



USDA WOOD INNOVATIONS GRANT PROGRAM | 2024

Bakers Place Case Study

A comparative exploration into mass timber and
conventional construction methods



THE
NEUTRAL
PROJECT

theneutralproject.com

About

This report was prepared by The Neutral Project LLC, a sustainability-focused real estate developer based in Madison, WI, with an additional office in San Jose, CA.

The case study focuses on a mixed-use project, Bakers Place, currently under construction in Madison, WI. The study assesses the environmental, economic, and scheduling performance of a hybrid mass timber design approach. This is compared to equivalent steel, concrete, and entire mass timber structural systems. The case study team developed structural models in design software REVIT, then ran embodied carbon life cycle assessment, and obtained construction estimates to compare each approach.

The Neutral Project has assembled a world-class team of experts in construction and sustainability to conduct the necessary research, including: EQUILIBRIUM, Priopta, Arup, RDH Building Science, WoodWorks - Wood Products Council, Michael Green Architects, C.D.Smith, Angus-Young, USDA Forest Service Forest Products Laboratory, and other esteemed industry organizations.

This case study was made possible with the help of funding from the United States Department of Agriculture (USDA) Wood Innovations Grant Program in 2021 and funding support from the Softwood Lumber Board (SLB).

This publication made possible through a grant from the USDA Forest Service.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible State or local Agency that administers the program or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information is also available in languages other than English.

Table of Contents

- 01 Case Study Overview
- 02 Structural Analysis
- 03 Cost and Schedule Analysis
- 04 Embodied Carbon Life Cycle Assessment
- 05 Other Considerations
- 06 The Neutral Project





⁰¹ Case Study Overview

Introduction

The built environment is one of the largest contributors of carbon emissions¹ (both embodied and operational). In total, it is responsible for more than a third of global carbon emissions.

A recent technological development made using timber construction in tall buildings a practical alternative to less sustainable structural materials like steel and concrete. This technology involves laminating lumber to create larger structural elements and is commonly referred to as “mass timber”.

The limited accessibility of data regarding the costs, schedule, and environmental consequences of implementing mass timber in commercial real estate ventures has hindered the adoption of this sustainable technology.

This report aims to publicly contribute this crucial information based on an actual precedent: a mixed-use development project in Madison, WI. The Bakers Place project is undergoing construction as of writing this report.

The study compares different structural framing materials applied to the same Bakers Place architectural design: Mass Timber-Steel Hybrid (as used in the actual project), All Mass Timber, All Steel, and Post-Tensioned Concrete².

Financial constraints typically make such comparative studies unfeasible for one-off commercial development projects due to the significant additional design and estimation work required. Funding from the USDA and SLB has made this research possible..

¹ United Nations Environment Programme and Yale Center for Ecosystems + Architecture (2023) “Building Materials and the Climate: Constructing a New Future”. Available at: <https://wedocs.unep.org/20.500.11822/43293> (Accessed: December 28, 2023)

² All schemes were named according to dominant materials used in their structural design, but may utilize components from other materials.

Case Study Goals

This case study is intended to spread the learnings and best practices of building sustainable mass timber projects in North America. The project team hopes that it will help guide developers, policy-makers, and other industry practitioners in evaluating and creating new sustainable mass timber developments. As an industry, we must change the paradigm and work together to promote information sharing and advance the use of mass timber and sustainable development practices in North America.

The four major goals of this case study are as defined below:

- Evaluate the environmental, economic, and scheduling performance of mass timber-steel hybrid approach by comparing it with functionally equivalent mass timber, steel, and concrete structural systems for each development through conducting multiple LCAs and securing construction estimates.
- Quantify the sustainability of mass timber for buildings from an embodied carbon standpoint by commissioning sustainability consultants and industry experts to perform multiple whole-building LCAs.
- Assess the business case for a mass timber-steel hybrid approach for commercial real estate development regarding building costs, schedule efficiency, constructability, capital markets and insurer risk acceptance, consumer preferences, and carbon sequestration.
- Improve the familiarity of local developers, design professionals, and builders with mass timber. Increase the awareness of mass timber construction with local planning, zoning, fire marshals, building departments, city commissions, and neighborhood groups.

Case Study Team

This case study has been made possible through the Wood Innovations Grant program by USDA and funding support from the Softwood Lumber Board. The Neutral Project was awarded a grant in 2021 to conduct a comparison research of structural designs for Bakers Place project.

