



The Carbon Footprint of Wood Buildings

Presented by
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AIA CES Course



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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

CLIMATE

Rising Temperatures and Melting Glaciers

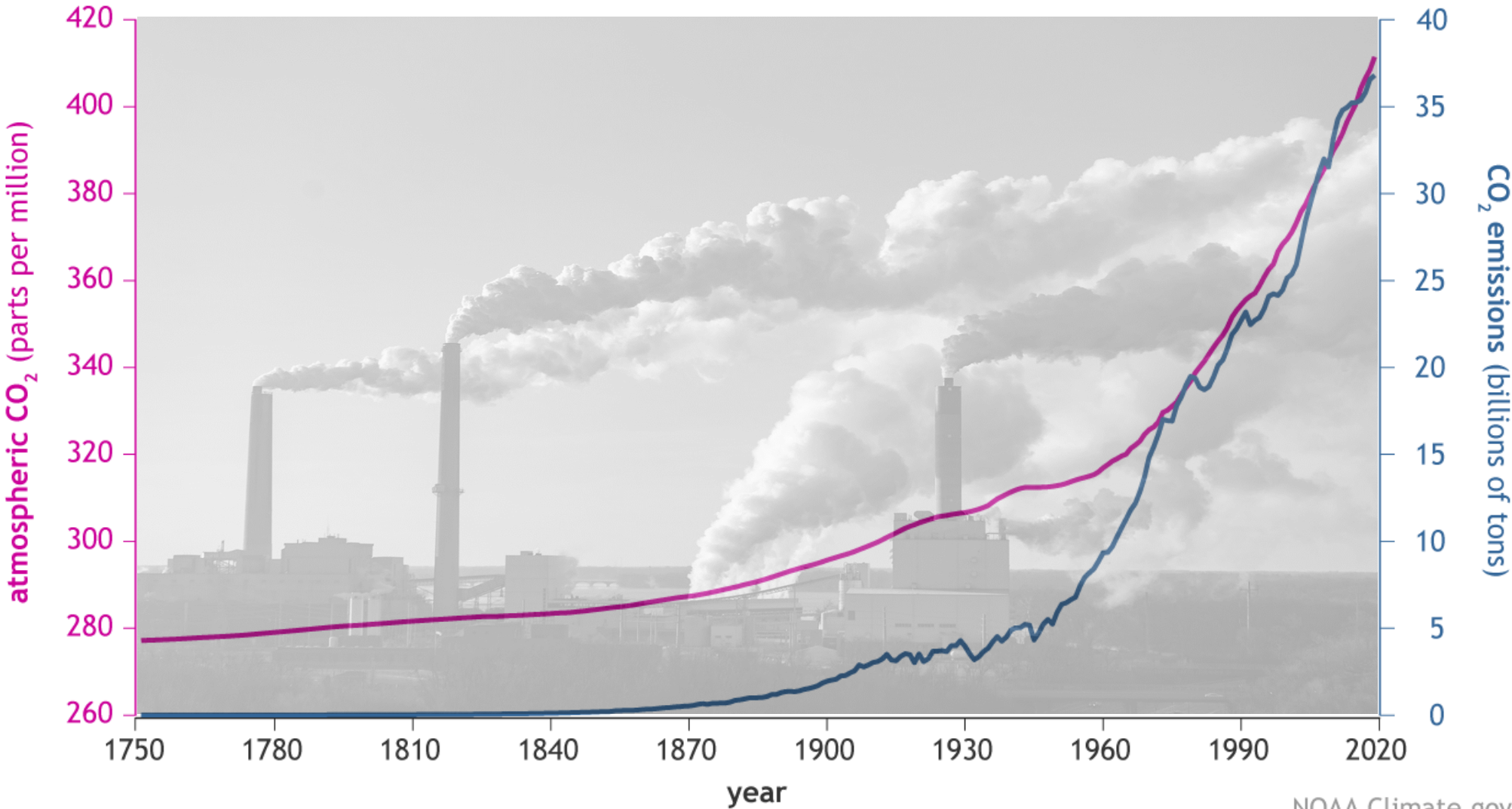


From Rising Waters to Catastrophic Wildfires



Carbon & Greenhouse Gas Emissions

CO₂ in the atmosphere and annual emissions (1750-2019)



