Educational Partners:

HOW HEALTHY MARKETS SUSTAIN FORESTS

High School Lesson – Life Cycle Analysis – Greenhouse Gas Emissions

How Healthy Markets Sustain Forests

Platte Fifteen Life Cycle Assessment

Developed By: Gina Smith, LEAF – Wisconsin's K-12 Forestry Education Program

Target Grade Level: 9-12

Appropriate for 6-8 with support (interpreting text & calculations)

Science Categories

Forestry, Climate Change, Sustainability, Economics

Time Frame 1.75-2.5 hours

- **Introduction:** 30 minutes
- **Activity 1:** 60minutes
- **Activity 2:** 45 minutes (optional)
- **Conclusion:** 10 minutes

Materials

- *How Healthy Markets Sustain Forests* episode
- Student Sheet: Life Cycle Assessment_Information Sheet_Activity 1
- Student Sheet: Life Cycle Assessment_Data Sheet_Activity 1
- Student Sheet: Life Cycle Assessment_Cost Study_Activity 1
- Student Sheet: Mass Timber in Wisconsin Buildings _Activity 2

Key Words

- Aesthetic, biogenic carbon cycle, biophilic design, carbon dioxide, carbon sequestration, climate change, cradle-to-gate/grave, cross-laminated timber, embodied carbon, environmental product declaration, global warming potential, glulam, greenhouse gas emissions, life cycle assessment, life cycle inventory, life cycle impact assessment, mass timber, raw materials, structural system

Learning Objectives

Students will be able to:

- Explain what a Life Cycle Assessment is, the steps involved in the process and how it helps people make decisions
- Examine information from a completed life cycle assessment on embodied carbon (global

warming potentia) and summarize ways to reduce embodied carbon based on findings from the life cycle assessment
- Identify factors (in addition to embodied carbon) that builders must consider when constructing buildings
- Complete an economic evaluation of mass timber in Wisconsin

Activity Summary

Students will view an Into the Outdoors episode and discuss the different things producers/manufacturers need to think about when producing a product. Students will examine a comparative life cycle analysis of the Platte Fifteen mass timber building, and two other equivalent buildings made from steel and concrete – with a focus on embodied carbon. Students will summarize the results of the life cycle analysis and suggest other factors that influence the decisions producers make. Students will conduct research to determine if they think mass timber viable forest product and building solution for Wisconsin.

Vocabulary

- **Aesthetic:** appreciation of beauty
- **Biogenic carbon cycle:** a natural process where carbon is recycled between plants, animals and the atmosphere through photosynthesis, consumption and decomposition
- **Biophilic design:** purposefully including human's desire to connect with nature in the built environment; can include environmental features, natural patterns, light, etc.
- **Carbon dioxide:** a greenhouse gas that is released when fossil fuels are burned; during photosynthesis it is absorbed by plants and combines with water to produce glucose (a sugar made of carbon, hydrogen and oxygen) and oxygen.
- **Carbon sequestration:** the process of capturing and storing atmospheric carbon
- **Climate change:** long-term shifts in temperatures and weather patterns; largely from increased greenhouse gas emissions from the burning of fossil fuels
- **Cradle-to-gate:** life cycle of a product from raw material supply to finished product
- **Cradle-to-grave:** full life cycle of a product from raw material supply to disposal
- **Cross-laminated timber:** an engineered wood product made by gluing layers of lumber together at right angles to create a strong, lightweight building material
- **Embodied carbon:** greenhouse gas emissions associated with materials through their extraction, transportation, production and disposal
- **Environmental Product Declaration:** standardized summary reports that document the environmental impact of a product through its life cycle; verified by an outside party
- **Global Warming Potential:** the total greenhouse gas emissions directly associated with the production of a product (embodied GHG emissions)
- **Glulam:** an engineered wood product made by gluing together layers of lumber to create longer, larger, and stronger building materials
- **Greenhouse Gas (GHG) emissions:** the release of carbon dioxide, methane and nitrous oxide into the Earth's atmosphere; the gases trap heat and contribute to the greenhouse effect; GHG

emissions are primarily generated by human activities like burning fossil fuels for energy

- **Life Cycle Assessment:** process that evaluates the environmental impact of a product, material or process for its entire life cycle – from the extraction of the raw materials used to make it to the manufacturing and use of the product to the disposal (or recycling) of the product
- **Life Cycle Inventory:** method used to track the input and output of energy and materials for each step in the production of a product; found in Life Cycle Inventory Database
- **Life Cycle Impact Assessment:** process of determining the potential human and ecological impacts from LCI data
- **Mass timber:** large, engineered wooden panels, columns, beams (made of cross-laminated timber, glulam, etc.) that can be used as alternatives to steel and concrete in construction
- **Raw materials:** materials used to produce goods or services; these materials are unprocessed or minimally processed
- **Structural system:** parts of a building that support it and keep it stable. Includes foundation, columns, beams, trusses, walls, slabs, footings

Background Information

The student texts provide the background information needed to complete the activities within this lesson.

Additional information related to the activities can be found at the following links:
Platte Fifteen Life Cycle Analysis:

- https://www.woodworks.org/resources/platte-fifteen-life-cycle-assessment/#:~:text=This%20life%20cycle%20assessment%20(LCA,office%20building%20in%20Denver%2C%20Colorado.

Sources of Greenhouse Gas Emissions:
- https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

U.S. Life Cycle Inventory Database:
- https://www.nrel.gov/analysis/lci.html

U.S. Life Cycle Inventory Database Roadmap:
- https://www.energy.gov/eere/buildings/articles/us-life-cycle-inventory-database-roadmap-brochure

Introduction to Life Cycle Assessment (U.S. Department of Energy)
- https://www.energy.gov/sites/default/files/2022-07/2022-07-14%20-%20Intro%20to%20LCA%20-%20Slides%20and%20Transcript_compliant_0.pdf

Learning Procedure

Introduction: *How Healthy Markets Sustain Forests* – Into the Outdoors episode

Show students the Into the Outdoors episode, *How Healthy Markets Sustain Forests.* Prompt students to listen for all the decisions the people producing forest products must make to provide the product to consumers.

- After the episode, ask students to share the different decisions that are involved in producing forest products.

Activity 1: Platte Fifteen Life Cycle Assessment

Pass out a copy of the Platte Fifteen Life Cycle Assessment – Information Sheet and Life Cycle Assessment Student Data Sheet to each student. Tell students they will be reviewing a Life Cycle Assessment that was conducted on the Platte Fifteen mass timber building in Denver, Colorado. Tell students that this is real data and information that was gathered and reviewed extensively. Explain that a **Life Cycle Assessment** (LCA) is a process that evaluates the environmental impact of a product, material or process for its entire life cycle – from the extraction of the raw materials used to make it to the manufacturing and use of the product to the disposal (or recycling) of the product. Tell students that while complete life cycle assessments look at all the impacts of material and energy use during the complete life cycle of a product (effects on water, land, etc.), during this activity they will only investigate the **embodied carbon** of the Platte Fifteen mass timber building and equivalent steel and cement buildings.

Remind students that greenhouse gas emissions include carbon dioxide, methane and nitrous oxide. Explain that greenhouse gases trap heat and contribute to the greenhouse effect which warms the planet. Remind students that while there are natural processes that produce GHGs, human activities like burning fossil fuels for energy have caused a rapid increase in GHG emissions over the past two centuries which is contributing to **climate change** (long-term shifts in temperatures and weather patterns). Explain to students that their task is to examine LCA data to learn about the embodied carbon of all three buildings to determine which building produces has the lowest Global Warming Potential over its lifetime. Explain that processes like these help builders make sustainable decisions about the design and construction of their buildings.

Students should work in groups (3-5 students per group) to complete the table on their Data Sheet (page 1). Outline the following step for students.

