
Photo: Structurlam

WOODWORKS
WOOD PRODUCTS COUNCIL

The Carbon Footprint of Wood Buildings

Presented by
Marc Rivard, WoodWorks
December 14, 2021

AIA CES Course

"The Wood Products Council" is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES), Provider #G516.

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Issues surrounding carbon are in the forefront of many building designers' minds. As a result, questions can arise as to what building products should be specified to help achieve a more sustainable structure. This course takes a brief look at the use of wood in construction and highlights some of the positive environmental benefits that it can bring to the building. Basic terminology surrounding carbon will be reviewed along with information on carbon sequestration in wood. Case studies showing the benefits of wood will be presented along with a short survey of carbon policy around the U.S.

Learning Objectives

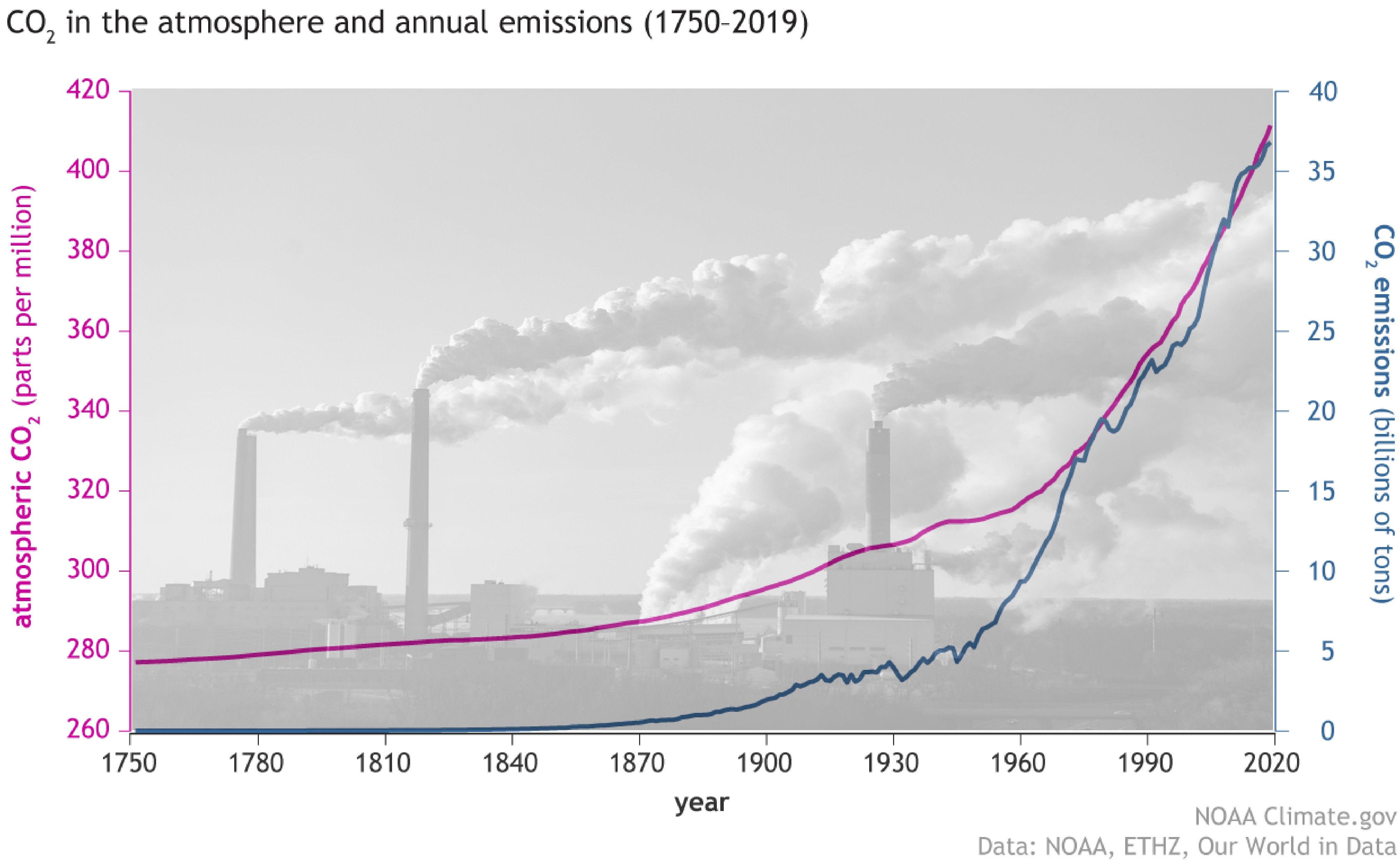
1. Review carbon basics and how material choice is related to sustainability.
2. Learn how wood products can be beneficial for the environment.
3. Understand carbon storage in wood products.
4. Evaluate case studies highlighting the benefits of wood construction.

Climate Change Background

Rising Temperatures and Melting Glaciers

From Rising Waters to Catastrophic Wildfires

Carbon & Greenhouse Gas Emissions



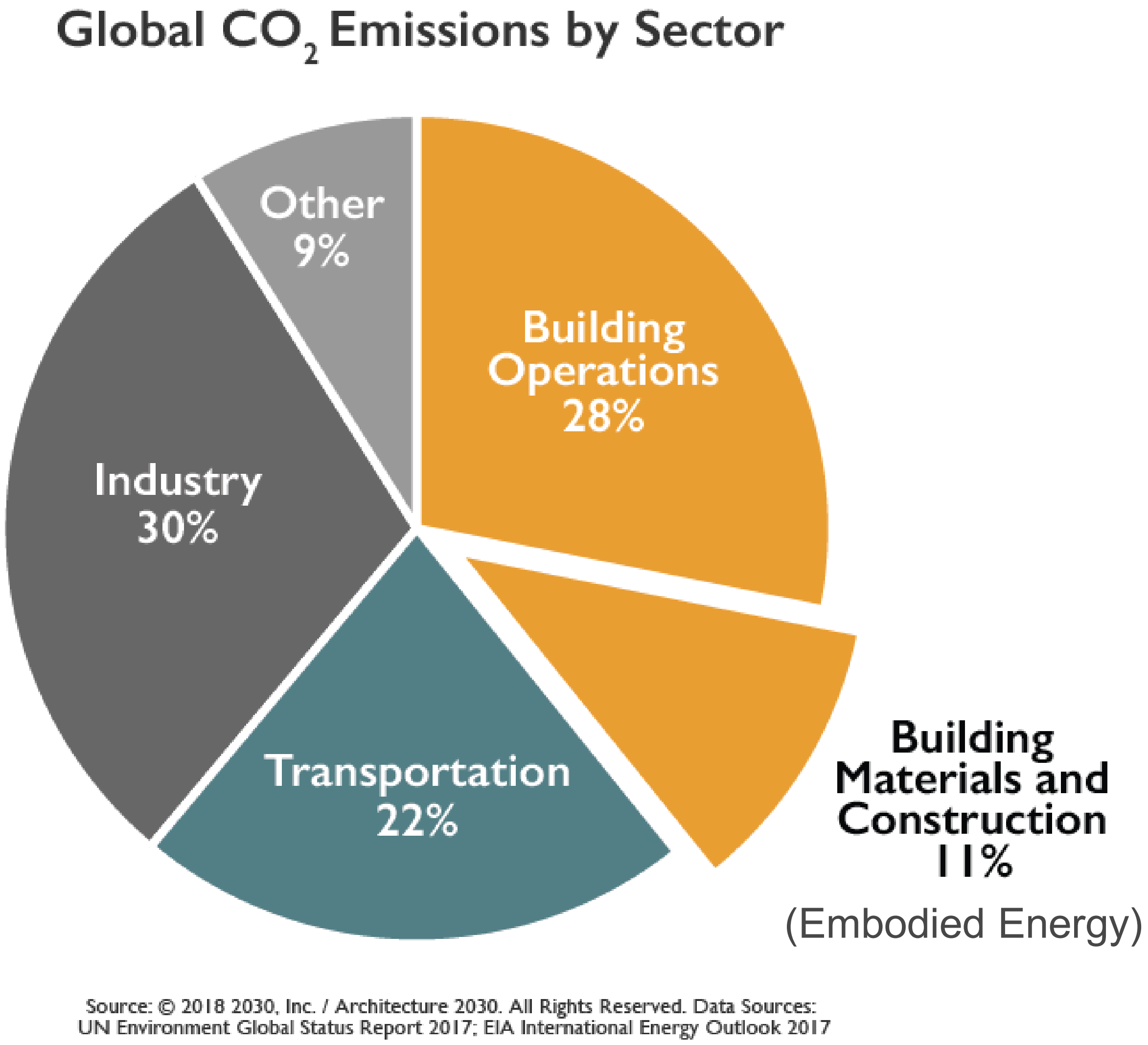
Global Population Increase

2050 = 9.9 billion people

2020 = 7.8 billion people

Source: www.prb.org

New Buildings & Greenhouse Gases



Buildings generate nearly **40%** of annual global greenhouse gas emissions (*building operations* + *embodied energy*)