Global Population Increase

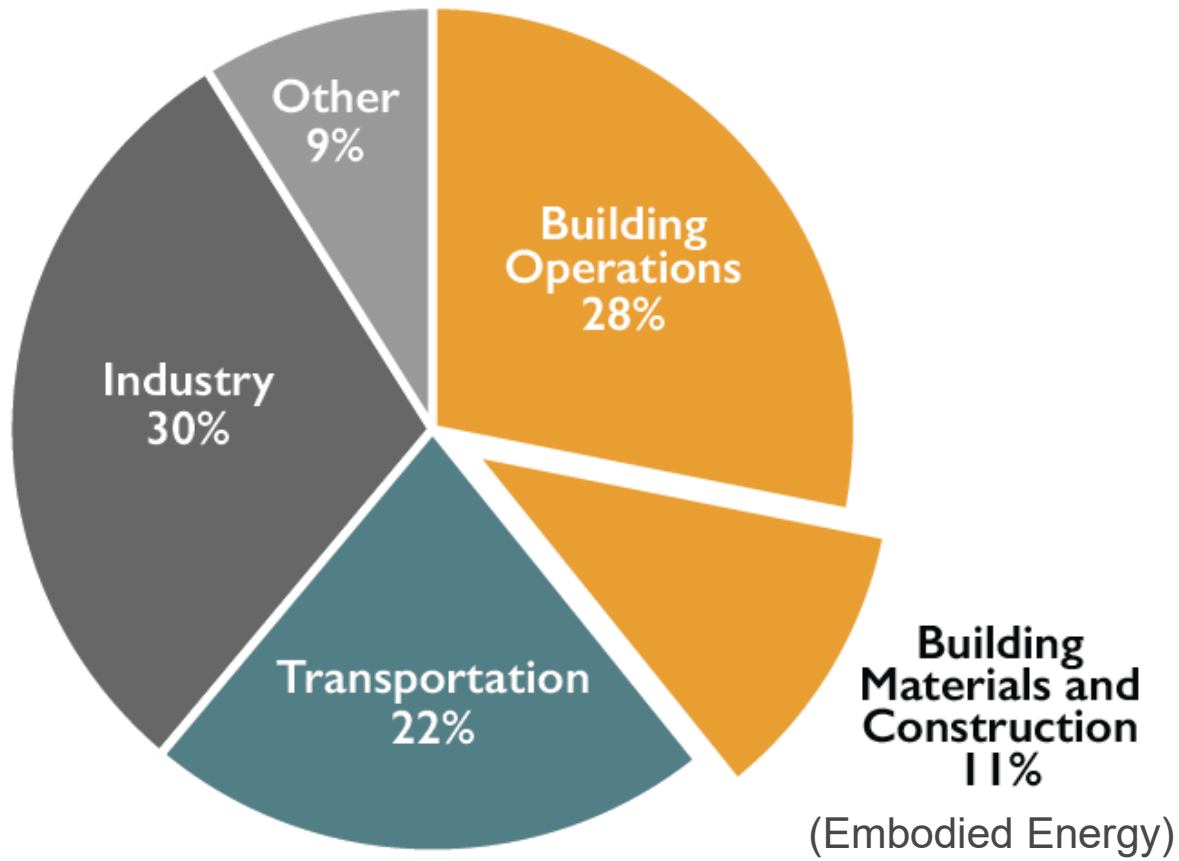
2020 = 7.8
billion people



2050 = 9.9
billion people

New Buildings & Greenhouse Gases

Global CO₂ Emissions by Sector



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

Embodied energy: **11%**
Concrete, iron, steel **~9%**

Source: © 2018 2030, Inc. / Architecture 2030. All Rights Reserved. Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

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 (CO₂). 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 ₂ O)	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 CO₂ equivalents

Carbon vs CO₂



1 ton Carbon \neq 1 ton CO₂

1 ton Carbon = (44/12=) 3.67 tons CO₂

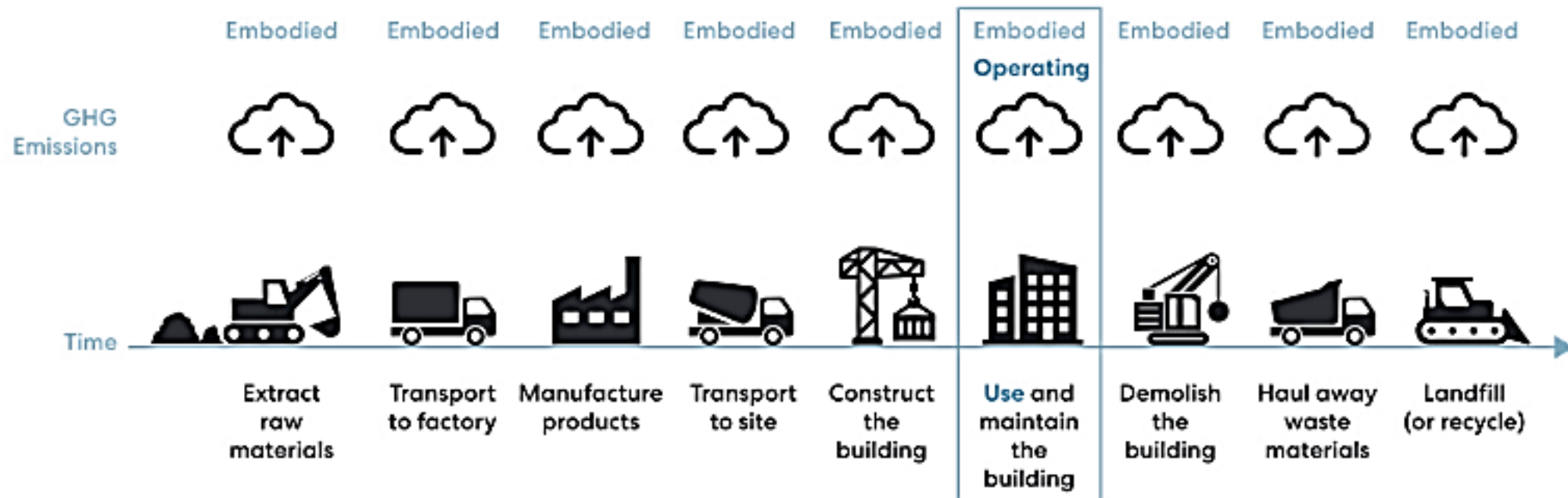
Carbon Terms

- **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



Embodied Carbon

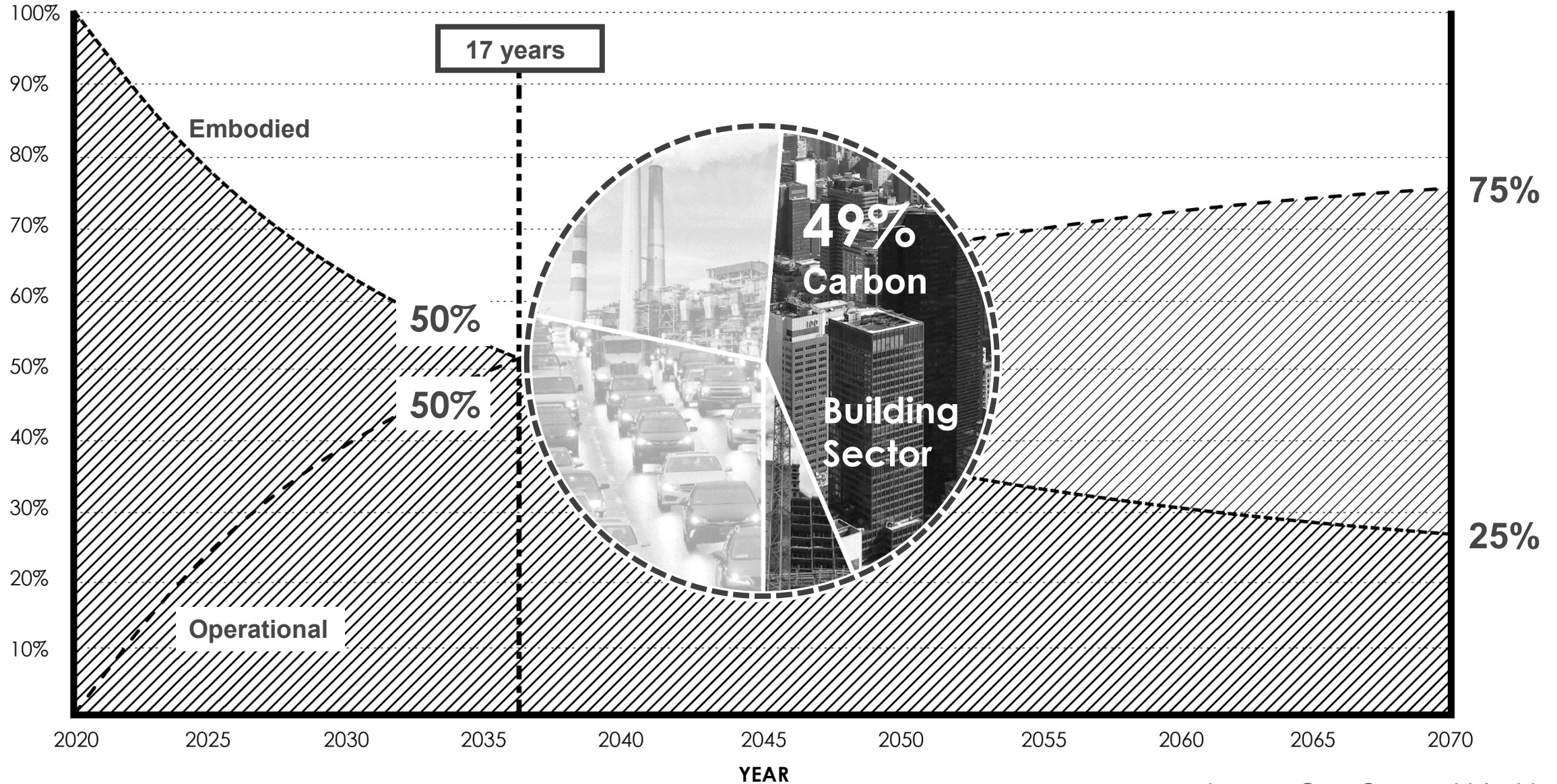
- Primarily related to **manufacturing of materials**
- More significant than many people realize, has been **historically overlooked**
- Big upfront GHG “cost” - which makes it a **good near-term target** for climate change mitigation