1. Read through the Platte Fifteen Life Cycle Assessment Information sheet. Don't make any notes or record any information on the Data Sheet during this first reading. Focus on understanding what the text says.
2. Read the Life Cycle Assessment – Student Data Sheet to determine what data needs to be gathered from the Life Cycle Assessment.
3. Reread, the Life Cycle Assessment. This time, record information in the data tables on the pages 1-2 of the Data Sheet as the read/review the information. They should not answer questions on the data sheet at this time or complete the data table on page 3 of the student sheet. Note – some data/information comes directly from the text while other data/information comes from the tables and figures. All members of the group should record information on their data sheet.
4. Tell students not to move on to answer any of the questions outside of the tables or move onto the table on page 3 yet.

Once all groups have completed the table, ask students if they can tell which building has the lowest Global Warming Potential over its lifetime? Have students explain why they think so. Tell students that information is often easier to understand when looking at the percentage of a total. Tell them they are going to complete a series of calculations that will help them analyze and understand their data better.

Review the process for calculating percentage of a total with students using the information from the table on page one of their student sheet.

Calculating a percentage of a total (Page 1-2, Questions 1-3)

Use the following formula to calculate percentage of the total:

GWP/M² of Concrete (below podium slab) ÷ GWP/M² of Concrete (full building) x 100%

Example: *If GWP of concrete above the podium slab of the mass timber building is 45 GWP/M² and GWP of the total concrete of the mass timber building is 300 GWP/M² ...*

1. *Calculate the GWP/M² of concrete below the podium slab (box 9)*

   GWP/M² of concrete below = GWP/M² of total concrete - GWP/M² of concrete above

   300 GWP/M² – 45 GWP/M² = 255 GWP/M²

2. *Calculate the %GWP of concrete (below podium slab) for the mass timber building*

   GWP/M² of Concrete (below podium slab) ÷ GWP/M² of Concrete (full building) x 100%

   255 GWP/M² ÷ 300 GWP/M² x 100% = 85%

Tell students to complete the questions and calculations from pages 1-2 of their student sheet and to complete the Percent of Total GWP/M² Per Life Cycle Stage for each Building System table on page 3 of their student sheet (they will be calculating percentages in this table).
Allow groups time to answer the questions and perform the calculations. After all groups have finished, discuss the answers as a class.

Have students do the final part of the LCA activity – a written summary of the results of the Life Cycle Assessment of GWP for a Platte Fifteen office building constructed out of mass timber, steel or concrete – independently. Review the process and expectations with students as outlined on their data sheet:

Complete a written summary of the results of the Life Cycle Assessment of GWP for a Platte Fifteen office building constructed out of mass timber, steel or concrete. Your summary should include the following information:

For each building:

- *Summary of GWP for the lifetime of each building (excluding stages A5, B1, B6, B7 & C1)*
- *Largest stage contributing to the GWP for each building*
- *Largest materials contributing to the GWP for each building*
- *At least one way to reduce the GWP for each building*

Overall Review:

- *Which office building provides the best opportunity to reduce the global CO_2 emissions produced by the building industry?*

Support statements in your summaries with evidence from the text, tables, charts, and your

calculations. Use complete sentences, proper grammar and correct spelling.
Tell students to submit their work to you when they have completed it. Once all students have completed their summaries, move on to the Activity 1 – Life Cycle Assessment - Cost Study.

Activity 1: Life Cycle Assessment – Cost Study

Pass out a copy of the Life Cycle Assessment – Cost Study – Activity 1 sheet to each student. Ask them the following questions:
The LCA of the Platte Fifteen Life Cycle Assessment demonstrated that mass timber buildings can reduce embodied carbon and GWP in buildings. Do you think they are cost effective?
How much more do you think they cost than steel or concrete buildings?
Are they worth the extra cost?

After students have discussed the questions, have them return to their group. Instruct them to read the Comparative Cost Study of the Platte Fifteen Life Cycle Assessment and discuss the questions:

- The LCA of the Platte Fifteen Life Cycle Assessment demonstrated that mass timber buildings can reduce embodied carbon and GWP in buildings. Do you think they are cost effective?
- How much more do you think they cost than steel or concrete buildings?
- Are they worth the extra cost?

When groups have finished reading the cost study and discussing the questions in their groups, lead a brief class discussion asking students if their answers to the questions have changed and why/why not.

Activity 2: Mass Timber in Wisconsin

Pass out a copy of the Mass Timber in Wisconsin – Activity 2 sheet to each student. Tell students that they have examined the Life Cycle Analysis of the Platte Fifteen office building in Denver, Colorado, and learned that using mass timber instead of steel and cement to construct buildings is effective at reducing embodied carbon and GWP over the life cycle of the building.

Tell them that there are many economic factors involved in determining whether forest products companies in Wisconsin can produce mass timber or construction companies in Wisconsin will use mass timber in buildings instead of steel and cement. Tell them to work with their group to conduct independent research to determine if they think mass timber is a viable forest product and/or building solution for Wisconsin. They should NOT complete the conclusion paragraph in their group. Make sure they know that there is an economic review at the end of the student sheet.
Allow students time to complete the activity.

Conclusion: Class Discussion & Conclusion

Have students return to their assigned space in the classroom. Ask students to share what they learned about producers and consumers of mass timber in Wisconsin. Ask them to share about the factors of production that are required to produce mass timber and if Wisconsin has them. Ask students to describe the supply and demand for mass timber in Wisconsin.

Tell students that they need to write a paragraph explaining whether they think mass timber is a building solution for Wisconsin. Tell them to use at least 3 pieces of evidence from their research to support their answer.

Elementary School Recommendations

Use the K-5 lesson from this Into the Outdoors episode, *How Healthy Markets Sustain Forests – Cost-Benefit Analysis,* with students in grades 2-5.
The following LEAF lessons may be used for early elementary learners:

LEAF K-1st Grade Forestry Lesson Guide, Lesson 4: Forest Products Time Machine

- Students learn about historical uses of forest resources. Students begin by sharing ways we use the forest while playing a game of Hot Pinecone. Next, the class explores forest resources used to create products of the past, while relating them to present-day goods. To conclude, students examine forest products and draw a picture of one they use every day. https://www.uwsp.edu/wp-content/uploads/2023/11/leaf-k-1-lesson-4-forest-product-time-machine.pdf

LEAF K-1st Grade Forestry Lesson Guide, Lesson 5: Animals Need Forests Too

- Students explore what the forest provides for its animal residents. Cooperatively, students create a forest ecosystem with their classmates and enter the forest as animals in search of food, water, shelter, and space.

LEAF 2nd-3rd Grade Forestry Lesson Guide, Lesson 4: Forests Are Important to Me!

- Students explore and graph their personal forest values. Using a checklist, they discover how many of the forest products they use are made right here in Wisconsin and map them. As a conclusion, students create a collage and write about why they value forests. https://www.uwsp.edu/wp-content/uploads/2023/11/leaf-2-3-lesson-4-forests-are-important-to-me.pdf

LEAF 2nd-3rd Grade Forestry Lesson Guide, Lesson 5: Decisions, Decisions

Students learn about forest management by making a plan for a schoolyard. Using a card game like Old Maid, students learn about some of the people involved in managing forests. As a conclusion, they act out the roles of people involved in forest management and sing a song about what forests can be managed for. https://www.uwsp.edu/wp-content/uploads/2023/11/leaf-2-3-lesson-5-decisions-decisions.pdf

Middle School Recommendations:

Middle school students should complete the 6-8 lesson from this Into the Outdoors episode, *How Healthy Markets Sustain Forests*.