The Neutral Project has assembled a world-class team to design and engineer the Bakers Place project, as well as conduct necessary research, structural, carbon, and cost analysis.

This team consists of:

- Michael Green Architecture, serving as the design architect,
- EQUILIBRIUM as the mass timber structural engineer, and Engineer of Record for the mass timber elements of the project,
- Rivion as LEED consultant,
- Angus & Young as the Executive Architect and Engineer of Record for non mass timber elements,
- RDH Building Sciences as the mass timber design and construction observation consultant,
- C.D.Smith as the general contractor, analyzing cost and schedule,
- Arup as the fire safety and building code consultant,
- Priopta as the whole building life cycle assessment (LCA) consultant,
- WoodWorks supported in drafting this case study and other questions that the project team had during the design phase of the project.
- USDA Forest Service Forest Products Laboratory reviewed the LCA results.

Some of the top experts in mass timber planning, engineering, and architectural design are represented among these companies, with a number of them having successfully completed projects funded by the United States Forest Service.

Lead Developer:



Design Architect:



Construction Partner:



Whole Building Life Cycle Assessment



Mass Timber Consultant



Case Study Sponsor and LCA Reviewer



Structural Engineer, Mass Timber EoR:



Executive Architect, Engineer of Record:



Fire Safety and Building Code Consultant:



Mass Timber Design and Construction Consultant:



Case Study: Bakers Place



About Bakers Place

Bakers Place is a mixed-use building project developed by The Neutral Project - a sustainability-focused real estate development company. Bakers Place will provide 206 residential units and 9000 square feet of retail space located in the rapidly growing city of Madison, Wisconsin.

The building ranges in height from nine up to 14 stories. Bakers Place will offer studio, one-, two-, and three-bedroom units, as well as an array of amenities.

Bakers Place embraces environmental innovation through the hybrid use of mass timber construction combined with steel elements, passive house principles, LEED certification, and green roofs, among other sustainable features.

The design of Bakers Place honors local history by preserving and incorporating the oldest part of the Gardner Baking Co. building that dates to the early 1900s.

The Bakers Place project is undergoing construction as of writing this report. The building structure will be complete in May 2024, and full completion of this project is anticipated in Q1 of 2025.

Building Statistics

PROPERTY INFORMATION	
Address	849 E Washington Avenue, Madison, WI
Zoning	Traditional Employment District (TE) Capital Gateway Corridor 160 foot height restriction (1009' above sea level)
Site Area	1.008 acres
Developer	The Neutral Project LLC
PROPOSED DEVELOPMENT	
Gross Square Footage	304,908 square feet
Density	204.4 units per acre
Net Rentable Area	164,707 square feet
Number of Residential Units	206
Average Unit Size	712 square feet
Retail Area	9,000 square feet
Parking Stalls	110
Amenities	Community Garden, Yoga Room, Library, Cafe, Potting Room, Roof Bar and Sky Lounge, Package Room, Mail Room, and Heated Parking.
Sustainability Target	Pursuing LEED Gold Certification

Baseline Hybrid Design

The original design for Bakers Place was commissioned by The Neutral Project and developed by Michael Green Architects, and EQUILIBRIUM structural engineers in 2020.

The Bakers Place project is a 14-story building consisting of a 3-story concrete podium and 11 stories of mass timber-steel hybrid construction with a primarily residential program above it. The hybrid building system combines a traditional post-and-beam structure with steel columns, glulam beams, and cross-laminated timber (CLT) decks.

For a one-off development of this scale, it's not economically reasonable to design and evaluate multiple alternative schemes in detail. Before starting this case study, the team had to use general industry knowledge and consultant suggestions to choose a basic structural approach. The Neutral Project decided on using a hybrid scheme on the assumption that it balances sustainability, cost, and a predictable delivery schedule.

In this report, The Neutral Project is providing a unique behind-the-scenes look at the performance of the selected structural design, the details of its construction and permitting, and benchmarking against alternative structural schemes.



Hybrid Structure Construction

Bakers Place Lo5 Construction 12/20/2023



Structural Schemes Comparison

The purpose of this case study is to compare the economic, environmental, and scheduling aspects of Bakers Place hybrid mass timber approach (the baseline) with functionally equivalent concrete, steel, and full mass timber structural systems. The tower structures are the primary focus of the study.