Embodied vs. Operational Energy

Traditional Non-Wood Building

% Energy



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*

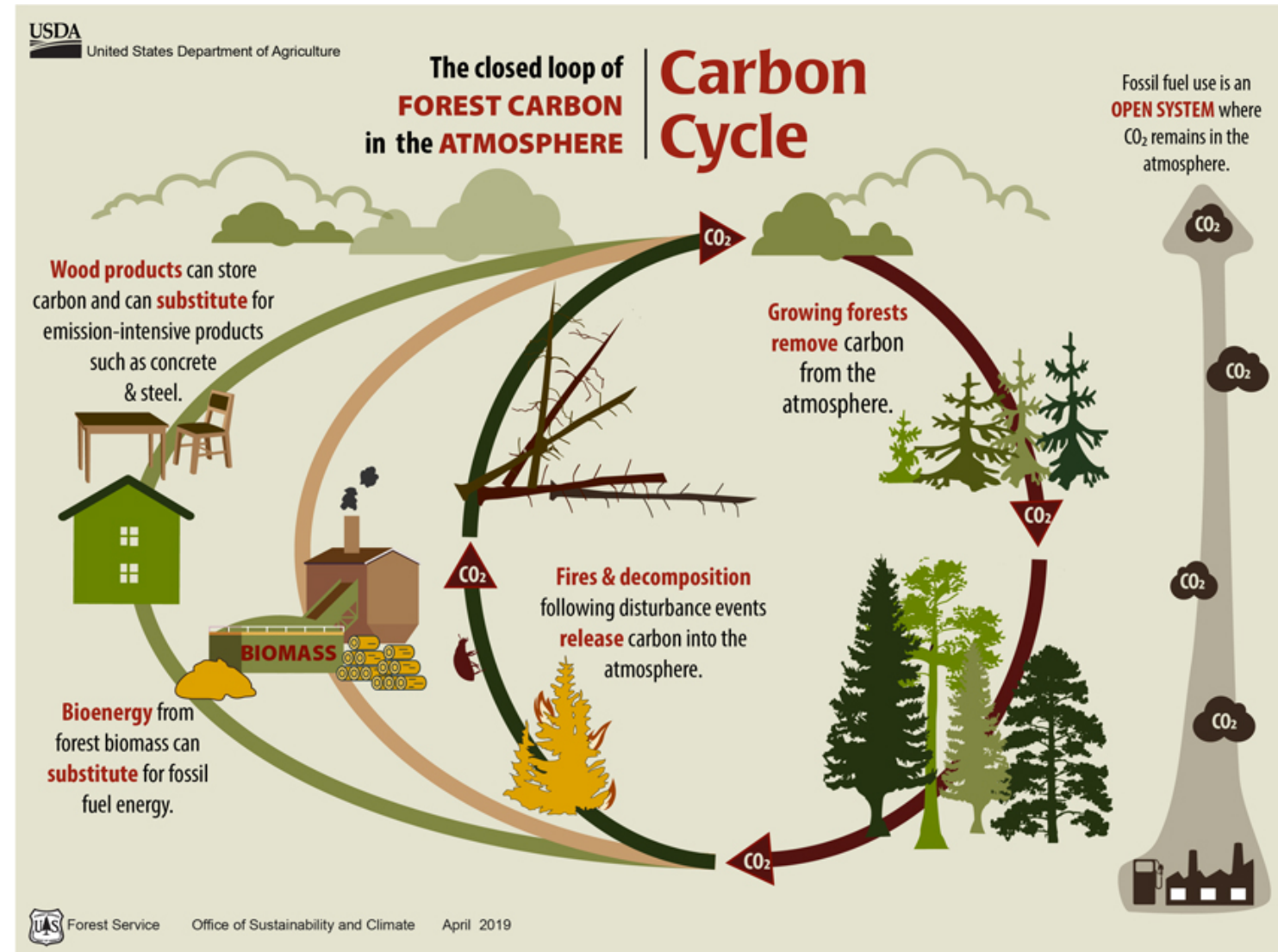
* Sequestered carbon may be included in embodied carbon calculation or considered separately.

How Does Wood Fit in?