Student Pages

See additional documents that will need to be included:

- Student Sheet: Life Cycle Assessment_Information Sheet_Activity 1
- Student Sheet: Life Cycle Assessment_Data Sheet_Activity 1
- Student Sheet: Life Cycle Assessment_Cost Study_Activity 1
- Student Sheet: Mass Timber in Wisconsin _Activity 2 *(optional)*

Standards

WISCONSIN STANDARDS FOR SCIENCE

- **SCI.CC6.h** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among their parts. *They analyze many complex natural and designed structures and systems to determine how they function. They design structures to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.*
- **SCI.PS1.A.h** *The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials,* states of matter, phase changes, and conservation of matter.
- **SCI.ETS2.B.h** *All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.*

WISCONSIN STANDARDS FOR SOCIAL STUDIES

- **SS.Econ1.a.h** *Perform a cost–benefit analysis on a real-world situation, using economic thinking to describe the marginal costs and benefits of a particular decision.*

- **SS.Econ2.a.h** *Connect the roles of consumers and producers in the product, labor, and financial markets, and the economy as a whole. Analyze the roles of the market for goods and services (product market) and the market for factors of production (factor market).*

- **SS.Econ2.b.h** *Differentiate between supply and demand and the resulting impact on equilibrium prices and quantities produced.*
- **SS.Econ3.a.h** *Assess how decisions about spending and production made by households, businesses, and governments determine the country's levels of income, employment, and prices.*

- **SS.Geog3.a.h** *Evaluate, in both current and historical context, how the prospect of gaining access to resources in contested zones creates competition among countries.*

- **SS.Geog5.a.h** *Analyze the intentional and unintentional spatial consequences of human actions on the environment at the local, state, tribal, regional, country, and world levels.*

- **SS.Geog5.b.h** *Hypothesize how changes in human behavior (e.g., organic agriculture, Genetically Modified Organisms, ecotourism) can result in changes that have effects on a global scale.*

WISCONSIN STANDARDS FOR ENVIRONMENTAL LITERACY AND SUSTAINABILITY

- **ELS.EX4.A.h** *Examine the role of renewable and nonrenewable resources in creating sustainable economies. Analyze how the movement of natural resources through acquisition, production, consumption, and disposal impact sustainability of local, regional, and global systems.*

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WISCONSIN STANDARDS FOR ENGLISH LANGUAGE ARTS

- **ELA.R.9-12.1** *Cite textual evidence that strongly supports an analysis of what the text says explicitly/implicitly and make logical inferences, develop questions for further exploration.*
- **ELA.R.9-12.2** *Objectively and accurately summarize texts, from a variety of genres, to determine one or more themes or central ideas and analyze its development, including how it emerges and is shaped and refined by specific details.*
- **ELA.W.9-12.3** *Create writing that utilizes organization: introduce a topic; organize complex ideas, concepts, analysis, information and claims to make important connections and distinctions. Establish and maintain a structure and conventions consistent with the mode of writing. Provide a concluding statement or section that follows from and supports the topic, themes, and experiences presented in the text.*
- **ELA.W.9-12.4** *Produce clear and coherent writing in which the development, organization and style are culturally sustaining and rhetorically authentic to task, purpose and audience.*
- **ELA.W.9-12.7** *Conduct short as well as more sustained research projects to answer a question or solve a problem that is rhetorically authentic and culturally sustaining; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating an understanding of the subject under investigation.*
- **ELA.W.9-12.8** *Gather relevant information from multiple authoritative print and digital, academic and popular sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.*
- **ELA.W.9-12.9** *Draw evidence from literary or informational texts to support analysis, reflection, and research.*

Resources

- Listed and linked in lesson and student pages.

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HOW HEALTHY MARKETS SUSTAIN FORESTS

Life Cycle Assesment – Information Sheet – Activity 1

Platte Fifteen Life Cycle Assessment
Mass Timber, Steel and Concrete Buildings

Excerpted from:
Platte Fifteen Life Cycle Assessment by KL&A Engineers and Builders, Adolfson & Peterson
Modified by Gina Smith from LEAF – Wisconsin's K-12 Forestry Education Program (13 Nov 2024) for use in this lesson.
Where appropriate, original text and citations from original sources have been preserved.

BACKGROUND INFORMATION:

Columns, beams, trusses, walls, slabs and footings are all key **structural** elements of a building. Along with the foundation, these elements form the building's **structural system** which supports its weight–much like a skeleton–and keeps it stable, strong, durable and safe. For many years, commercial buildings in North America have relied on steel or concrete for their structural systems. Today, however, a growing number of owners, developers, architects, engineers and builders are choosing **mass timber** structural systems for their unique advantages that include **aesthetic** appeal, **biophilic design**, renewable resource use, **carbon sequestration** and faster construction times.

The building industry is responsible for 39% of global carbon dioxide (CO_2) emissions. Carbon dioxide is one of four major greenhouse gases that also include methane, nitrous oxide and water vapor. According to the U.S. Environmental Protection Agency, carbon dioxide produced by human activities is the largest contributor to global warming. [1] Of the 39% of global CO_2 produced by the building industry, 28% come from building operations and 11% come from **embodied carbon** emissions.

In the building industry, embodied carbon emissions are the CO_2 emissions that are produced during the extraction, transportation, production and disposal of materials used in construction. While operational CO_2 emissions can vary over the lifetime of a building, embodied CO_2 emissions are more immediate (determined by the end of the production of the materials) and permanent (don't change from that point on). Over the last 20 years, the building industry has decreased the energy required to operate buildings, which has reduced operational CO_2 emissions. To significantly reduce overall CO_2 emissions produced by the building industry, it is important to think about the embodied carbon emissions of buildings and building materials.

Mass timber is a wood product made from trees. During photosynthesis, trees absorb CO_2 from the atmosphere and combine it with water to create glucose (a carbohydrate made of carbon) and oxygen gas. As trees grow, they store carbon from the glucose in their trunks, branches, bark, leaves and roots. When trees are harvested their carbon remains stored in the wood. The carbon is only released back into the atmosphere when the wood decays or burns. Because mass timber **sequesters carbon**, using it as a structural building material can reduce the embodied carbon of buildings and decrease global CO_2 emissions.

Life Cycle Assessments:

A **Life Cycle Assessment** is the process that evaluates the environmental impact of a product, material or process for its entire life cycle. LCAs often focus on **Global Warming Potential (GWP)** – the total **greenhouse gas emissions (GHG)** or embodied carbon directly associated with the production of a product because of the link between GHGs and **climate change**. LCAs are based on **Environmental Product Declarations (EPD), Life Cycle Inventories (LCI)** and **Life Cycle Impact Assessments (LCIA).**

Environmental Product Declarations are summary reports that document the environmental impact of a specific product through its life cycle. EPDs are written by someone from outside the company in a standard format so they are easy to use and understand. A Life Cycle Inventory is the method used to track the input and output of energy and materials for each step in the production of a product. A Life Cycle Impact Assessment uses LCI data to determine potential human and ecological impacts of a product. LCAs, LCIs, LCIAs, and EPDs all estimate environmental impact and global warming potential based on current available science and best practice.
A complete Life Cycle Assessment includes information from multiple LCI data sets. For example, a life cycle assessment of mass timber would include LCI data sets for harvesting the timber, transporting timber to the mill, milling lumber, transporting lumber to the manufacturing site, manufacturing mass timber, transporting it to the building site, all the way through the recycling or disposal of the mass timber.

YOUR TASK

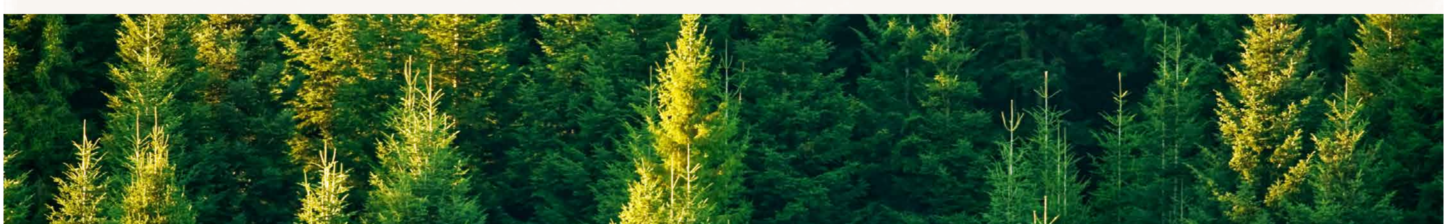
You will use information and data from the Platte Fifteen Life Cycle Assessment to compare greenhouse gas emissions from three equivalent buildings made with three different structural systems – mass timber, steel or concrete – to investigate whether it is possible to reduce greenhouse gas emissions by using mass timber elements instead of steel or concrete.