1: Mass Timber-Steel Hybrid

Steel columns / Glulam beams / CLT decks



2: All Mass Timber

Glulam beams and columns / CLT decks



3: All Steel

Steel beams and columns / concrete metal on deck



4: Post-Tensioned Concrete

Reinforced concrete columns / post-tensioned concrete slab

Methodology

The case study was conducted in the following sequence:

1. The Neutral Project assembled a consultant team and provided all existing drawings and calculations for the baseline hybrid design.
2. The project architect (MGA) and structural engineer (EQUILIBRIUM) designed three additional structural systems (full mass timber, steel and concrete) that are functionally equivalent to Bakers Place. In each scenario, the structural column spacing was aligned as closely as possible with the baseline architectural floor plan and unit layout.
3. The structural engineer (EQUILIBRIUM) created a BIM model in Revit for alternate schemes used to run simulations.
4. The project's general contractor (C.D. Smith) estimated a construction schedule and detailed hard costs for each of the schemes.
5. The life cycle assessment consultant (Priopta) ran a Life Cycle Analysis for each of the schemes using One Click LCA software.
6. Using identical takeoff data as Priopta, USDA Forest Product Laboratory ran a comparative LCA using different software from Athena Impact Estimator, Tally and SimaPro LCA. With the goal to compare outputs from these LCA tools and offer insights to differentiate the commercial LCA tools.
7. Using all of the above, The Neutral Project compiled this case study report to document the findings of our comparison of functionally equivalent hybrid mass timber, full mass timber, steel, and concrete high-rise structures.

Summary of Findings

The results of this case study vividly illustrate the relative strengths and weaknesses of different design and construction approaches to a functionally equivalent building:

- **Cost.** Post-tensioned Concrete structure is the cheapest structure to build, providing almost 10% savings for structure compared to the All Mass Timber.
- **Schedule.** All Steel structure has the fastest construction time.
- **Sustainability.** All Mass Timber structure is the most efficient at reducing carbon impact.

Although the concrete and steel structures lead the way in terms of cost and schedule, the sustainability measures of both of these structures are woefully inadequate, as demonstrated in Section 4 of this report.

The Mass Timber-Steel Hybrid scheme provides a balanced performance with the overall second-highest carbon reduction potential, second fastest construction time, and a lower cost than an all mass timber scheme.

SCHEME	TIME TO BUILD	COST PER SF	GLOBAL WARMING POTENTIAL	CARBON REDUCTION
Mass Timber-Steel Hybrid (Baseline)	26.5 months	\$263	244 kgCO ₂ e/m ²	- 16%
All Mass Timber	26 months	\$271	232 kgCO ₂ e/m ²	- 20%
All Steel	25 months	\$262	282 kgCO ₂ e/m ²	- 3%
Post-Tensioned Concrete	25.5 months	\$247	289 kgCO ₂ e/m ²	0%

Hybrid Approach Viability

The hybrid scheme achieves a balance between efficient time savings, costs, and carbon reduction.

Cost. Mass Timber-Steel Hybrid scheme is cheaper than the all mass timber scheme by about 3% and costs almost the same as the all steel scheme.

Schedule. The hybrid approach is second only to the All Steel scheme because it requires more trade coordination for steel-to-glulam and steel-to-steel connections. In practice, this can be resolved by using a joint group of trades (i.e. Union Carpenters, Ironworkers, and Laborers) for structural erection. C.D. Smith used a similar approach for The Ascent in Milwaukee (as of 2023, the tallest mass timber building in the world) and it proved to be a harmonious assembly process.

Carbon. The Mass Timber-Steel Hybrid model achieves about 15% carbon reduction compared to the Post-Tensioned Concrete scheme. Which is about 5 percentage points lower than the carbon reduction potential on the All Mass Timber scheme.



⁰² Structural Analysis

Method

The structural scheme designs for this case study are conceptual and represent only the primary structural elements together with building components needed to achieve functionally equivalent performance. The intent was to create designs that were accurate enough to be used in a comparison for cost, speed of construction, and embodied carbon.

EQUILIBRIUM's method in developing these designs followed these steps:

1. Choose structural systems that meet fire rating requirements,
2. Place columns as appropriate based on unit layouts,
3. Design and/or approximate a design for a "typical floor",
4. Extrapolate the typical floor framing throughout the part of the building above the podium,
5. Evaluate the impact on floor-to-floor heights,
6. Design a "typical" column stack,
7. Evaluate the impact on lateral systems and the podium structure.

Assumptions

The same podium structure was kept for each building, except for differences required due to the height and weight of the building above.