C L I M A T E

Carbon Benefits of Wood

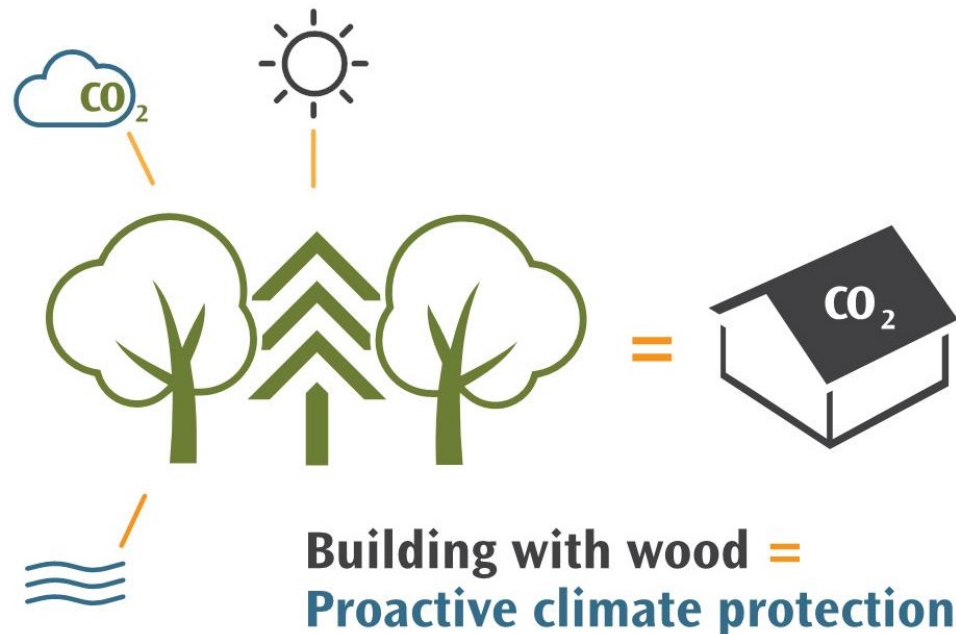
- **Less energy intensive** to manufacture than steel or concrete
- **Less fossil fuel consumed** during manufacture
- **Avoid process emissions**
- Carbon **storage** in forests and **promote forest health**
- Extended carbon **storage** in **products**



More Carbon Terms

Carbon Sequestration: The process by which CO₂ 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**.



Carbon Storage

Wood \approx 50% Carbon (dry weight)