Embodied energy: **11%**

Concrete, iron, steel **~9%**

Image: Architecture 2030

US Climate Policy

In the absence of strong Federal Policy, states and municipalities have adopted their own regulations

- CA: Buy Clean California – first US law to address embodied carbon in construction materials
    - GWP must not exceed set limits
    - Currently targets structural steel, steel rebar, glass, and mineral wool

Federal Policy is advancing under the Biden Administration:

- Rejoining the Paris Agreement
- Several first-week executive actions aimed at advancing zero-carbon technologies, increasing reforestation and carbon sequestration

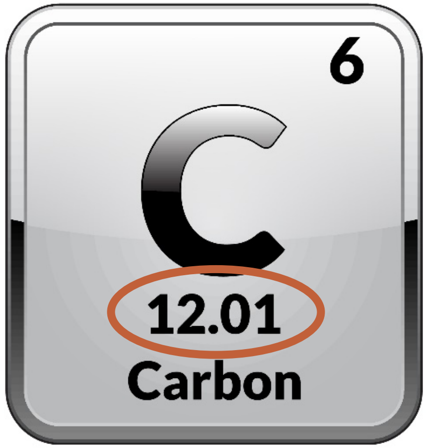
Measuring Greenhouse Gases

Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The time period usually used for GWP's is 100 years. (EPA)

	GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	28-36
Nitrous Oxide (N_2O)	265-298
Fluorinated Gases	Thousands to Tens of Thousands

Carbon Dioxide Equivalents (CO_{2eq}) = International standard practice is to express greenhouse gases in terms of CO_2 equivalents

Carbon vs CO_2



+ 2 *

= 44 CO_2

1 ton Carbon ≠ 1 ton CO_2

1 ton Carbon = (44/12=) 3.67 tons CO_2

Carbon Terms

- **Embodied Carbon**: Carbon emissions associated with the entire life cycle of the building including harvesting, mining, manufacturing, transporting, installing, maintaining, decommissioning, and disposing/reuse of a material or product
- **Operational Carbon**: Carbon emissions associated with operating a building including power, heat, and cooling

Image: Boston Society for Architecture

Embodied Carbon

- Primarily related to **manufacturing of materials**
- More significant than many people realize, has been **historically overlooked**
- Big upfront GHG “cost” - which makes it a **good near-term target** for climate change mitigation