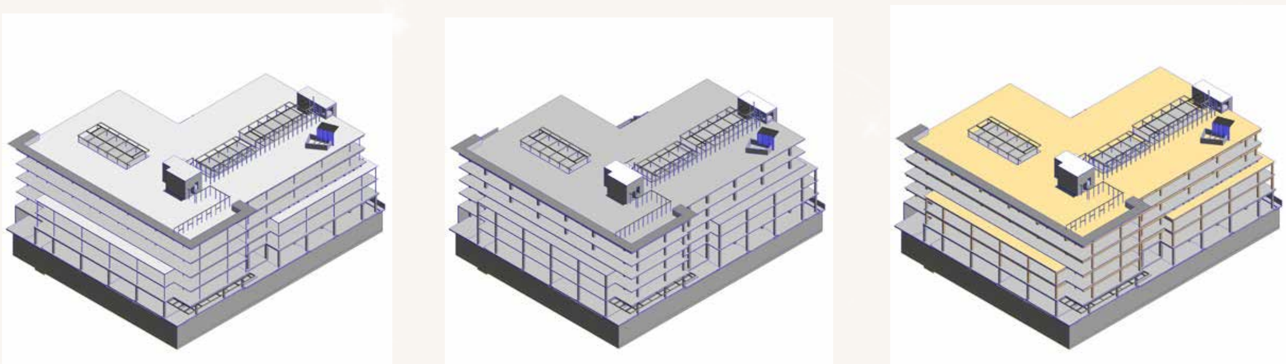
The Platte Fifteen Life Cycle Assessment:

The Platte Fifteen Life Cycle Assessment used in this activity uses an LCA to compare the embodied carbon, construction costs, and speed of construction for three equivalent buildings made with different structural systems: mass timber, steel and concrete.

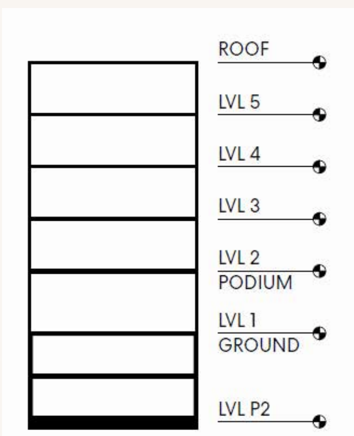
The Buildings:

The study is based on Platte Fifteen (WoodWorks Wood Products Council, 2020), a mass timber office building in Denver, Colorado. When it was built in 2019, Platte Fifteen was the largest mass timber building in Denver. It has an above grade floor area of 150,000 ft^2 (14,000 m^2), and a height of 70-feet (21.4-meters). It was constructed by general contractor Adolfson and Peterson (A&P). It was constructed on a concrete and steel base and has two below-grade parking levels and four levels above grade. The building was designed by architect OZ Architecture and structural engineer KL&A Engineers and Builders. The steel and concrete buildings were designed by KL&A using the same measurements and criteria as the Platte Fifteen building. The steel and concrete buildings were not constructed.





Isometric representation of the three structural framing systems: mass timber, steel and concrete.
(Figure 4 in the Platte Fifteen Life Cycle Assessment)



Because below grade construction extends below the water table, the concrete base of all three buildings are almost identical beneath the Level 2 podium. The foundation (LVL P2) has a waterproofed 32-inch concrete slab and 10-inch-thick concrete walls and the main level and first below grade level have 12-inch concrete slabs and concrete columns. The only variations in the structural systems of the buildings occur in the four stories above the podium (LVL 2-5 and Roof).

Structural systems for the buildings are summarized in the table.

Vertical Structural Systems for Levels 2-5 and Roof (gravity system)			
	Mass Timber	**Steel**	**Concrete**
Floors	3.5-inch 3-ply CLT panels with 3-inch concrete slab	Concrete floors on a composite steel deck (6-inches total) supported by steel beams and girders	8-inch concrete slabs
Roof	3-ply CLT panel on glulam beams	3-inch steel on steel beams and girders	8-inch concrete slabs
Columns	Glulam beams and columns transfer the load to a 16-inch concrete slab at Level 2	Steel beams and columns transfer the load to a 16-inch concrete slab at level 2	Concrete columns transfer the load to an 8-inch concrete slab at level 2
Lateral Structural System			
Core	2 x 10-inch concrete cores and a steel rod at the northeast elevation	2 x 10-inch concrete cores and a steel rod at the northeast elevation	2 x 12-inch concrete cores and a concrete shear wall at the northeast elevation

Other Architectural Elements for Levels 2-5 and Roof	
Vertical Enclosure	Glass, brick and metal panel with fire resistance rating of 1-hour
Ceiling	Gypsum board, suspended metal framing and insulation between parking level 1 and office levels; none for other levels

List of helpful abbreviations and definitions:

Cross-laminated Timber (CLT): an engineered wood product made by gluing layers of lumber together at right angles to create a strong, lightweight building material
Glulam: an engineered wood product made by gluing together layers of lumber to create longer, larger, and stronger building materials
Composite steel: when steel is combined with another material, like concrete to make it stronger
Photo credit: JC Buck

Life Cycle Assessment Parameters:

Life Cycle Assessments of the structural systems, vertical enclosure, ceiling finishes, and roof enclosure were completed by KL&A, utilizing Tally® software. Tally is a life cycle assessment tool that calculates the environmental impacts of building material selections. The app allows builders to calculate impacts directly in their Autodesk ™ Rivet ™ building information modeling software. Construction costs and speed of construction for all three systems were provided by the original contractor, A&P.

The standard Life Cycle Stages are shown in the figure below. The stages used for this comparative building LCA were **cradle-to-grave**, including Module D: Reuse, Recycle, and Energy Recovery. Stages related to the construction process and use of the building (A5, B1, B6, B7 and C1) were not included in the LCA since they relate to operational CO_2 emissions not embodied CO_2 emissions. Stages B2-B5: maintenance, repair, replacement, and refurbishment are included in the study but do not impact the results since the lifetime of the materials are expected to be the same as the lifetime of the building which results in no additional embodied CO_2 emissions in these stages.

Life Cycle Stages & Study Scope

Product			Constr-uction		Use							End-of-Life				Module D		
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D1	D2	D3
Raw material supply	Transport	Manufacturing	Transport	*Construction\Installation*	Use	Maintenance	Repair	Replacement	Refurbishment	*Operational Energy Use*	*Operational Water Use*	Deconstruction	Transport	Waste Processing	Disposal	Reuse	Recycling	Energy Recovery
✓	✓	✓	✓			✓	✓	✓	✓				✓	✓	✓	✓	✓	✓

Figure 3. Life Cycle Stages[3] as defined by EN 15978. Processes included in Tally modeling scope are shown in bold. Italics indicate optional processes.

Notes about the Mass Timber Structural System LCA

Stage A4, Transportation, was included in the assessments. The mass timber products (glulam and CLT) used the truck transport distance from the manufacturer and supplier in Québec, Canada, to the building site in Denver, Colorado, a distance of 3,490 km (2,169 miles). All other products for three buildings: concrete, steel, metals, architectural elements, used average distances from the LCI database.

Negative GWP values in any LCA or EPD show stored carbon or avoided impacts from renewable resource use and/or material recycling. Large negative impacts are usually only observed in plant-based products because plants sequester carbon.

Trees, like all plants, are part of a carbon cycle where they continuously exchange carbon with the atmosphere through an uptake during photosynthesis and a release during decomposition or burning. This carbon cycle is called the **biogenic carbon cycle**. The biogenic carbon cycle for mass timber products starts when the tree is harvested from the forest (Stage A1), when it contains approximately 50% of elemental carbon by mass. [3] The carbon content entering the system after harvest, known as sequestered carbon, is stored in the mass timber until the building reaches its end-of-life and is demolished or deconstructed, and then buried in a landfill, burned for energy, recycled, or reused (Stages C and D).