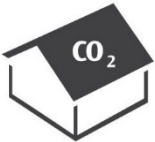

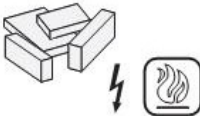


Image: Kaiser + Path



Image: Lever Architecture

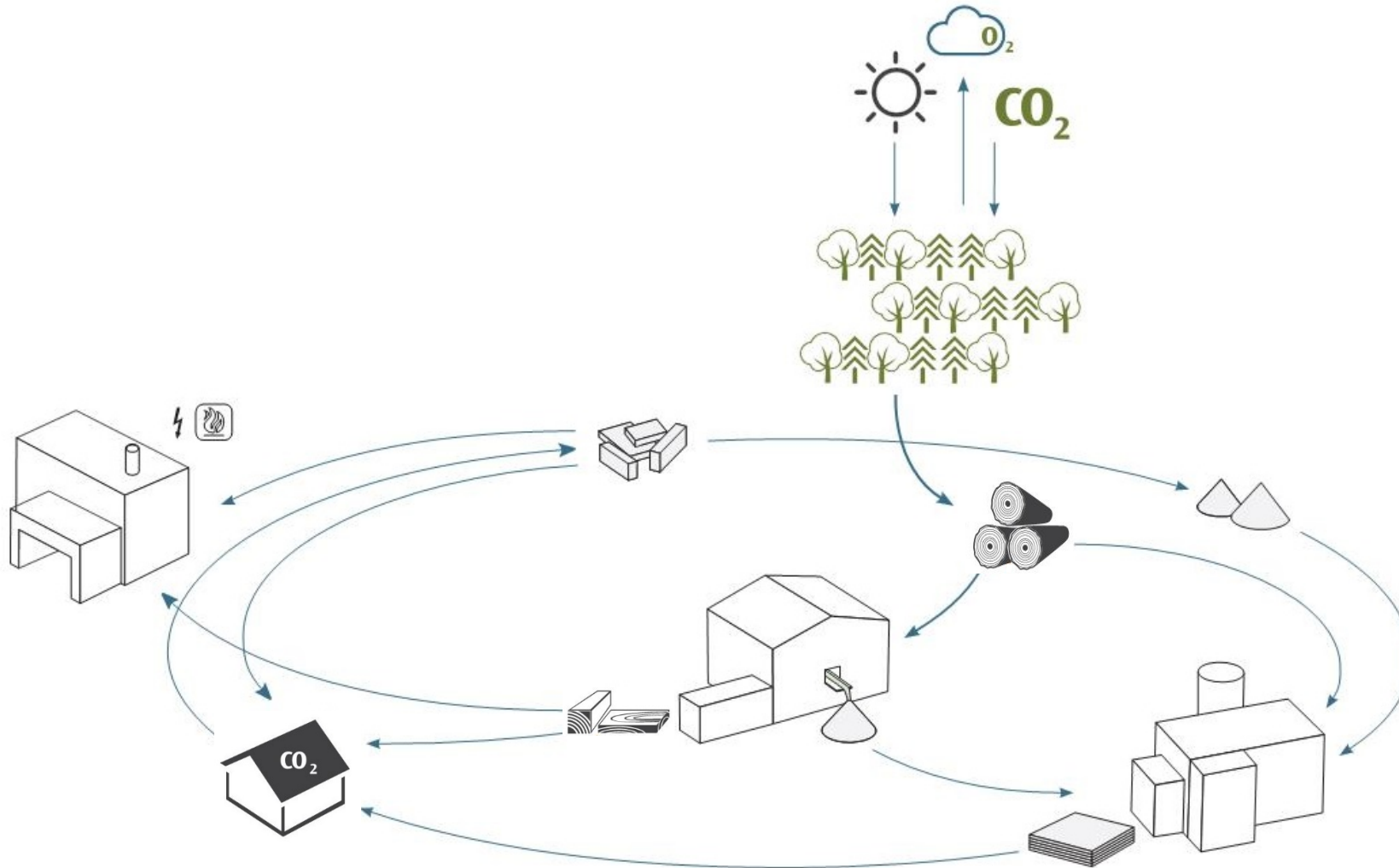
Long-Term Positive Effects

		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

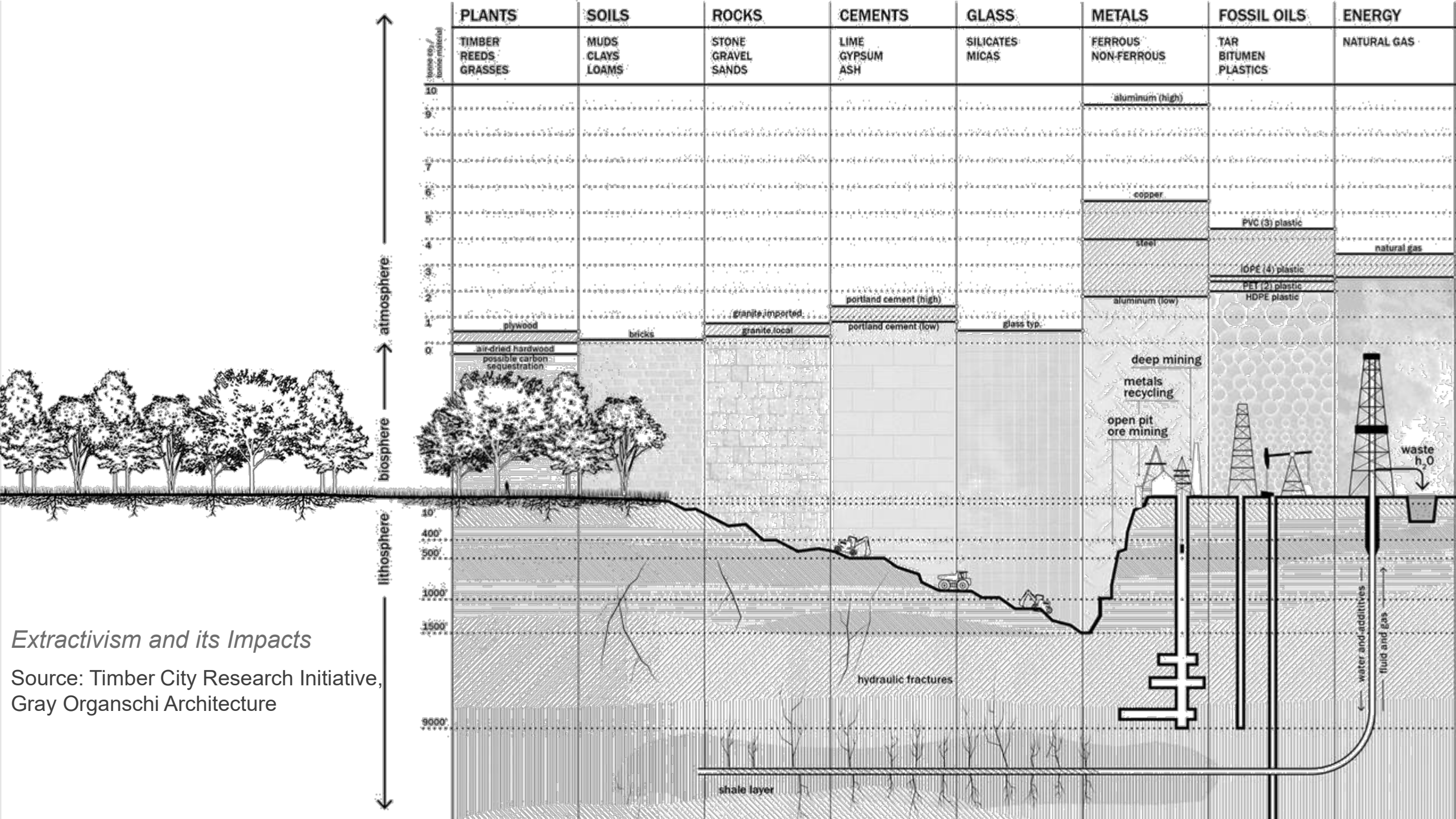
Source: Building with Wood – Proactive Climate Protection, Dovetail Partners, Inc.

Carbon Cycle

Renewable Resource | Carbon Sequestration



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



Specifics of Carbon Storage

CLIMATE

Where is Carbon Stored?

Harvested Wood Pools

- Harvested Wood Products
- Solid Waste Disposal Sites

Forest Pools

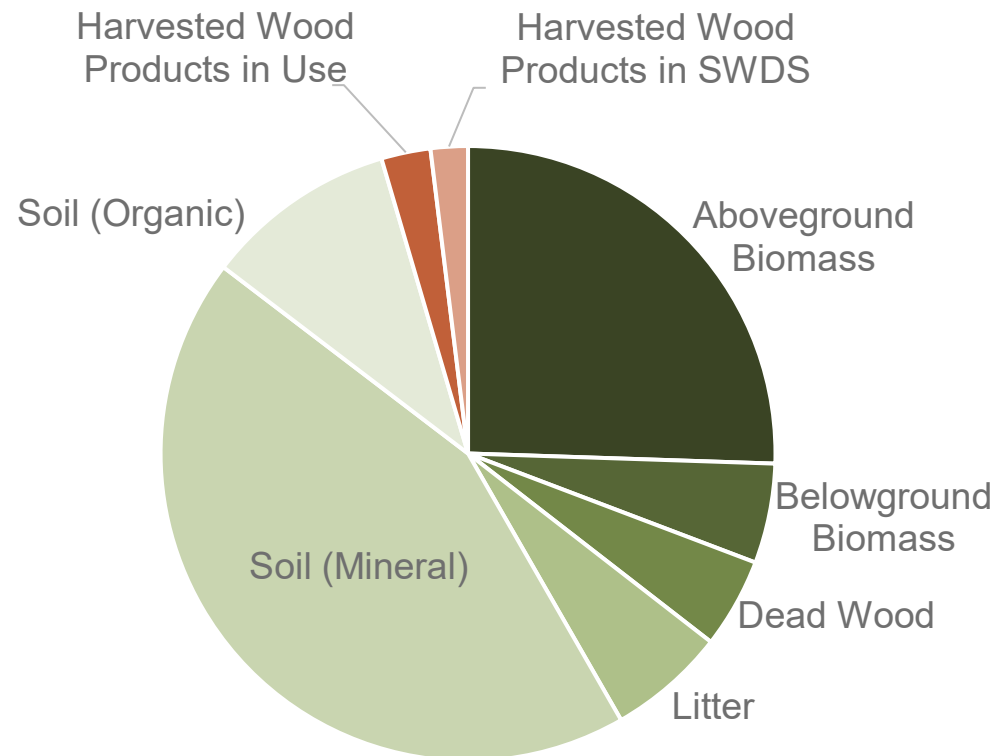
- Aboveground Biomass
- Belowground Biomass
- Dead Wood
- Litter or Forest Floor
- Soil Organic Carbon