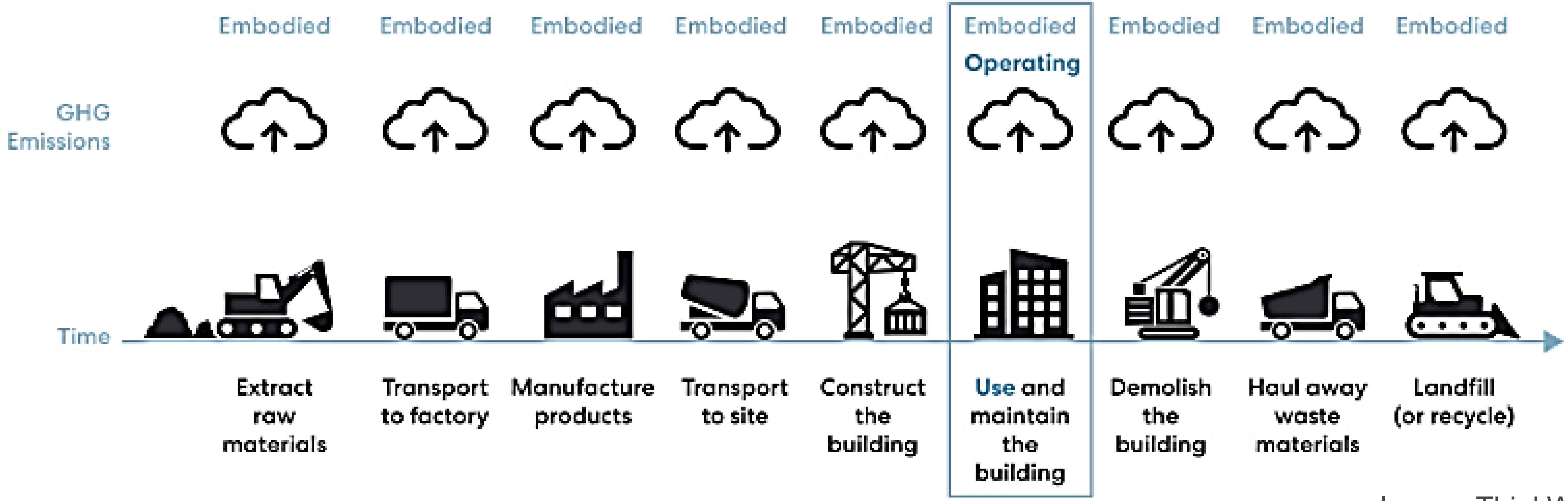


Image: ThinkWood

Embodied vs. Operational Energy

Traditional Non-Wood Building

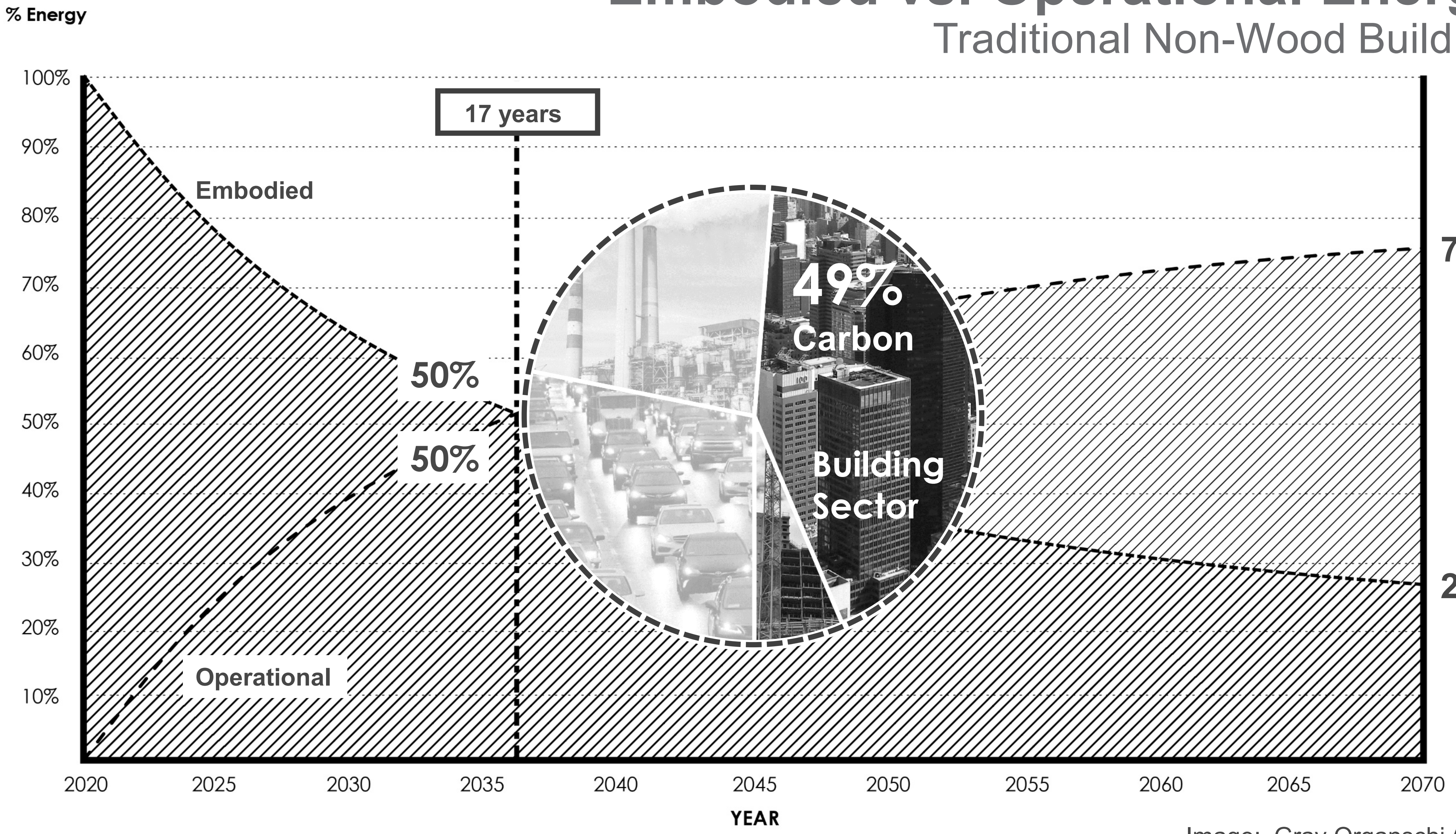


Image: Gray Organschi Architecture

Embodied Energy vs Embodied Carbon

Embodied Energy:

Amount of energy used to:

- Extract, harvest, mine resources
- Process and assemble materials
- Transport products
- Construct building
- Maintain and repair building
- Deconstruct building and dispose or recycle materials

Embodied Carbon:

Carbon emissions resulting from:

- Combustion of fuels to generate embodied energy
- Chemical reactions

Carbon emissions may be offset by:

- Carbon sequestration during growth or manufacturing*

* Sequestered carbon may be included in embodied carbon calculation or considered separately.

How Does Wood Fit in?

Carbon Benefits of Wood

- **Less energy intensive** to manufacture than steel or concrete
- **Less fossil fuel consumed** during manufacture
- **Avoid process emissions**
- Carbon **storage in forests** and **promote forest health**
- Extended carbon **storage in products**

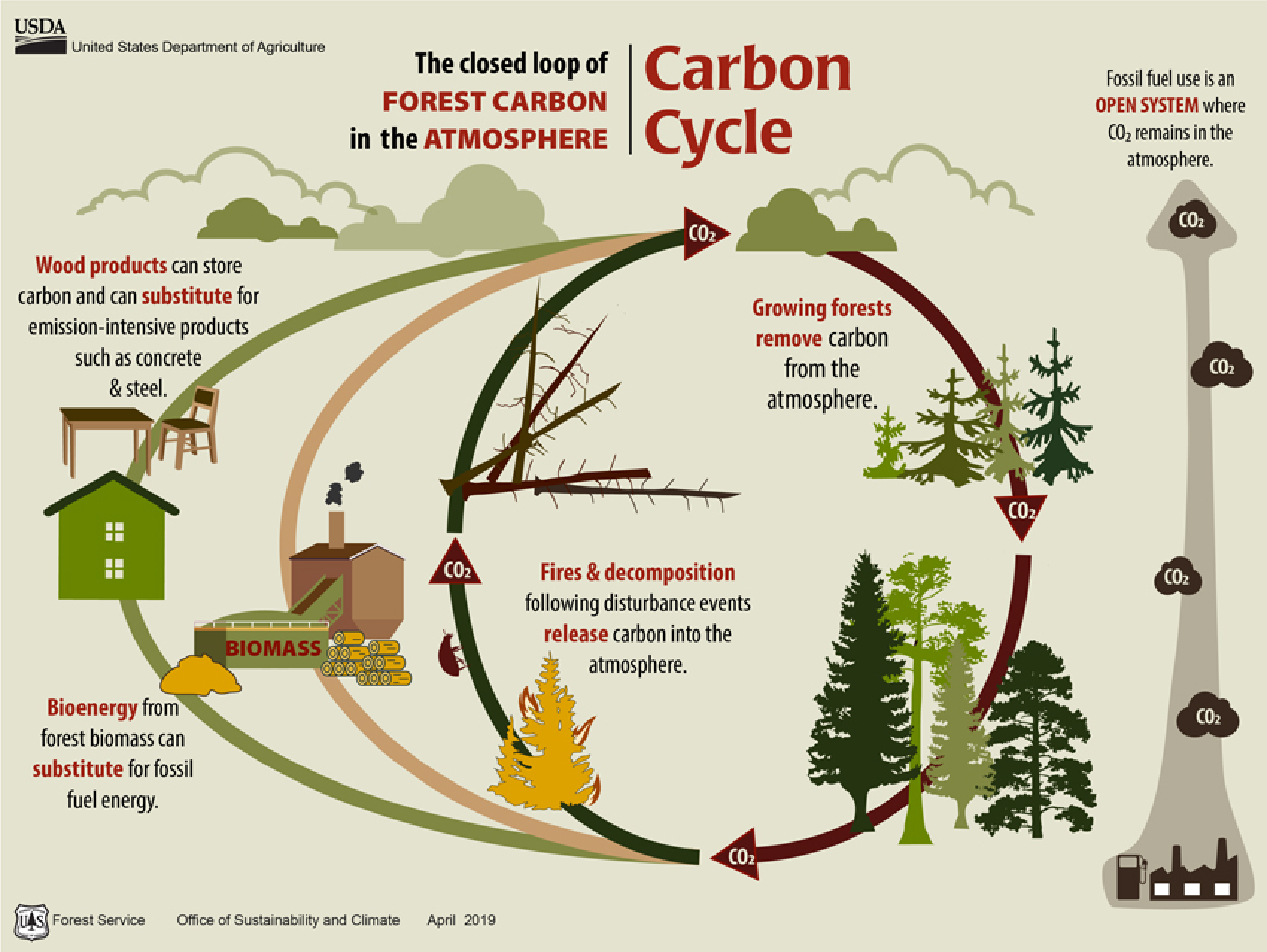


Image: USDA US Forest Service

More Carbon Terms

Carbon Sequestration: The process by which CO_2 is **removed** from the atmosphere and deposited in solid or liquid form in oceans, living organisms, or land.

Carbon Storage: Carbon is **stored as a solid** in the form of plant material: roots, trunks, branches, stems, and leaves. It can continue to be stored in **wood building materials**.

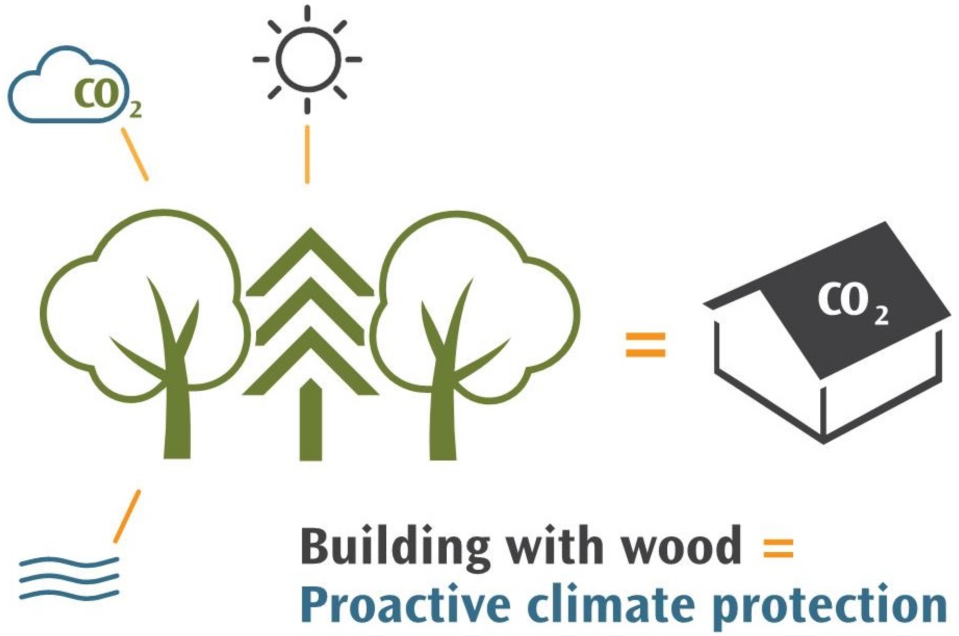
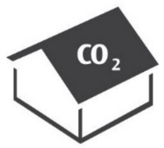
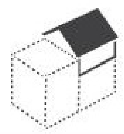
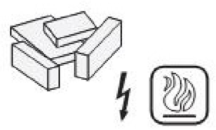


Image: Dovetail Partners, Inc.