There are different ways to think about how the biogenic carbon cycle impacts carbon sequestration in LCAs. Tally ®'s approach includes the cradle-to-grave stages and considers the wood volume's carbon content as it enters the assessment at Stage A1 (uptake) and the final disposition of the carbon content at Stages C and D.

The Platte Fifteen mass timber building has 701,845 kg of glulam beams and columns and 502,556 kg of CLT panels. To show how carbon is sequestered in a mass timber building, the carbon and carbon dioxide storage of the harvested trees used to make CLT panels have been calculated as shown in the table below.

Data			Calculations		
% of Carbon as weight of wood	50%		**Sequestered Carbon per kg CLT**	1 kg x 50% =	0.5 kgCeq/kg
Atomic Mass of Carbon	12 (amu)		**Sequestered CO_2 per kg CLT**	0.5 kgCeq/kg x 44kgCO_2eq/12kgCeq =	1.83 kgCO_2eq/kg
Molecular Mass of CO_2	44 (amu)		*Since the CO_2 is sequestered, this is a negative value because the CO_2 is not being released*		-1.83 kgCO_2eq/kg
Mass of CLT panels	502,556 kg		**CO_2 sequestered in CLT panels at Stage A1**	-1.83 kgCO_2eq/kg x 502,556 kg =	-921,353 kgCO_2eq

Sequestered carbon dioxide is measured in kgCO_2eq (kilogram of carbon dioxide equivalent)

To calculate the total GWP of the CLT panels, other stages of the Life Cycle must be considered. During Stage A4 (transportation), +95,764 kgCO_2eq are released which reduces the overall sequestered CO_2 by 10.4%.

kgCO_2eq released during A4 / kgCO_2eq sequestered during A1 x 100%

+95,764 kgCO_2eq / 921,353 kgCO_2eq x 100% = 10.4%

Stages C4 (Disposal) and D (Reuse, Recycle, Energy Recovery) also impact the total amount of CO_2 sequestered by the cross-laminated timber in the LCA. In the Tally ® LCA, the disposition of CLT is determined based on the most common practices used in North America. [2] In North America, 17.5% of disposed mass timber is recycled (recovered) and continues to store the CO_2. 17.5% of the disposed CLT is incinerated to produce energy which releases CO_2 into the atmosphere and decreases the total amount of CO_2 sequestered. And 65% of the CLT disposed goes to the landfill. 68% of landfilled CLT decomposes releasing carbon into the atmosphere and decreasing total amount of CO_2 sequestered, whereas 32% of landfilled CLT does not decompose and stores the carbon forever.

Notes about the Construction Stage A5

Stage A5 – Construction and Installation was not considered in this LCA. Environmental impacts examined during Stage A5 usually include labor, labor transport, waste disposal, crane operations, and construction materials such as scaffolding and framework. All these factors would increase the embodied carbon of the buildings. Speed and ease of construction should also be considered when calculating embodied carbon for Stage A5. Less crane time and fewer days with onsite activity will reduce embodied carbon during Stage A5. A 1996 British case study concluded that Stage A5 contributed between 5-9% of the total GWP of a 50,000 ft^2 office building when comparing wood, steel, and concrete systems. [4] The wood system was reported to require the least amount of energy to construct, then concrete, then steel.

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Data from the Platte Fifteen Life Cycle Assessment

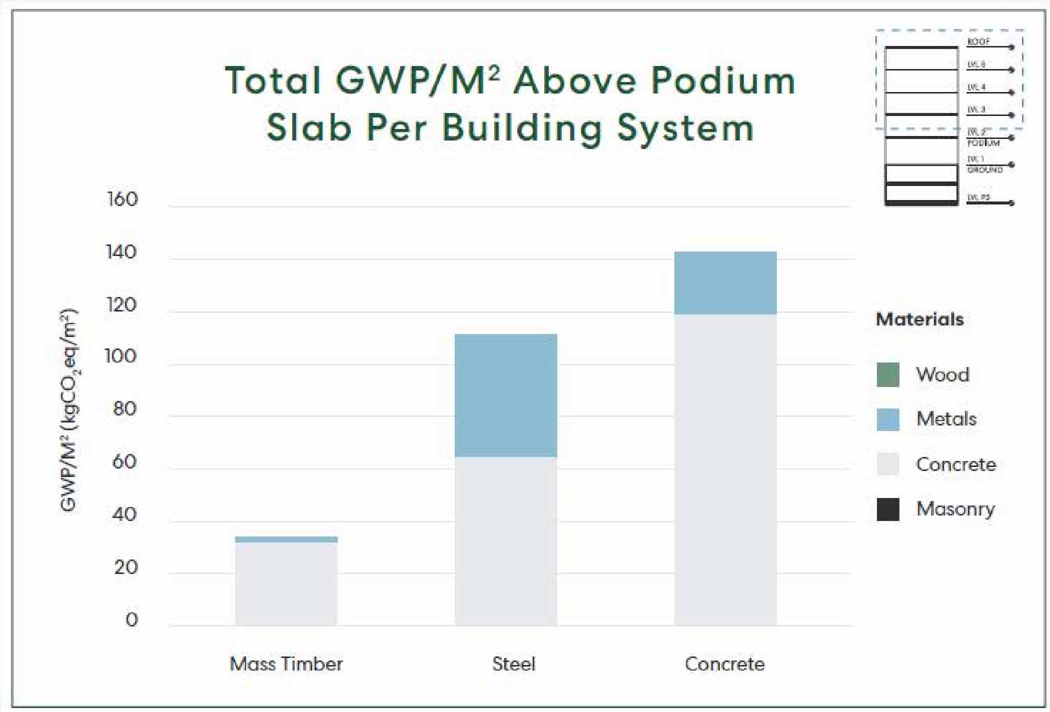

Chart 1: Total Global Warming Potential (GWP) per square meter above the podium slab for three building systems, showing contributions in each system from three material categories. Mass timber's GWP of 0.33/M² is so small it is not even visible in the chart.

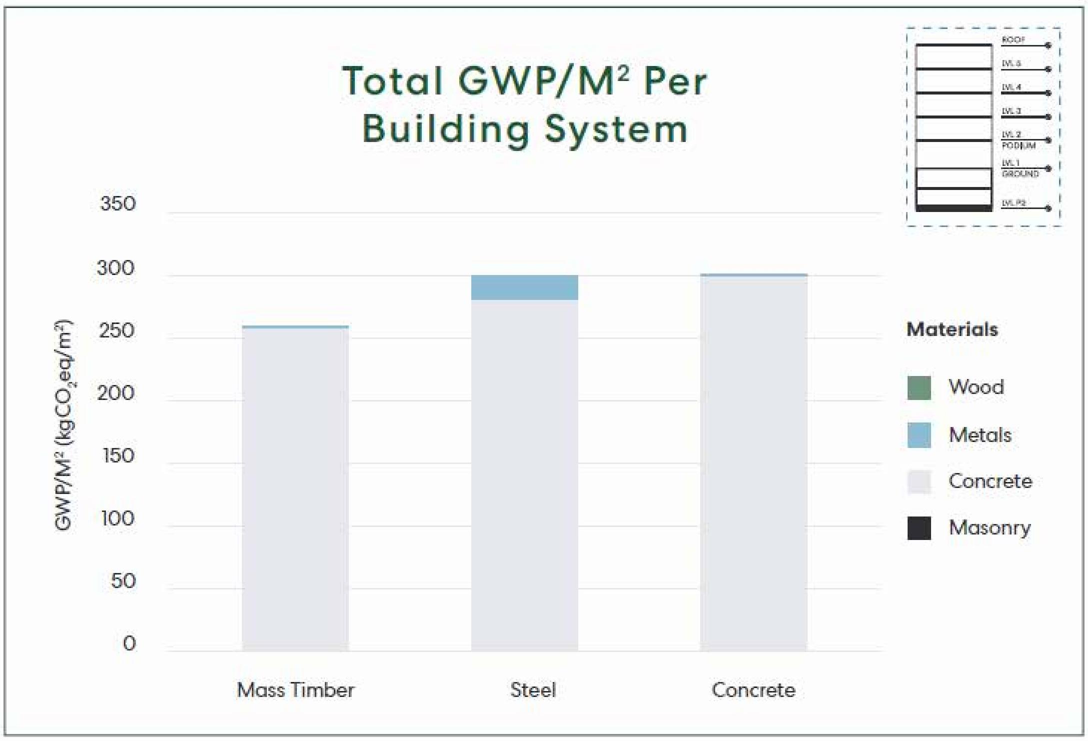

Chart 2: Total building GWP per square meter of each system with material contribution.