Image: naturallywood.com

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

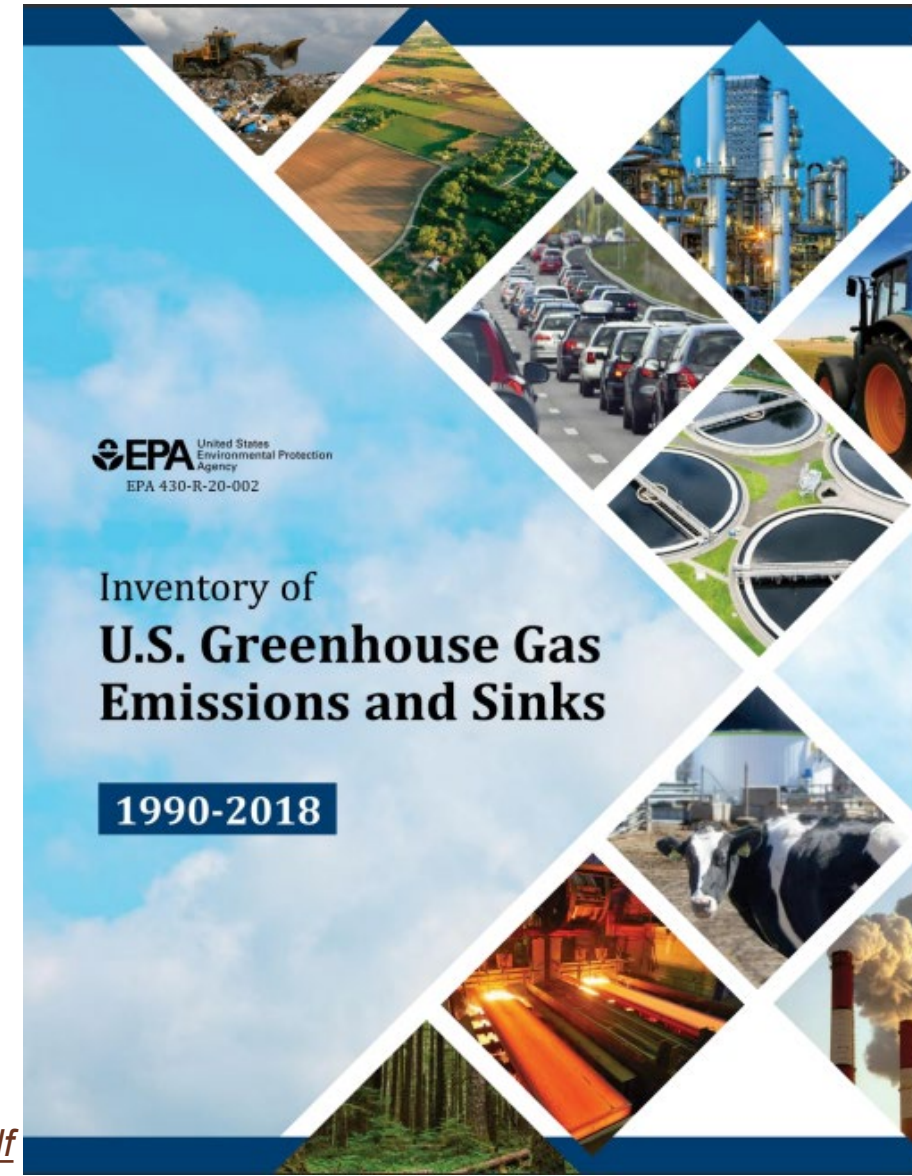


Table 6-12: Forest Area (1,000 ha) and C Stocks in *Forest Land Remaining Forest Land* and Harvested Wood Pools (MMT C)

	1990		2005		2015	2016	2017	2018	2019
<i>Forest Area (1,000 ha)</i>	<i>279,748</i>		<i>279,749</i>		<i>280,041</i>	<i>280,041</i>	<i>279,893</i>	<i>279,787</i>	<i>279,682</i>
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

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.