Carbon Storage

Wood ≈ 50% Carbon (dry weight)

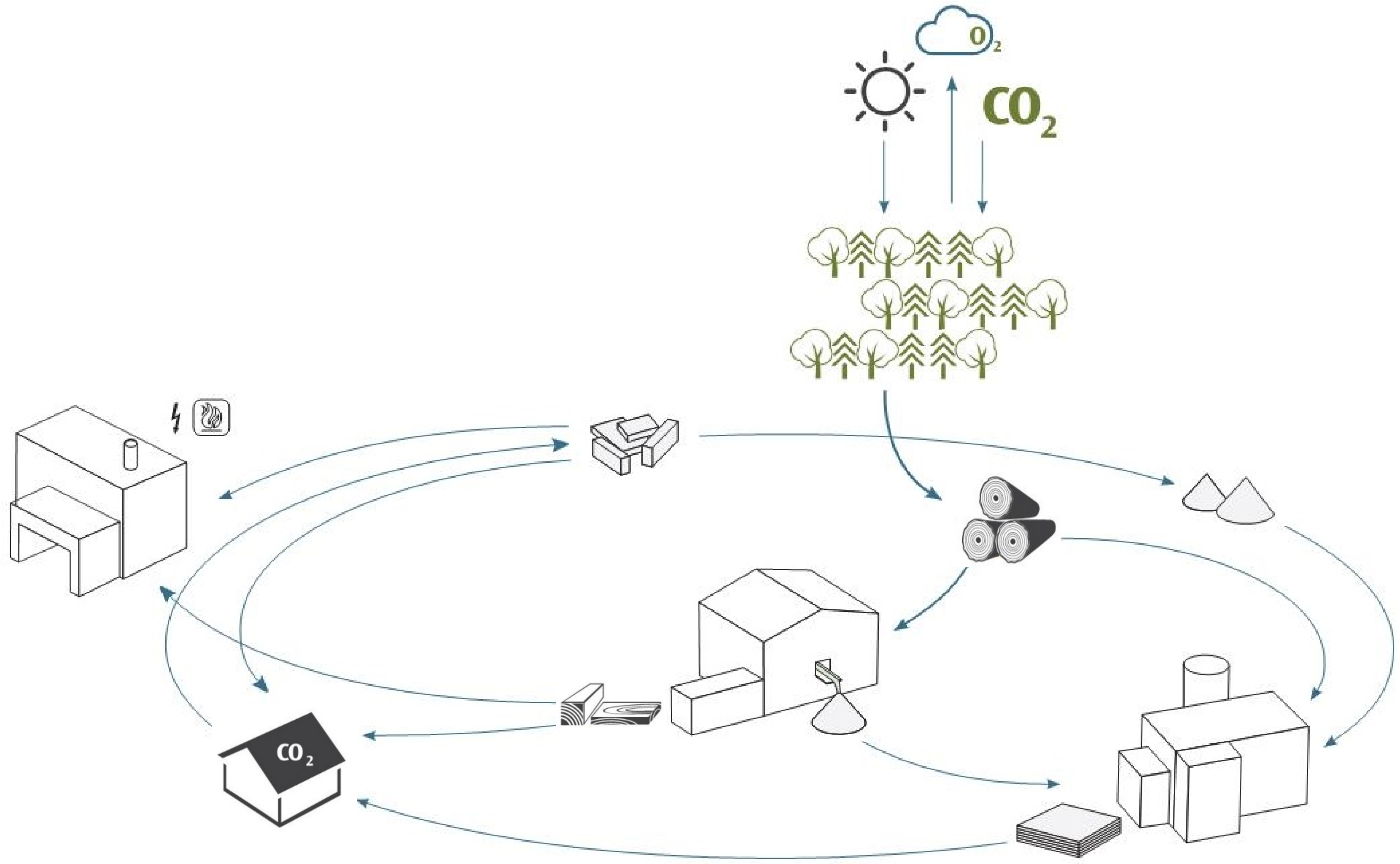
Long-Term Positive Effects

		Energy effect	Carbon effect	Value-added effect
	**Forest**	Stores solar energy	Removes C from Atmosphere	**Increases forest value;** supplies wood
	**Timber**	Often local, short transit	C in raw material	**Strengthens rural economies**
	**Lumber**	**Low embodied energy**	**Stores C**; replaces materials w/ greater C impact	Supports energy independence; strengthens US Forestry
	**Wood structure**	**Low thermal conductivity** & bridging	**Stores C**; reduces insulation / GHG emissions	**Cost effective** & provides **biophilic environment**
	**Modernization, refurbishment, urban densification**	**Lightweight** & easy to transport	**More C storage**	Increasing use of prefab; saves resources & retains value
	**Demo, recycling, energy recovery**	Low energy recycling or emissions neutral energy recovery	Extended C fixation due to recycling	**Innovative solutions for circular economy**

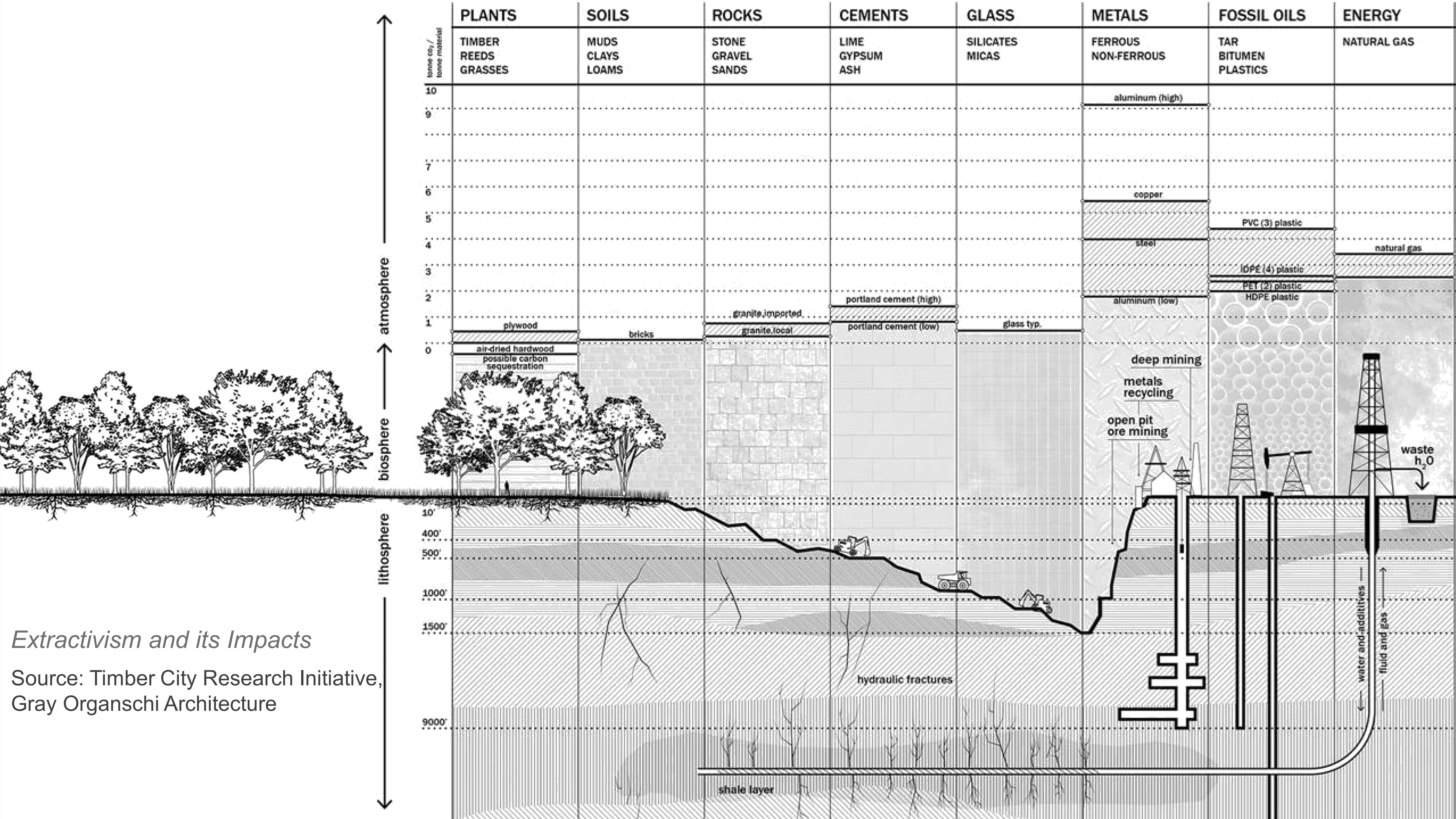
Source: Building with Wood – Proactive Climate Protection, Dovetail Partners, Inc.