Chart 3 shows the contribution of each material to the GWP. It shows the amount of structural material quantities (SMQ) as a percentage of the total building mass next to the GWP contribution of each material as a percentage of the total GWP. This chart includes materials above the podium.

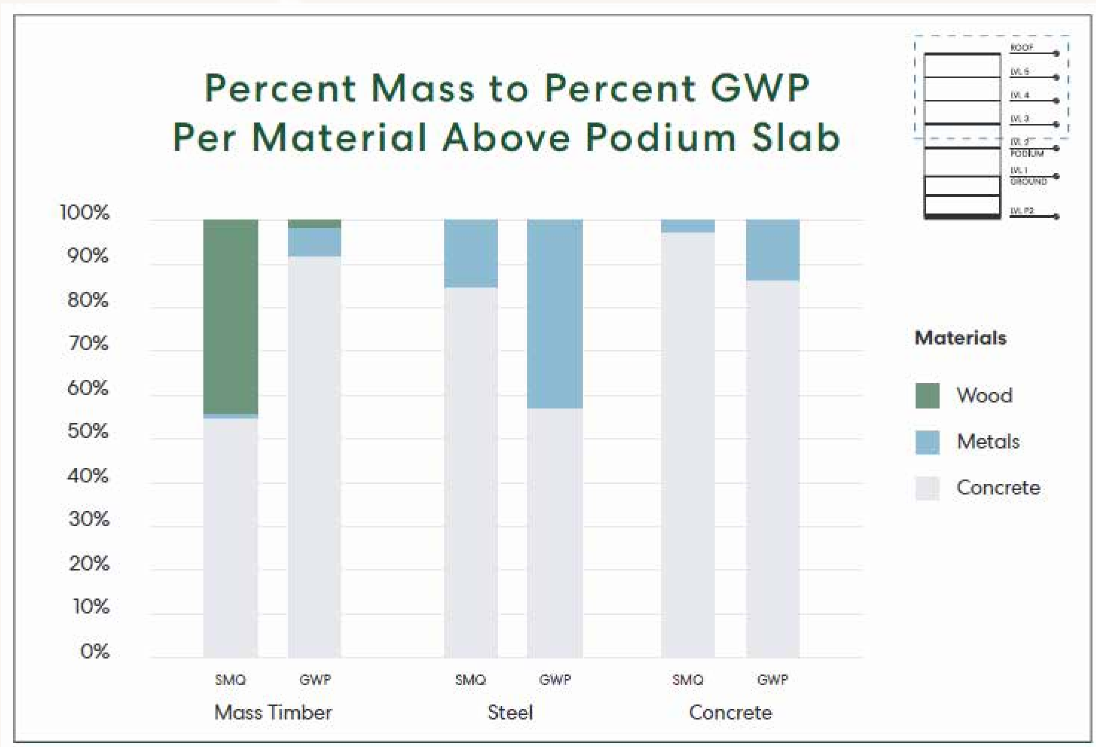

Chart 3: Relative contribution of materials to mass and GWP of each system, above the podium slab.

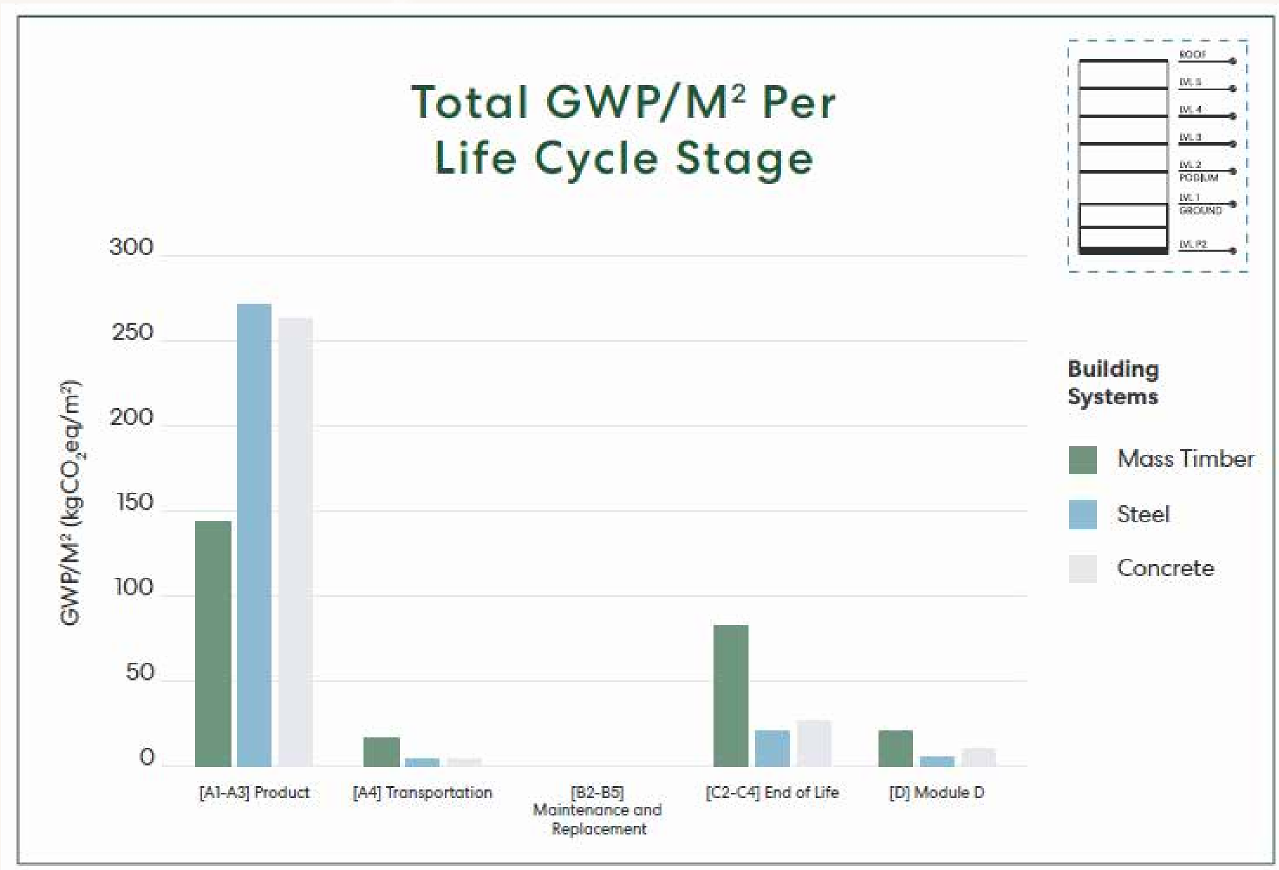

Chart 4: GWP contribution per square meter per life cycle stage of each building system.

Acknowledgements

Text modified from:

Fietel, Alexis et al. (2021). ***Platte Fifteen Life Cycle Assessment.*** KL&A Engineers & Builders.