Image: Weyerhaeuser



Image: LP Building Solutions



Image: Structurecraft



Image: Georgia-Pacific

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

Tools to Evaluate Carbon Impact

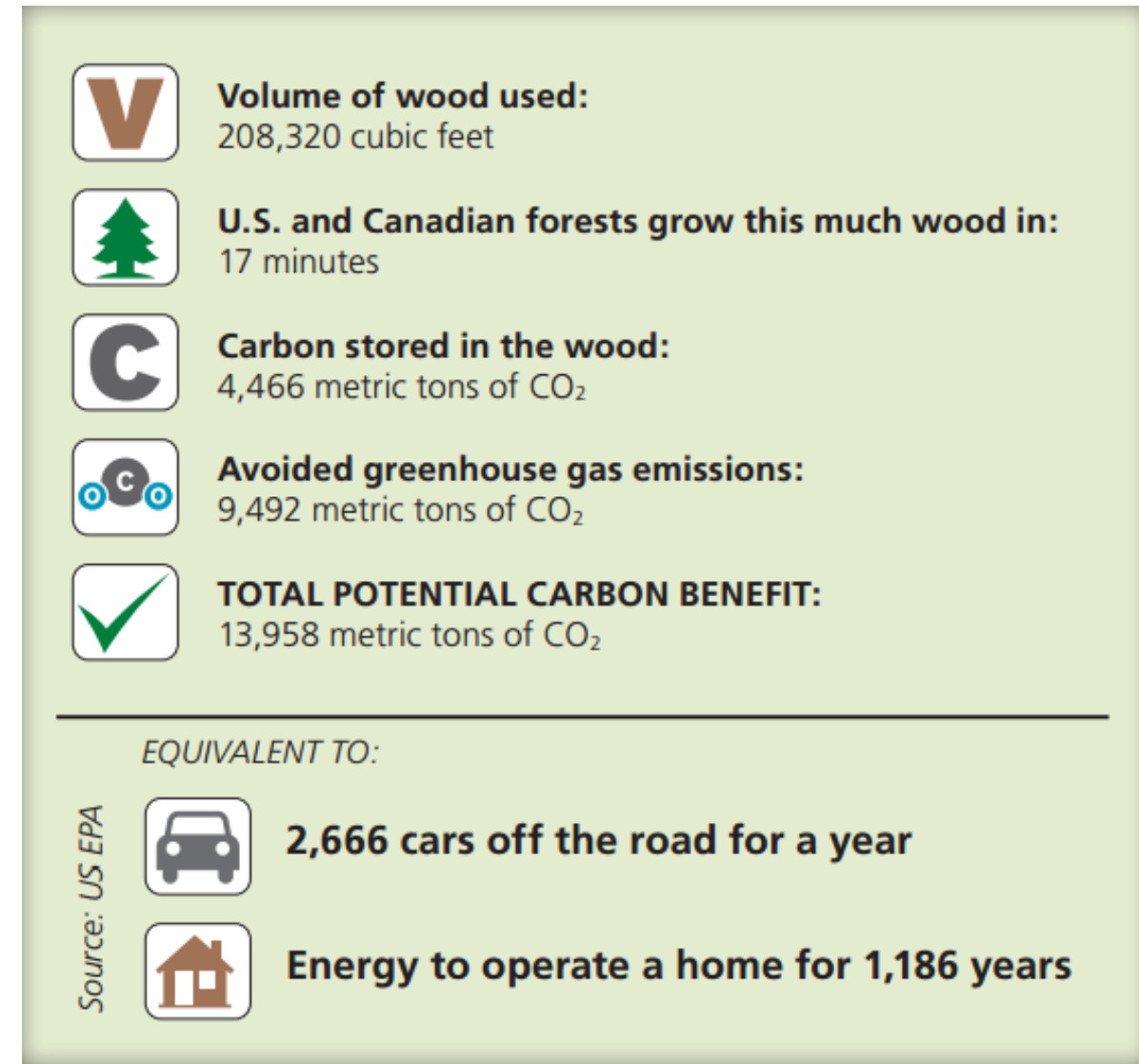
CLIMATE

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

- # Understanding the Role of Embodied Carbon in Climate Smart Buildings
-
- ## Report on Carbon Reduction and Design Best Practices
- THINK
WOOD.
- Located in downtown Denver, Flatiron Fifteen is a five-story workspace that incorporates a mass-timber frame built using glue-laminated timber (glulam) beams and columns as well as cross-laminated timber (CLT) floor and roof panels.
- Photo: © GCA Architecture/CC-BY, courtesy of Flatiron Fifteen
-
- ## How to Calculate the Wood Carbon Footprint of a Building
- Expanding the possibilities of wood building design
- Sponsored by Think Wood | By Elle Sonne Hall, Ph.D.
- F**rom an environmental perspective, it is widely known that buildings matter. Buildings consume nearly half the energy produced in the United States, use three-quarters of the electricity, and account for nearly half of all carbon dioxide (CO₂) emissions. The magnitude of their impacts in the driving force behind many initiatives to improve tomorrow's structures—from energy regulations and government procurement policies, to green building rating systems and programs such as the Architecture 2030 Challenge. The focus on energy efficiency, in particular, has led to widespread improvements, so much so that many designers are now giving greater attention to the impacts of structural building materials. This greater attention has revealed that greenhouse gas (GHG) emissions associated with materials
- used in buildings and construction account for 24 percent of building sector emissions and 11 percent of global GHG emissions.¹ Are we able to dive deeper into these numbers to find ways to reduce a building's carbon footprint to meaningful levels? What are the methods used to measure building material carbon footprint and do they tell the whole story? Are there simple tools to assess material choices? This course seeks to address these and other questions by explaining the principal methods and tools that are used to assess carbon footprint in the context of building materials. It includes a primer on product terminology, including life-cycle assessment (LCA), environmental product declarations (EPDs), carbon footprint, embodied carbon, and whole-building LCA (WBLCA) tools. It explains how designers
- ### CONTINUING EDUCATION
- CE**
Learning Objectives
1 AIA LU/ELECTIVE
- After reading this article, you should be able to:
1. Explain what a carbon footprint is in the context of building materials.
 2. Describe the difference between life-cycle assessment (LCA), environmental product declaration (EPD), and whole-building LCA.
 3. Identify different whole-building LCA tools and how they can be used to develop a whole building carbon footprint.
 4. Define what is and is not included in a wood EPD and why.
 5. Discuss the building's forest carbon cycle, and ways to track and assure forest sustainability in North America.
- To receive AIA credit, you are required to read the entire article and pass the test. Go to ce.architecturalrecord.com for complete test and to take the test for free. This course may also qualify for one Professional Development Hour (PDH). Most states now accept AIA credits for engineers' requirements. Check your state licensing board for all rules, rules, and regulations to confirm.
- AIA COURSE NUMBER
- 90 ARCHITECTURAL RECORD SEPTEMBER 2020

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



Case Studies

CLIMATE

Bullitt Center

Seattle, WA



Photo: John Stamets

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 CO₂



Avoided greenhouse gas emissions:
1,158 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:
1,703 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



325 cars off the road for a year



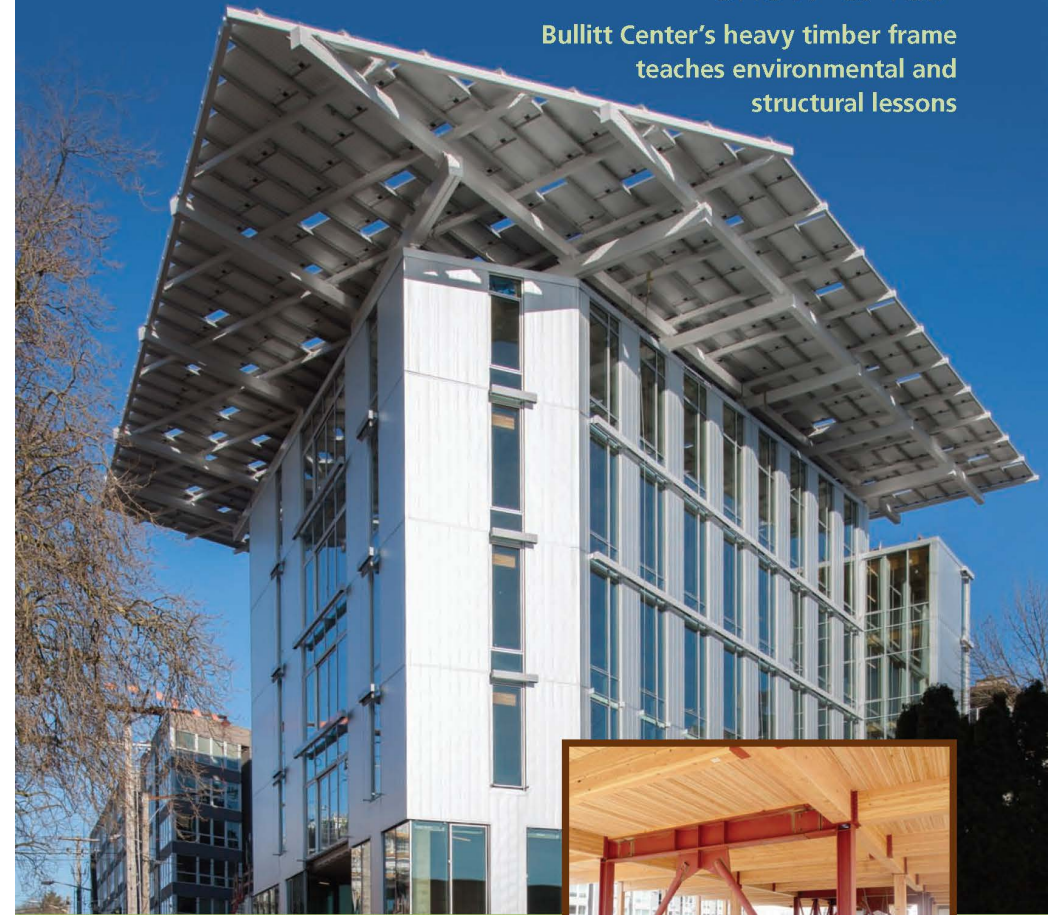
Energy to operate a home for 145 years

CASE STUDY

BULLITT CENTER

Wood Shines in Sustainable 'Show & Tell'