Carbon Cycle

Renewable Resource | Carbon Sequestration



Source: Building with Wood – Proactive Climate Protection, Dovetail Partners, Inc.



Extractivism and its Impacts

Source: Timber City Research Initiative, Gray Organschi Architecture

Specifics of Carbon Storage

Where is Carbon Stored?

Harvested Wood Pools

- Harvested Wood Products
- Solid Waste Disposal Sites

Forest Pools

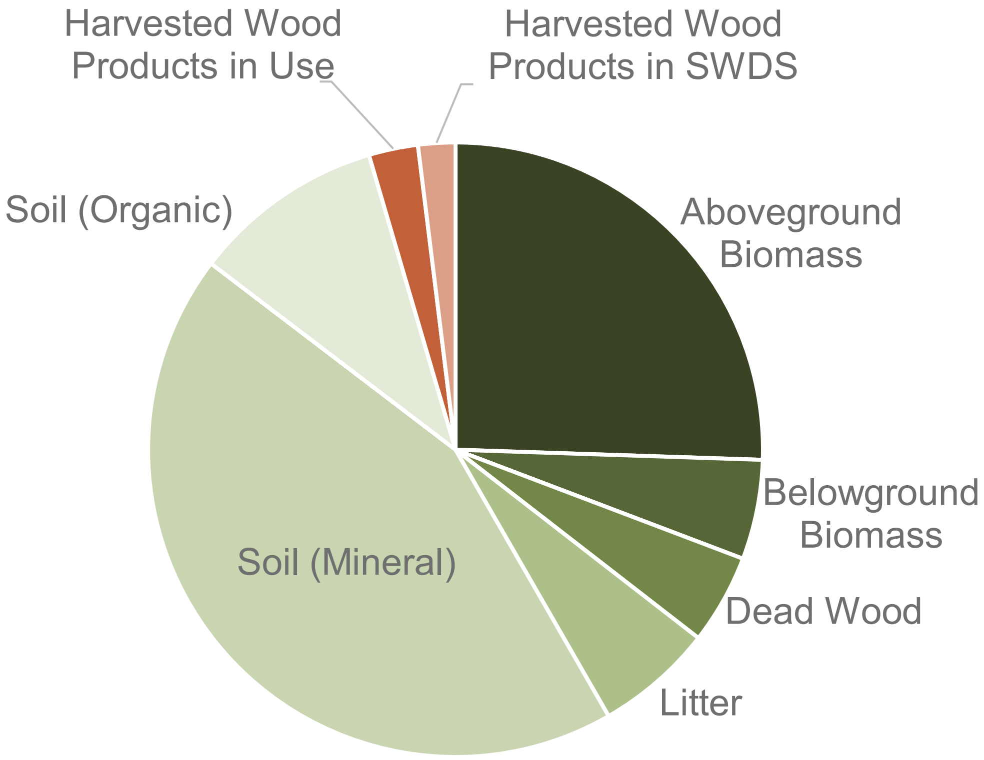
- Aboveground Biomass
- Belowground Biomass
- Dead Wood
- Litter or Forest Floor
- Soil Organic Carbon


Image: naturallywood.com

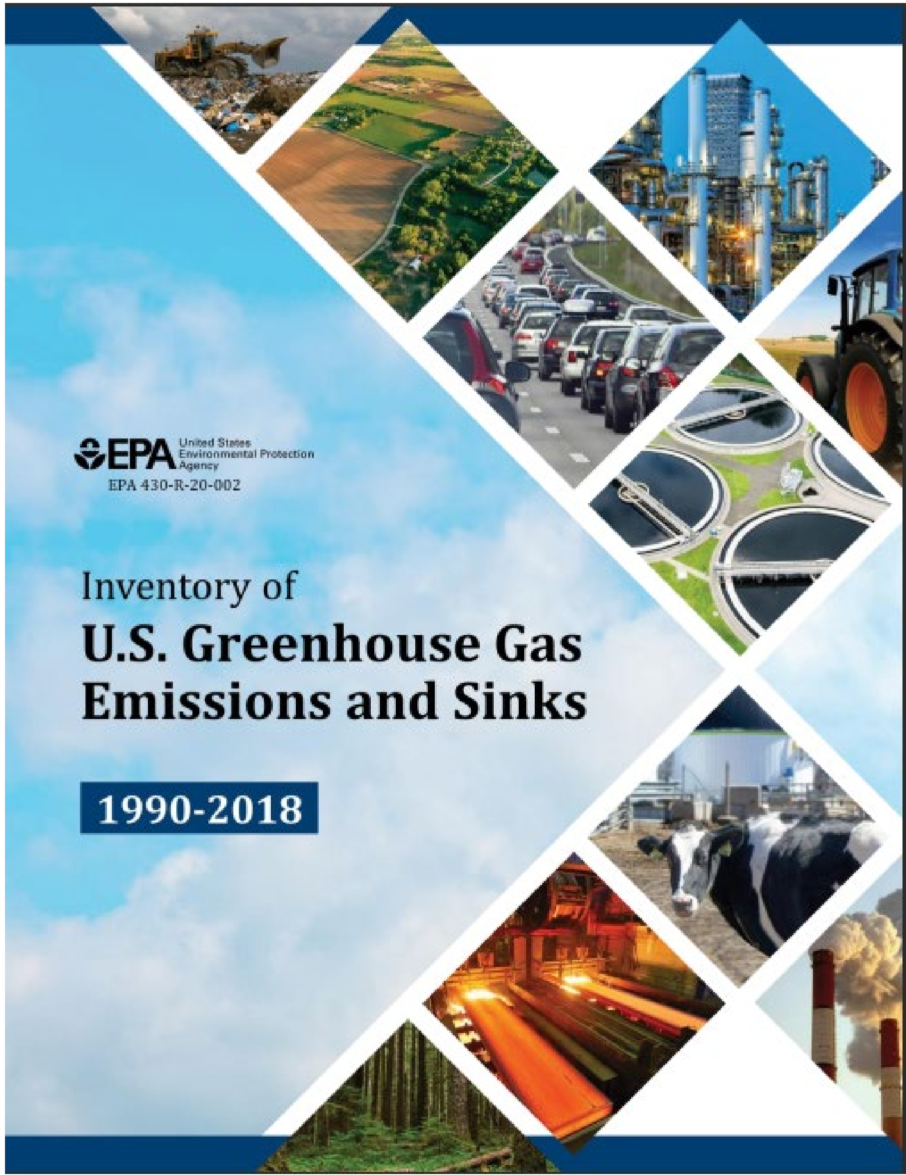
Source: https://usaforests.org/

Carbon Storage in Harvested Wood Products

As of 2019, the carbon stock for Harvested **Wood Products in Use** in the conterminous 48 states is estimated at **1,521 Million Metric Tons**.