White, Jason. (2021). ***Platte Fifteen Life Cycle Assessment.*** Adolfson & Peterson.
https://www.woodworks.org/resources/platte-fifteen-life-cycle-assessment/#:~:text=This%20life%20cycle%20assessment%20(LCA,office%20building%20in%20Denver%2C%20Colorado.

Sources:

1. U.S. EPA. (22 Oct 2024). *Sources of Greenhouse Gas Emissions.* United States Environmental Protection Agency. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
2. Dovetail Partners. (2014). *Municipal Solid Waste and Construction and Demolition Wood Waste Generation and Recovery in the United States.* *https://www.dovetailinc.org/portfoliodetail.php?id=5e2eec99f0f7e*
3. S.H., L., & R.A., S. (Oct 2003). *A Reassessment of Carbon Content in Wood: Variation Within and Between 41 North American Species*. Biomass and Bioenergy, pp. Volume 25, Issue 4.
4. Cole, R.J., & Kernan, P.C. (1996). *Life-Cycle Energy Use in Office Buildings*. Buildings and Environments, pp. Vol. 31, No. 4, pg. 307-317.

Into the Outdoors

Educational Partners:

HOW HEALTHY MARKETS SUSTAIN FORESTS

Life Cycle Assesment – Student Data Sheet – Activity 1

INSTRUCTIONS: Use this form to gather information from Platte Fifteen Life Cycle Assessment of mass timber, steel, and concrete office buildings.

Platte Fifteen Life Cycle Assessment GWP of Mass Timber, Steel and Concrete Structural Systems			
	Mass Timber	**Steel**	**Concrete**
Materials types of materials were used in the building?			
GWP/M² of Wood above podium slab *(Chart 1)*	1.		
GWP/M² of Metal above podium slab *(Chart 1)*	2.	2.	2.
GWP/M² of Concrete above podium slab *(Chart 1)*	3.	3.	3.
Total GWP/M² of all materials above podium slab *(Chart 1)*	4.	4.	4.
GWP/M² of Wood full building *(Chart 2)*	5.		
GWP/M² of Metal full building *(Chart 2)*	6.	6.	6.
Concrete of Concrete full building *(Chart 2)*	7.	7.	7.
Total GWP/M² of all materials full building *(Chart 2)*	8.	8.	8.
GWP/M² of Concrete below podium slab	9. 7 – 3	9. 7 – 3	9. 7 – 3

Use information from the table above to answer the following questions.

1. What percentage of GWP in the mass timber building is from concrete below the podium slab?

GWP/M² of Concrete (below podium slab) ÷ GWP/M² of Concrete (full building) x 100%

(9 ÷ 7) x 100%

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2. What percentage of GWP in the steel building is from concrete below the podium slab?

GWP/M^2 of Concrete (below podium slab) ÷ GWP/M^2 of Concrete (full building) x 100%

(9 ÷ 7) x 100%

3. What percentage of GWP in the concrete building is from concrete below the podium slab?

GWP/M^2 of Concrete (below podium slab) ÷ GWP/M^2 of Concrete (full building) x 100%

(9 ÷ 7) x 100%

Percent mass to Percent GWP Per Material Above Podium Slab			
	Mass Timber	**Steel**	**Concrete**
% Mass of Wood above podium *(Chart 3)*			
% GWP of Wood above podium *(Chart 3)*			
% Mass of Metals above podium *(Chart 3)*			
% GWP of Metals above podium *(Chart 3)*			
% Mass of Concrete above podium *(Chart 3)*			
% GWP of Concrete above podium *(Chart 3)*			

Use information from the table above to answer the following questions.

1. What do you notice about the relationship between the percent mass of wood used in the Mass Timber building compared to percent GWP from wood used in the Mass Timber building?

   Explain why you think this happens.

2. What do you notice about the relationship between the percent mass of concrete used in the Mass Timber building compared to percent GWP from concrete used in the Mass Timber building?

   Explain why you think this happens.

Percent of Total GWP/M² Per Life Cycle Stage for each Building System			
Mass Timber			
Life Cycle Stage	**GWP/M²** ($kgCO_2eq/m^2$)	**Calculate % of total GWP/M²** GWP/M² ÷ Total GWP/M² Mass Timber x 100%	**% of Total**
Product [A1-A3] *(Chart 4)*			
Transportation [A4] *(Chart 4)*			
End of Life [C2-C4] *(Chart 4)*			
Module D [D] *(Chart 4)*			
Total GWP/M² Mass Timber			
Steel			
Life Cycle Stage	**GWP/M²** ($kgCO_2eq/m^2$)	**Calculate % of total GWP/M²** GWP/M² ÷ Total GWP/M² Mass Timber x 100%	**% of Total**
Product [A1-A3] *(Chart 4)*			
Transportation [A4] *(Chart 4)*			
End of Life [C2-C4] *(Chart 4)*			
Module D [D] *(Chart 4)*			
Total GWP/M² Mass Timber			
Concrete			
Life Cycle Stage	**GWP/M²** ($kgCO_2eq/m^2$)	**Calculate % of total GWP/M²** GWP/M² ÷ Total GWP/M² Mass Timber x 100%	**% of Total**
Product [A1-A3] *(Chart 4)*			
Transportation [A4] *(Chart 4)*			
End of Life [C2-C4] *(Chart 4)*			

Module D **[D]** *(Chart 4)*			
Total GWP/M² **Mass Timber**			

Complete a written summary of the results of the Life Cycle Assessment of GWP for a Platte Fifteen office building constructed out of mass timber, steel or concrete. Your summary should include the following information:

For each building:

- Summary of GWP for the lifetime of each building (excluding stages A5, B1, B6, B7 & C1)
- Largest stage contributing to the GWP for each building
- Largest materials contributing to the GWP for each building
- At least one way to reduce the GWP for each building

Overall Review:

- Which office building provides the best opportunity to reduce the global CO_2 emissions produced by the building industry?

Support statements in your summaries with evidence from the text, tables, charts, and your calculations. Use complete sentences, proper grammar and correct spelling.

HOW HEALTHY MARKETS SUSTAIN FORESTS

Life Cycle Assesment – Cost Study – Activity 1

Educational Partners:

Comparative Cost Study
Mass Timber, Steel and Concrete Buildings

Excerpted from:
Platte Fifteen Life Cycle Assessment by KL&A Engineers and Builders, Adolfson & Peterson
Modified by Gina Smith from LEAF – Wisconsin's K-12 Forestry Education Program (13 Nov 2024) for use in this lesson.
Where appropriate, original text and citations from original sources have been preserved.

The LCA of the Platte Fifteen Life Cycle Assessment demonstrated that mass timber buildings can reduce embodied carbon and GWP in buildings. Do you think they are cost effective?

How much more do you think they cost than steel or concrete buildings?

Are they worth the extra cost?

The LCA focused primarily on life cycle analysis and design choices related to embodied carbon savings. Building material choices also have a cost in terms of dollars and time. Because the study was based on a constructed mass timber building that was compared with a structural steel alternative at the time the building was in the design-development stage, the actual costs of the steel or concrete alternatives used in the Life Cycle Assessment are not available. The original contractor, Adolfson & Peterson Construction, agreed to share the cost comparison data from the design-development stage of the steel building and to prepare an estimate for the concrete version of the structure used in this study. This allows us to attempt to answer, at least for the Platte Fifteen building, the question: what is the cost of sustainable material alternatives?

For this cost study, the cost estimates include all concrete foundations and substructure, primary structure, topping slabs, and slabs on grade and exterior vertical enclosures. Special systems installed to protect the mass timber from the weather during construction were also included in the cost estimates.

Most of the time, the initial pricing of mass timber systems shows an increased cost for mass timber materials over steel and concrete materials. That happened in this study also. The material cost of the mass timber structure was over 8% higher than the material cost of the steel structure. However, larger mass timber buildings can often be constructed in less time than concrete or steel structures though. For the Platte Fifteen office building, the contractor estimated that the mass timber structure could be built 2 months faster than the steel structure, and 3.5 months faster than the concrete structure. The cost study used this to adjust the cost of labor, equipment, waste and cranes for the mass timber building. Adding these considerations reduced the cost for the mass timber building from being 8.4% higher than the cost of a steel structure to being only 4.9% higher than the cost of the steel structure.

