baseline time

Steel: + 2 months

Concrete: + 3.5 months

**Cost Premium Over Steel (%)**

- **Raw Material Installed**:
  - Concrete System: 3.27%
  - Mass Timber System: 8.37%
- **Structure Construction**:
  - Concrete System: 3.9%
  - Mass Timber System: 4.89%
### Cost Premium Over Steel (%)

- **Concrete System**
  - Raw Material Installed: 3.27%
  - Structure Construction: 3.9%
  - Whole Building Construction: 1.55%

- **Mass Timber System**
  - Raw Material Installed: 8.37%
  - Structure Construction: 4.89%
  - Whole Building Construction: 1.95%

**Mass Timber:** Baseline time

**Steel:** + 2 months

**Concrete:** + 3.5 months
DOLLAR COST vs CARBON COST

Structural System GWP and Whole Building Cost (%)

- Mass Timber: Baseline
- Steel
- Concrete

The Gap

GWP vs Cost
CREDIT BUYER

DEVELOPMENT / BUILDING

CO₂

CO₂

CO₂

CO₂

CO₂

CREDIT BUYER

$
Mass Timber:
Baseline time

Steel:
+ 2 months

Concrete:
+ 3.5 months

DOLLAR COST & CARBON COST

Cost Premium Over Steel (%)

- Raw Material Installed:
  - Concrete System: 3.27%
  - Mass Timber System: 8.37% (Δ = $4.96 / sf)

- Structure Construction:
  - Concrete System: 3.9%
  - Mass Timber System: 4.89%

- Whole Building Construction:
  - Concrete System: 1.55%
  - Mass Timber System: 1.95%

Carbon Credit = $155,450 (0.35%)
Multifamily / Retail
Type IV-B Construction, IBC 2018 with Denver Amendments
12 Story
No below grade
L1: Drilled Piers + Concrete Slab on Grade
L2-L4: Concrete Slabs
L5 - Roof: Mass Timber
Concrete Cores
20’ x 20’ Grid

RETURN TO FORM
Denver, Colorado
Multifamily / Retail
Type IV-B Construction, IBC 2018 with Denver Amendments
12 Story
No below grade
L1: Drilled Piers + Concrete Slab on Grade
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Concrete Cores
20’ x 20’ Grid
MASS TIMBER (AS DESIGNED)

STEEL (CFS & DECK)

PT CONCRETE
Total GWP/M² Per Life Cycle Stage

- Mass Timber
- Steel
- Concrete
## Mass Timber

- **Substructure**: 28%
- **Superstructure**: 72%

## Steel

- **Substructure**: 22%
- **Superstructure**: 78%

## Concrete

- **Substructure**: 20%
- **Superstructure**: 80%
Maximum Stored Biogenic Carbon Potential

<table>
<thead>
<tr>
<th></th>
<th>CLT</th>
<th>GluLam Framing</th>
<th>GluLam Columns</th>
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<td>(120)</td>
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1738 Metric Ton of CO₂eq

= 4.3 Million Miles Driven by Standard Vehicle
= 240 First Class Roundtrip Flights from Denver to London
= 335 Homes’ Electricity Use for 1 Year
= 5 Minutes for US and Canadian Forests to Grow
Office / Retail
Type III-B over IA Construction, IBC 2015
7 Story
- P2: Concrete Mat Slab Foundation
- P1, L1: Concrete Slabs
- L2: Concrete Podium Slab
- L3: Roof: Mass Timber

Concrete Cores
30’ x 30’ Grid

Multifamily / Retail
Type IV-B Construction
12 Story
- No below grade
- L1: Drilled Piers + Concrete Slab on Grade
- L2-L4: Concrete Slabs
- L5: Roof: Mass Timber

Concrete Cores
20’ x 20’ Grid
HOW TO LEVERAGE MASS TIMBER IN DESIGN

• COST
  • GRID EFFICIENCY
  • PANEL OPTIMIZATION
  • BEARING & SCREWED CONNECTIONS
  • FINISHES

• PREFABRICATION
  • PANELIZED SYSTEM
  • COORDINATE & PRECUT

• SPEED OF CONSTRUCTION
  • CORE WALLS CRITICAL PATH
  • PREFABRICATED/ PANELIZED FAÇADE
  • PANEL SEQUENCING
  • TEMPORARY PROTECTION

• DESIGN FOR DISASSEMBLY / EASE OF DECONSTRUCTION & RECOVERY
MASS TIMBER IS SUSTAINABLE...

- LOW EMBODIED CARBON
- STORES CARBON
- RENEWABLE
- REUSABLE
- EASE OF DECONSTRUCTION & RECOVERY
• IS FAST
• IS QUIET
• IS LIGHTER
• REQUIRES LIMITED LABOR
• HAS LITTLE WASTE
• REDUCES CONSTRUCTION TRAFFIC

UNDER CONSTRUCTION, MASS TIMBER...
IN THE FINISHED BUILDING, MASS TIMBER...

- IS HEALTHY - CREATES BIOPHILIC ENVIRONMENT
- NATURAL AESTHETIC
- HIGH LEASE RATES
- HIGH LEASING VELOCITY
- ADVANCES DEVELOPER BRANDING, ESG COMMITMENTS
- EARN CARBON CREDITS, GREEN FINANCING
MASS TIMBER INDUSTRY...

- ENCOURAGES FOREST HEALTH & MAINTENANCE
- SUPPORTS RURAL ECONOMIES
- LEVERAGES BIOMIMICRY
- RESPONDS TO SOCIETAL DEMAND FOR SUSTAINABLE CONSUMER PRODUCTS
THANK YOU

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