Carbon Stocks in Forest Land and Harvested Wood Pools, 2019



https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

Table 6-12: Forest Area (1,000 ha) and C Stocks in *Forest Land Remaining Forest Land* and Harvested Wood Pools (MMT C)

	1990	2005	2015	2016	2017	2018	2019
Forest Area (1,000 ha)	***279,748***	***279,749***	***280,041***	***280,041***	***279,893***	***279,787***	***279,682***
Carbon Pools (MMT C)							
Forest Ecosystem	**51,527**	**53,886**	**55,431**	**55,592**	**55,746**	**55,897**	**56,051**
Aboveground Biomass	11,833	13,484	14,561	14,672	14,780	14,884	14,989
Belowground Biomass	2,350	2,734	2,982	3,008	3,033	3,056	3,081
Dead Wood	2,120	2,454	2,683	2,707	2,731	2,753	2,777
Litter	3,662	3,647	3,638	3,639	3,639	3,640	3,641
Soil (Mineral)	25,636	25,639	25,640	25,640	25,637	25,637	25,638
Soil (Organic)	5,927	5,929	5,927	5,927	5,926	5,926	5,926
Harvested Wood	**1,895**	**2,353**	**2,567**	**2,591**	**2,616**	**2,642**	**2,669**
Products in Use	1,249	1,447	1,490	1,497	1,505	1,513	1,521
SWDS	646	906	1,076	1,094	1,112	1,129	1,148
Total C Stock	**53,423**	**56,239**	**57,998**	**58,183**	**58,362**	**58,539**	**58,720**

Notes: Forest area and C stock estimates include all *Forest Land Remaining Forest Land* in the conterminous 48 states

https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

Harvested Wood Products

- **Solid sawn** wood products have the lowest level of embodied energy.

- Wood products requiring more processing steps (for example, plywood, engineered wood products, flake-based products) require more energy to produce but still require **significantly less energy** than their non-wood counterparts.

Source: USFPL Wood Handbook; Wood as a Sustainable Building Material

Image: Weyerhaeuser

Image: LP Building Solutions

Image: Structurecraft

Image: Georgia-Pacific

Tools to Evaluate Carbon Impact

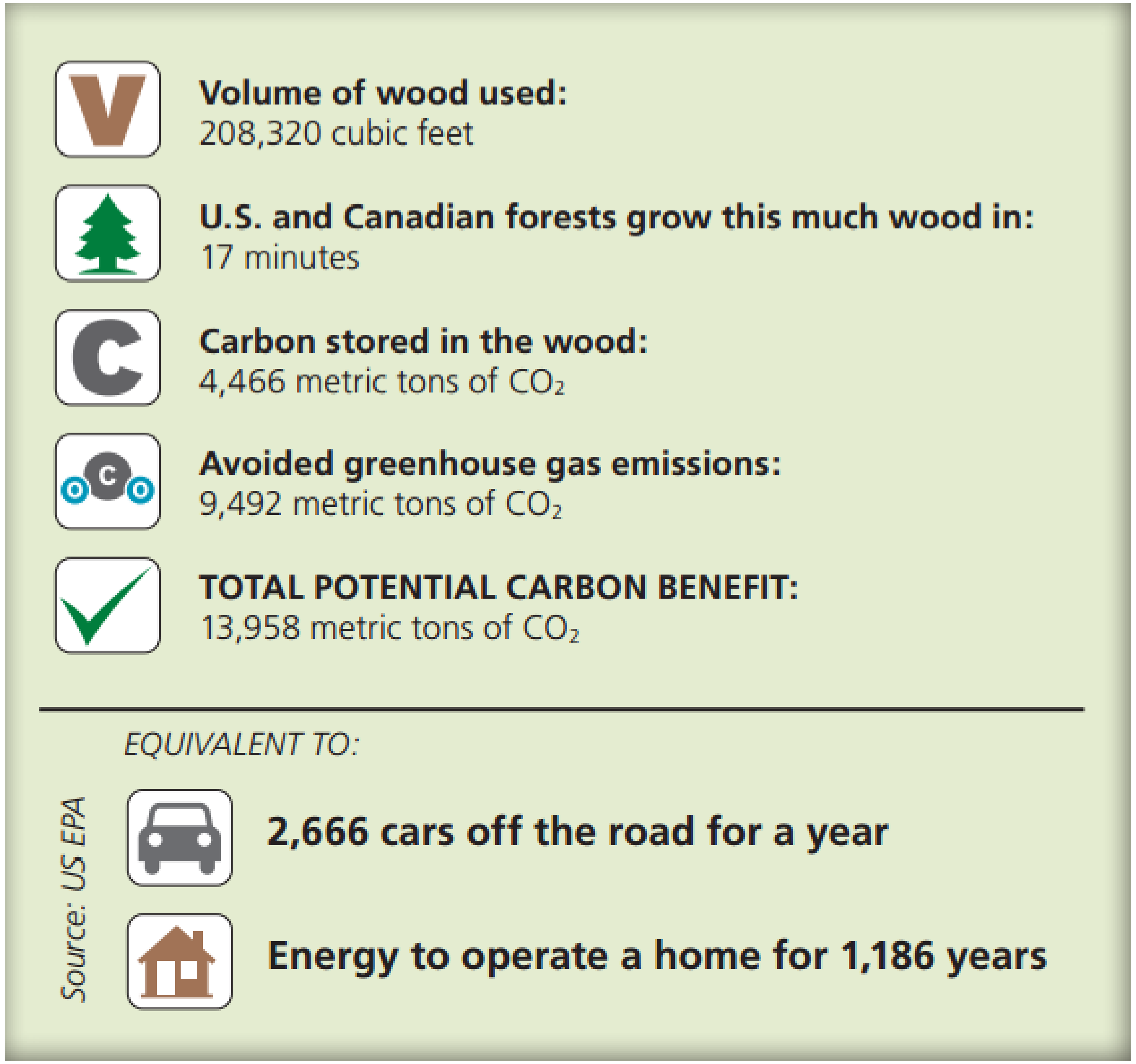
Whole Building Life Cycle Analysis (WBLCA)

"Evaluation of the inputs, outputs, and potential environmental impacts… throughout its life cycle"

- WBLCA covers all stages in the life cycle of a building and its components
- Several tools available; various methodologies
- https://www.thinkwood.com/education/calculate-wood-carbon-footprint
- https://www.thinkwood.com/blog/understanding-the-role-of-embodied-carbon-in-climate-smart-buildings

WoodWorks Carbon Calculator

- Available at **woodworks.org**
- Estimates total wood mass in a building
- Relays **estimated** carbon impacts:
  - Amount of **carbon stored** in wood
  - Amount of **greenhouse gas emissions avoided** by choosing wood over a non-wood material