There are other factors related to cost that were not included in this cost study, but which would benefit the Platte Fifteen mass timber building. Two of these factors were early leasing and a higher lease rate. Early leasing was a result of the faster construction time of the mass timber building. Higher lease rates were due to the exposed timber structure which created a unique, **biophilic** built environment that led to the offices being leased very quickly. The building was 85% leased within one month after it was completed. In addition, the lease prices were some of the highest in the city and were above any other low to mid-height office buildings in the Denver central business district.

Conclusion

The LCA and cost data presented in this study show the embodied carbon savings of mass timber structural systems that can be achieved with minimal cost impact. The results cannot be directly applied to taller or different building types since they will be affected by the size of the structure, fire resistance requirements, and how the buildings are finished. But the results do indicate that similar positive results could be expected in a variety of building types.

Steel and concrete have been an important part of our buildings for a long time and will likely continue to be used in new buildings. We need to discover innovative approaches to reduce the impact of steel and concrete on building GWP. We also need to demonstrate to builders that thoughtful design, improved use of materials and reduced construction times, can lead to the construction of mass timber structures that sequester carbon, reduce building GWP and have a minimal increase in cost over steel and concrete buildings.

Realizing the capability of mass timber and its potential contributions to reducing embodied carbon is an opportunity for the building industry to preserve our natural environment.

The LCA of the Platte Fifteen Life Cycle Assessment demonstrated that mass timber buildings can reduce embodied carbon and GWP in buildings but are they cost effective?

How much more do they cost than steel or concrete buildings and are they worth the extra cost?

HOW HEALTHY MARKETS SUSTAIN FORESTS

Mass Timber in Wisconsin – Activity 2

Educational Partners:

You examined the Life Cycle Analysis of the Platte Fifteen office building in Denver, Colorado, and learned that using mass timber instead of steel and cement to construct buildings is effective at reducing embodied carbon and GWP over the life cycle of the building.

There are many economic factors involved in determining whether forest products companies in Wisconsin can produce mass timber or construction companies in Wisconsin will use mass timber in buildings instead of steel and cement. With your group conduct independent research to determine if you think mass timber is a viable forest product and/or building solution for Wisconsin.

Economic Evaluation of Mass Timber in Wisconsin	
Producers & Consumers	
Who **produces** mass timber (CLT or glulam) in Wisconsin? (If nobody does, where is it produced?)	
Who **consumes** (uses) mass timber (CLT or glulam) in Wisconsin? (If nobody does, where in the US is it used?)	
What Factors of Production are required to produce mass timber?	
Land	
Capital (including infrastructure)	
Labor	

Educational Partners:

Does Wisconsin have the factors of production required to produce mass timber? Explain.	
What is the supply and demand for mass timber in Wisconsin? How does this relate to scarcity and opportunity cost?	
Describe the Market **(Supply and Demand)** for mass timber in Wisconsin.	
How will supply and demand impact **cost** of using mass timber in Wisconsin?	
How does supply and demand for mass timber affect **scarcity**?	
What are the **opportunity costs** of choosing to build with mass timber over steel and concrete?	

CONCLUSION: Write a paragraph explaining whether you think mass timber is a viable forest product and building solution for Wisconsin. Use at least 3 pieces of evidence from your research to support your answer.

Economics Review

The following background information has been used and updated, with permission, from the LEAF Wisconsin K-12 Forestry Lesson Guide, 9-12 Unit, Lesson 4: The Forest Marketplace.
https://www.uwsp.edu/wcee/wcee/leaf/leaf-curriculum/k-12-forestry-lesson-guides/

The Demand for Forest Resources

Demand for products, including forest resources, is most heavily related to population, income, and societal trends. As human populations grow, so does the demand for **goods** and **services**. As the average annual income increases, so does demand for goods and services. The demand for goods is also related to societal trends. Trends begin in many ways, including innovation, marketing, and endorsement. A variety of trends have influenced the forest products industry. One notable trend was an increase in demand for exotic woods like teak and mahogany. That demand decreased after the harmful effects of rainforest clearcuts were widely understood.

The Supply of Forest Resources

Forest resource supply in a region can be determined by looking at three characteristics:

- Availability of forest resources
- Production capacity of the forest industry
- Supportive infrastructure

The availability of forest resources in a region can be estimated using:

- Volume of standing timber (by species, size, and grade): to determine the total resource
- Net annual growth of trees: to determine productivity of the forest
- Forest ownership: to determine accessibility to the resource; landowners have different objectives; not all owners are willing to harvest trees

This information can be gathered from U.S. Forest Service surveys. The U.S. Forest Service conducts inventory and analysis in all the major forested states in the U.S. The statistics are published annually in some states and every five to 10 years in others. The surveys provide a variety of statistical information organized by tree species, size, ownership, region, and grade. The surveys are useful for determining timber supply and comparing the forest resources of the different states and regions of the U.S.

Production capacity of the forest industry in a region can be estimated using:

- Number of **forest products** establishments
- Type and size of the forest products establishments
- Availability of skilled workers

These three indicators help to define the size and diversity of the industry, the potential gaps and surpluses in production, and the availability of human resources. The U.S. Forest Service publishes assessments of the timber industry in all the major forested states in the U.S. The assessments provide statistics on industry status, the volume of production of primary wood products, production efficiency, and timber growth and removals. The assessments are useful for comparing states and regions in the U.S. and determining the status and trends in the industry. Visit the Wisconsin DNR website (https://dnr.wisconsin.gov/topic/forestbusinesses/factsheets) for specific information on forestry and the Wisconsin economy.
Supportive **infrastructure** helps businesses produce and transport their products and includes:

- Transportation systems
- Availability of water
- Waste disposal
- Education system
- Security
- Other services

Infrastructure is usually provided by the government and funded through tax monies.

The Economics of Trade

CIRCULAR FLOW

The **circular flow** of economic activity describes the economic relationships that exist between households, businesses, and government. In the **product market**, households give money to businesses in exchange for goods and services and both households and businesses pay taxes to the government in exchange for the goods and services they supply. In the **resource market**, the government and businesses pay households for their productive resources (jobs they do) and the government pays businesses for goods and services the businesses supply to the government. This simplified economic model illustrates how the three players exchange goods, services, productive resources, and money.

COMPETITION

Competition for resources is the core concept around which modern economics is built. Prices, wages, production methods, type and quantity of production, size and organization of business firms, distribution of resources, levels of environmental regulation and compliance, outsourcing, and tax rates all result directly or indirectly from competitive processes.

Competition acts as both stick and carrot (it can threaten punishments or offer rewards). If a worker does not perform, or if the living wage in a region is relatively high, the employer can replace the worker or can move production to a region where wages are lower. If the employer does not treat the employee as well as other employers would, the employee can quit and go somewhere else if a job is available. If a company is not run efficiently or is too small to compete with large companies, customers can choose to go where they find better service at the same price or equal service at a lower price. All companies are subject to replacement by those that can do the job better or more cheaply. On the other hand, if the job is done well (better service at a cheaper price), the company is more likely to be rewarded.

SUPPLY AND DEMAND

In a capitalist economy, producers combine natural, human, and financial resources to provide goods and services that **consumers** are willing and able to purchase. The market price of a product or resource is determined by the interaction of **supply-and-demand**.

The costs and benefits of purchasing a good or service determine the amount of a product that a consumer will buy in a given time period. This is known as demand. As costs or benefits change, the demand for a product will also change. In general, as prices decrease, demand increases.

The amount of a good or service that producers are willing to sell during a certain period is determined by the amount of profit they can make. Producers intend to make the largest profit possible from their sales. Since profit is the difference between revenues and costs, anything that influences either can influence the amounts sellers want to sell. In general, the higher the price, the more producers will want to sell.