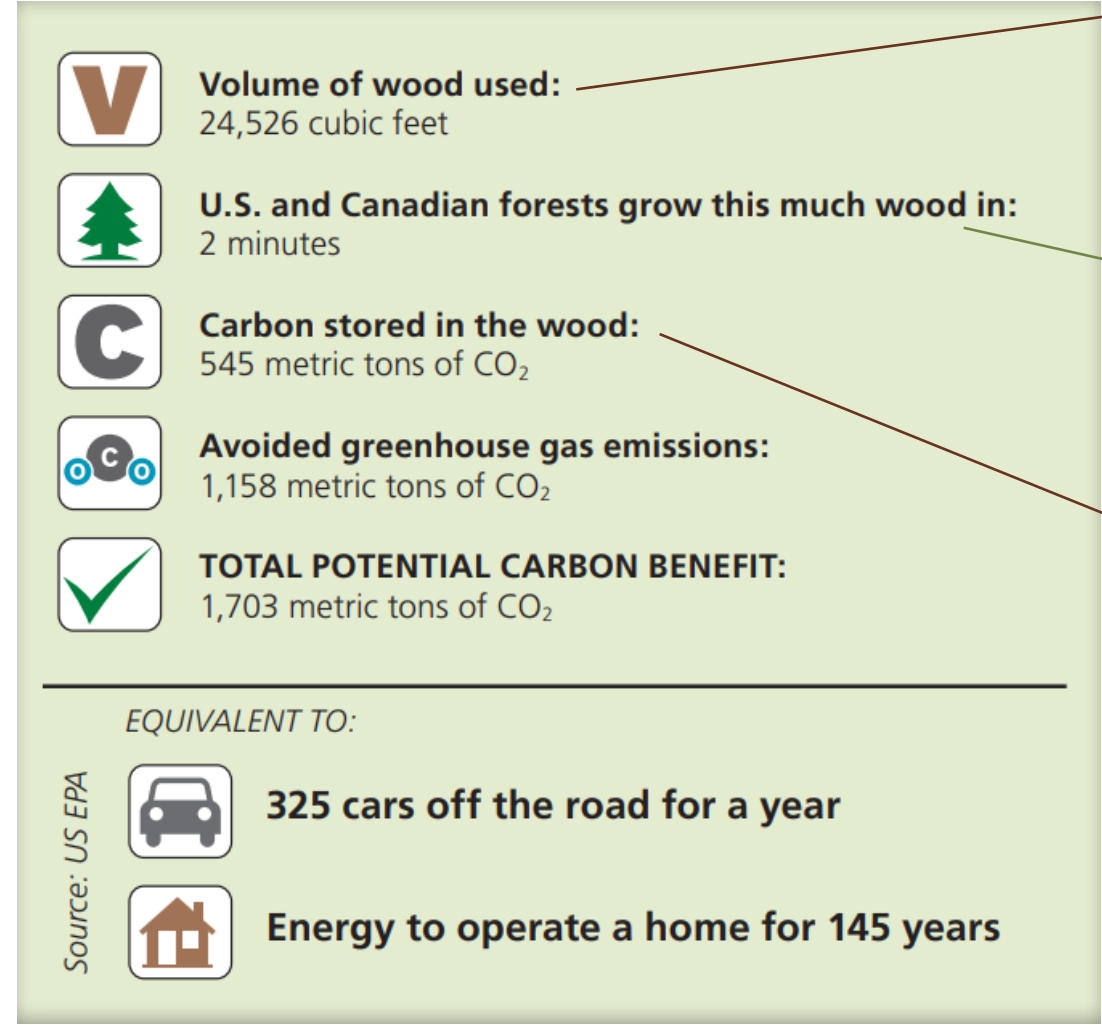
Bullitt Center's heavy timber frame
teaches environmental and
structural lessons



WoodWorks

Bullitt Center

Seattle, WA



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 CO₂ (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 CO₂



Avoided greenhouse gas emissions:

494 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:

1,770 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



374 cars off the road for a year



Energy to operate 187 homes for a year

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: CO₂ on this chart refers to CO₂ 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

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Crescent Terminus

Atlanta, GA



Photo: Richard Lubrant

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

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

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 CO₂



Avoided greenhouse gas emissions:
9,196 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:
13,523 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



2,583 cars off the road for a year



Energy to operate a home for 1,149 years

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: CO₂ on this chart refers to CO₂ equivalent.



Arena Stage at the Mead Center for American Theater Washington, DC

- 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



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 CO₂



Avoided greenhouse gas emissions:

460 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:

675 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



129 cars off the road for a year



Energy to operate a home for 58 years

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: CO₂ on this chart refers to CO₂ equivalent.

Herrington Recovery Center – Roger's Memorial Hospital

Oconomowoc, WI



Photo: Curtis Waltz

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

- 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

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 CO₂



Avoided greenhouse gas emissions:

480 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:

710 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



135 cars off the road for a year



Energy to operate a home for 60 years

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: CO₂ on this chart refers to CO₂ equivalent.

El Dorado High School

El Dorado, AR



Photo: Dennis Ivy

IIIA

- 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 CO₂



Avoided greenhouse gas emissions:

7,780 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:

11,440 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



2,100 cars off the road for a year



Energy to operate a home for 970 years

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, FPLInnovations. Note: CO₂ on this chart refers to CO₂ 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 with 1-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 CO₂



Avoided greenhouse gas emissions:

59 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:

163 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



31 cars off the road for a year



Energy to operate a home for 14 years

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: CO₂ on this chart refers to CO₂ 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



Photo: Gary Folkins

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 CO₂



Avoided greenhouse gas emissions:
3,031 metric tons of CO₂



TOTAL POTENTIAL CARBON BENEFIT:
4,457 metric tons of CO₂

EQUIVALENT TO:

Source: US EPA



942 cars off the road for a year



Energy to operate 471 homes for a year

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, FPIinnovations. Note: CO₂ on this chart refers to CO₂ equivalent.

Forest to Cities

A Systemic Solution in Action



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