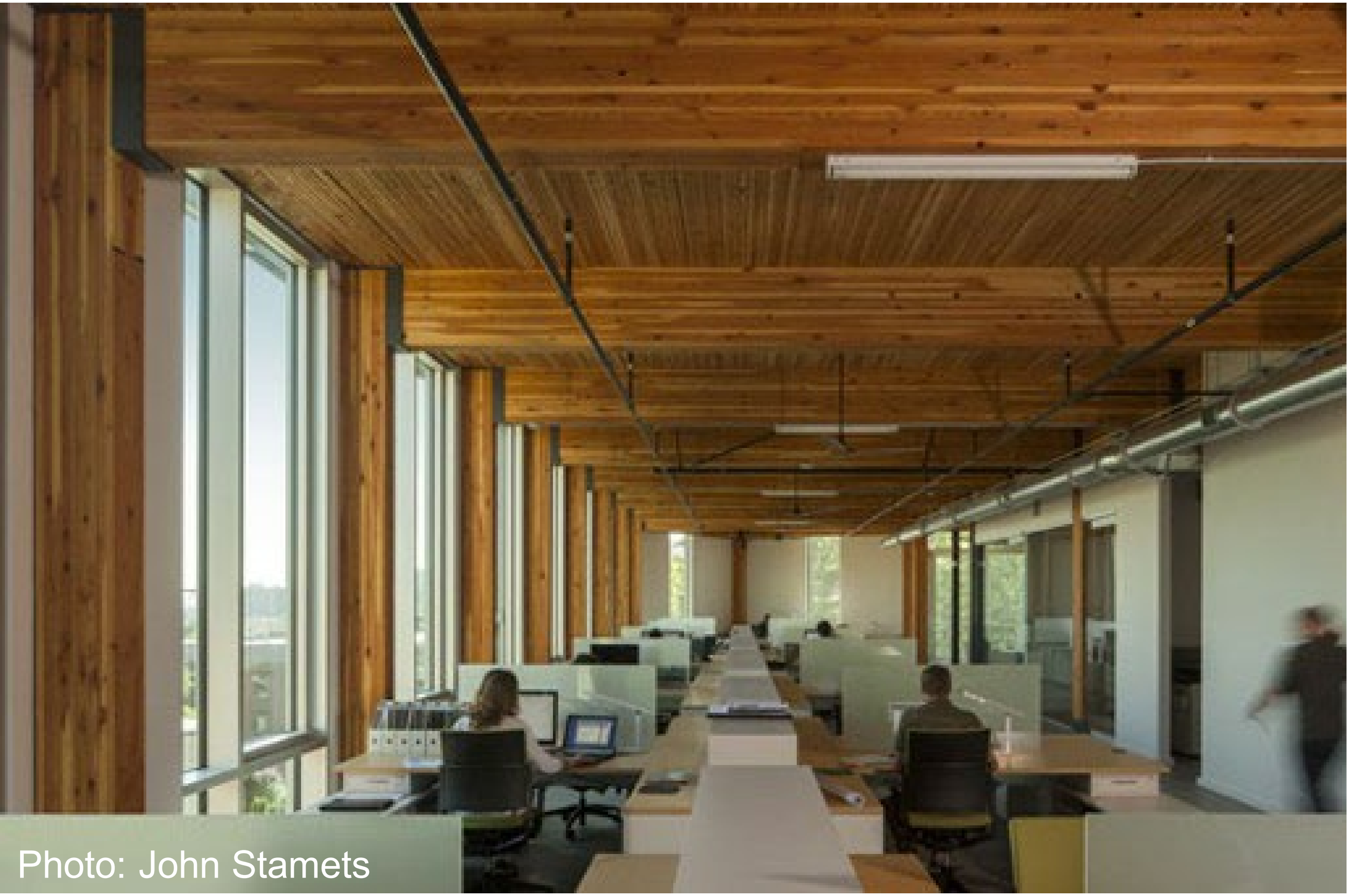


WoodWorks™
WOOD PRODUCTS COUNCIL

http://www.woodworks.org/carbon-calculator-download-form/

Case Studies

Bullitt Center
Seattle, WA



Architect: The Miller Hull Partnership
Structural Engineer: DCI Engineers

IV (HT)

- Designed for a **250-year** life span
- Met criteria for **Living Building Challenge 2.0**
- Rooftop photovoltaic cells generate electricity for the building; building recycles its own water
- 6 over 2 design; 52,000 sf
- Heavy timber frame: glulam and NLT panels

Bullitt Center
Seattle, WA

Volume of wood used:
24,526 cubic feet

U.S. and Canadian forests grow this much wood in:
2 minutes

Carbon stored in the wood:
545 metric tons of CO_2

Avoided greenhouse gas emissions:
1,158 metric tons of CO_2

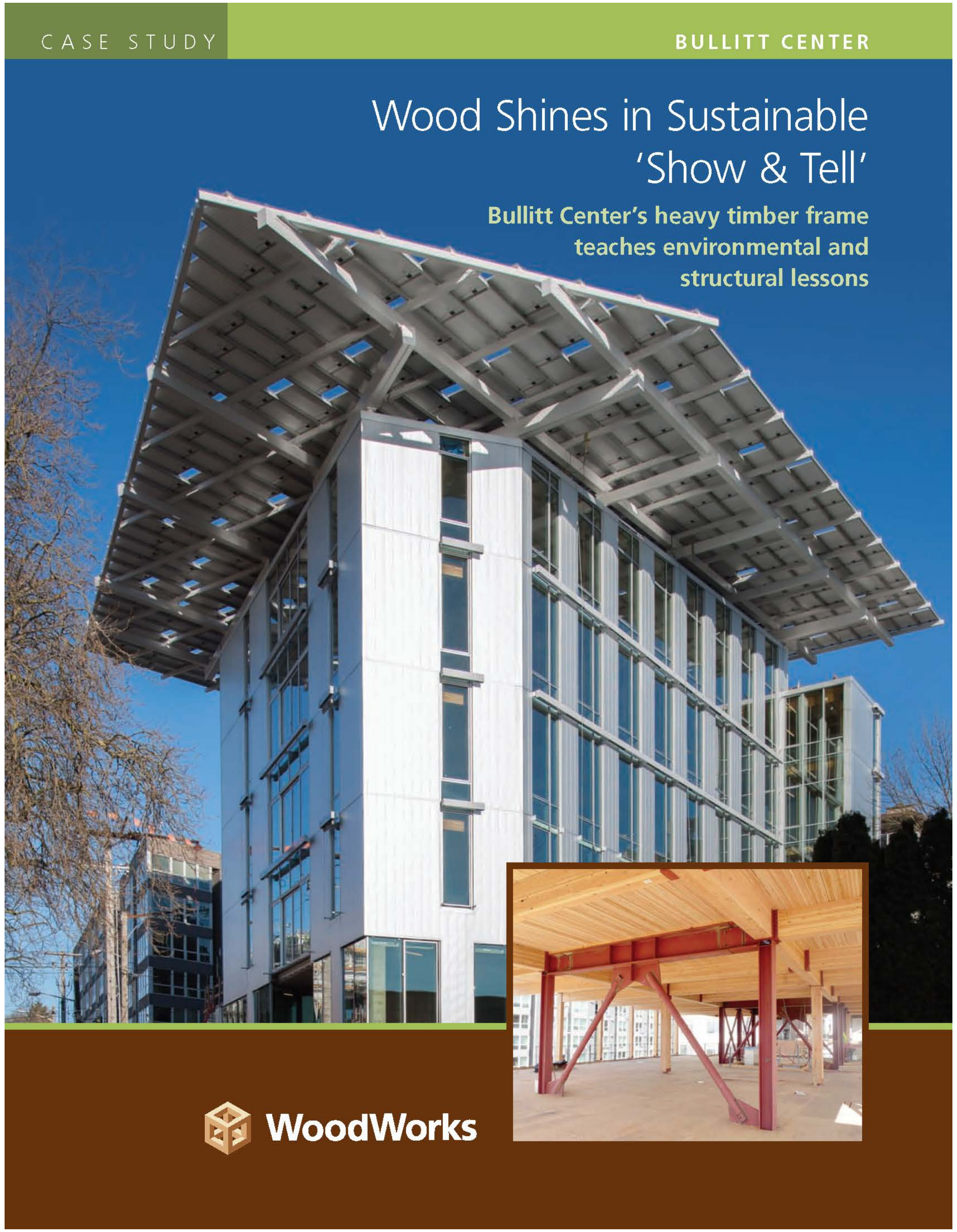
TOTAL POTENTIAL CARBON BENEFIT:
1,703 metric tons of CO_2

EQUIVALENT TO:

325 cars off the road for a year

Energy to operate a home for 145 years

Source: US EPA



Bullitt Center

Seattle, WA

Volume of wood used:
24,526 cubic feet

U.S. and Canadian forests grow this much wood in:
2 minutes

Carbon stored in the wood:
545 metric tons of CO_2

Avoided greenhouse gas emissions:
1,158 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,703 metric tons of CO_2

EQUIVALENT TO:

325 cars off the road for a year

Energy to operate a home for 145 years

Source: US EPA

Volume of wood:
Based on user inputs

Volume of Wood → Volume of Logs → Volume of Trees → Tree Growth Rate

Volume of Wood → Mass of Wood → Mass of Carbon (50% of wood) → Mass of CO_2 (3.67 x mass of Carbon)

Candlewood Suites
Redstone Arsenal, AL


Photo: IHG Army Hotels, Lendlease

Architect: Lendlease
Project Engineer: Schaefer Structural Engineers

IIIB

- 4 stories; 62,688 sf
- **First CLT hotel** in USA
- **37% faster** overall construction
- 40% fewer construction workers
- Trained unemployed veterans

Candlewood Suites

Redstone Arsenal, AL

Photo: IHG Army Hotels, Lendlease

Carbon Benefits

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed by the tree while growing, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and reused or manufactured into other products. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood products used:
935,696 board feet (equivalent)

U.S. and Canadian forests grow this much wood in:
5 minutes

Carbon stored in the wood:
1,276 metric tons of CO_2

Avoided greenhouse gas emissions:
494 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,770 metric tons of CO_2

EQUIVALENT TO:

374 cars off the road for a year

Energy to operate 187 homes for a year

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Candlewood Suites
Redstone Arsenal, AL

Emissions avoided by choosing wood over alternative building material based on building type

Total Potential Carbon Benefit = Carbon Stored + Emissions Avoided

Convert Total Potential Carbon Benefit to laymen's terms like emissions from operating a car or a home

Carbon Benefits

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed by the tree while growing, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and reused or manufactured into other products. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood products used:
935,696 board feet (equivalent)

U.S. and Canadian forests grow this much wood in:
5 minutes

Carbon stored in the wood:
1,276 metric tons of CO_2

Avoided greenhouse gas emissions:
494 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,770 metric tons of CO_2

EQUIVALENT TO:

374 cars off the road for a year

Energy to operate 187 homes for a year

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Crescent Terminus
Atlanta, GA

Project Architect: Lord Aeck Sargent
Structural Engineer: SCA Consulting Engineers

IIIA

- 5 stories wood over 3 stories of concrete parking (Type IA podium)
- Savings by using wood could be spent on **luxury amenities**
- Dedication to **sustainable investments**
- Flexibility in design
- **Rooftop gardens** supported by wood trusses

Crescent Terminus
Atlanta, GA

Photo: Crescent Communities

Project Architect: Lord Aeck Sargent
Structural Engineer: SCA Consulting Engineers

Volume of wood products used:
3.1 million board feet (equivalent)

U.S. and Canadian forests grow this much wood in:
16 minutes

Carbon stored in the wood:
4,327 metric tons of CO_2

Avoided greenhouse gas emissions:
9,196 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
13,523 metric tons of CO_2

EQUIVALENT TO:

2,583 cars off the road for a year

Energy to operate a home for 1,149 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Arena Stage at the Mead Center for American Theater

Washington, DC

Photo: Nic Lehoux

- 200,000 square feet
- First modern structure to use heavy timber in DC
- **Hybrid wood & glass enclosure** around 2 existing historic structures
- Wood columns did **double-duty** to support roof gravity loads *and* façade wind loads
- Exposed wood **saved money** on finishes

Architect: Bing Thom Architects
Base Building Structural Engineer:
Fast+Epp Structural Engineers
Specialty Timber Façade Design-Builder:
StructureCraft Builders, Inc.

Arena Stage at the Mead Center for American Theater

Washington, DC

Bing Thom Architects | Fast + Epp | Photo: Nic Lehoux

Volume of wood used:
8,800 cubic feet of panel and engineered wood products

U.S. and Canadian forests grow this much wood in:
1 minute

Carbon stored in the wood:
215 metric tons of CO_2

Avoided greenhouse gas emissions:
460 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
675 metric tons of CO_2

EQUIVALENT TO:

129 cars off the road for a year

Energy to operate a home for 58 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

Herrington Recovery Center – Roger's Memorial Hospital

Oconomowoc, WI

- 3 stories; 21,000 square feet, 20 bed treatment facility
- Safe, confidential facility
- Institutional building with a **residential feel**
- Serene, spiritual environment; **biophilic** properties of wood
- LEED Silver
- **Locally available** wood products

Architect: TWP Architecture
Structural Engineer: Pujara Wirth Torke, Inc.

Herrington Recovery Center – Roger's Memorial Hospital

Oconomowoc, WI

Photo: Tom Davenport

Architect: TWP Architecture
Structural Engineer: Pujara Wirth Torke, Inc.

Volume of wood used:
9,500 cubic feet of panel and engineered wood products

U.S. and Canadian forests grow this much wood in:
1 minute

Carbon stored in the wood:
230 metric tons of CO_2

Avoided greenhouse gas emissions:
480 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
710 metric tons of CO_2

EQUIVALENT TO:

135 cars off the road for a year

Energy to operate a home for 60 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

El Dorado High School
El Dorado, AR

IIIA

Photo: Dennis Ivy

- 322,500 square feet
- **$2.7 million savings** by switching from steel and masonry to wood
- **Exposed wood** to acknowledge Arkansas landscape and provide enriching educational space
- Barrel-vaulted roof with exposed **glulam bowstring trusses** in the arena

Architect: CADM Architecture, Inc.
Structural Engineer: Engineering Consultants, Inc.

El Dorado High School
El Dorado, AR

Photo: W.I. Bell

Architect: CADM Architecture, Inc.
Structural Engineer: Engineering Consultants, Inc.

Carbon Benefits

For more information on the calculations below, visit woodworks.org.

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed during the tree's growing cycle, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and used elsewhere. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood used:
4,340 cubic meters / 153,140 cubic feet of lumber, panels and engineered wood

U.S. and Canadian forests grow this much wood in:
13 minutes

Carbon stored in the wood:
3,660 metric tons of CO_2

Avoided greenhouse gas emissions:
7,780 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
11,440 metric tons of CO_2

EQUIVALENT TO:

2,100 cars off the road for a year

Energy to operate a home for 970 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent

The Long Hall
Whitefish, MT


Photo: gravityshots.com, Innovative Timber Systems, LLC

VB

- 4,863 square feet, 2 stories
- CLT **cost competitive** with CMU
- **Aesthetic**, **thermal**, and **environmental** benefits
- **5 days** to erect wood structure; prefab benefits on tight site
- CLT walls with1-hr fire rating
- 25' clear span w/ glulam beams

Designer: Datum Design Drafting
Structural Engineer: DSB Engineering & Consulting, P.C.

The Long Hall
Whitefish, MT


Photo: Innovative Timber Systems, DSB Engineering & Consulting

Volume of wood products used:
148 cubic meters/5,227 cubic feet of CLT and glulam

U.S. and Canadian forests grow this much wood in:
26 seconds

Carbon stored in the wood:
104 metric tons of CO_2

Avoided greenhouse gas emissions:
59 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
163 metric tons of CO_2

EQUIVALENT TO:

31 cars off the road for a year

Energy to operate a home for 14 years

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, *based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent. Results from this tool are estimates only. Detailed life cycle assessments (LCA) are required to accurately determine a building's carbon footprint.*

1430 Q
Sacramento, CA

IIIA

- **6 stories of wood + mezzanine** over 2-story concrete podium (IIIA over IA)
- 63,000 square feet
- **First** of its kind in USA
- Needed 6 floors of residential units to make the project viable
- Concrete and steel were too expensive

Architect: HRGA, The HR Group Architects
Structural Engineer: Buehler

1430 Q
Sacramento, CA

Photo: Gary Folkins

1430 Q

Volume of wood products used:
1,708 cubic meters (60,334 cubic feet)

U.S. and Canadian forests grow this much wood in:
5 minutes

Carbon stored in the wood:
1,426 metric tons of CO_2

Avoided greenhouse gas emissions:
3,031 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
4,457 *metric tons of* CO_2

EQUIVALENT TO:

942 cars off the road for a year

Energy to operate 471 homes for a year

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 *on this chart refers to* CO_2 *equivalent.*

Forest to Cities

A Systemic Solution in Action

www.ForesttoCities.org

Marc Rivard, SE, PE
Marc.rivard@woodworks.org
6179973890

This concludes The American Institute of Architects Continuing Education Systems Course

Photo: Structurlam | Seagate Structures