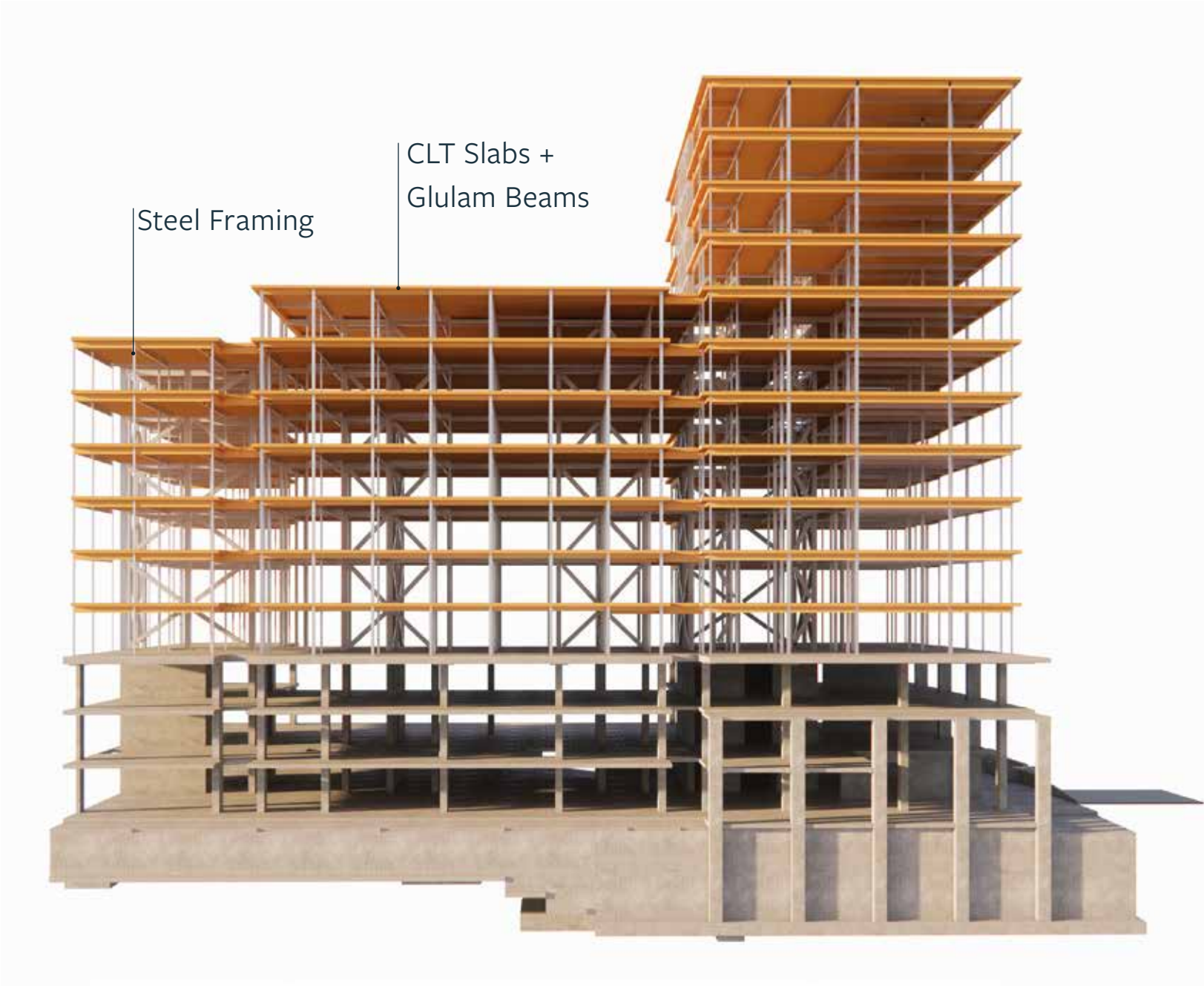
Lateral systems used in each scheme required some rearrangement of units. The design of various schemes kept volumetrically similar building structures, rather than pursuing identical numbers of units.

The design guidelines are based on the International Building Code (IBC) 2021 and its referenced standards:

- **Superimposed Dead Load.** 15 psf not including gypcrete acoustic topping where applicable,
- **Live Load.** 40 psf (reducible) + 15 psf (non-reducible) for partitions
- **Fire Rating.** 2 hours for floors and 1 hour for the roof (2 hours, for occupiable roof sections).

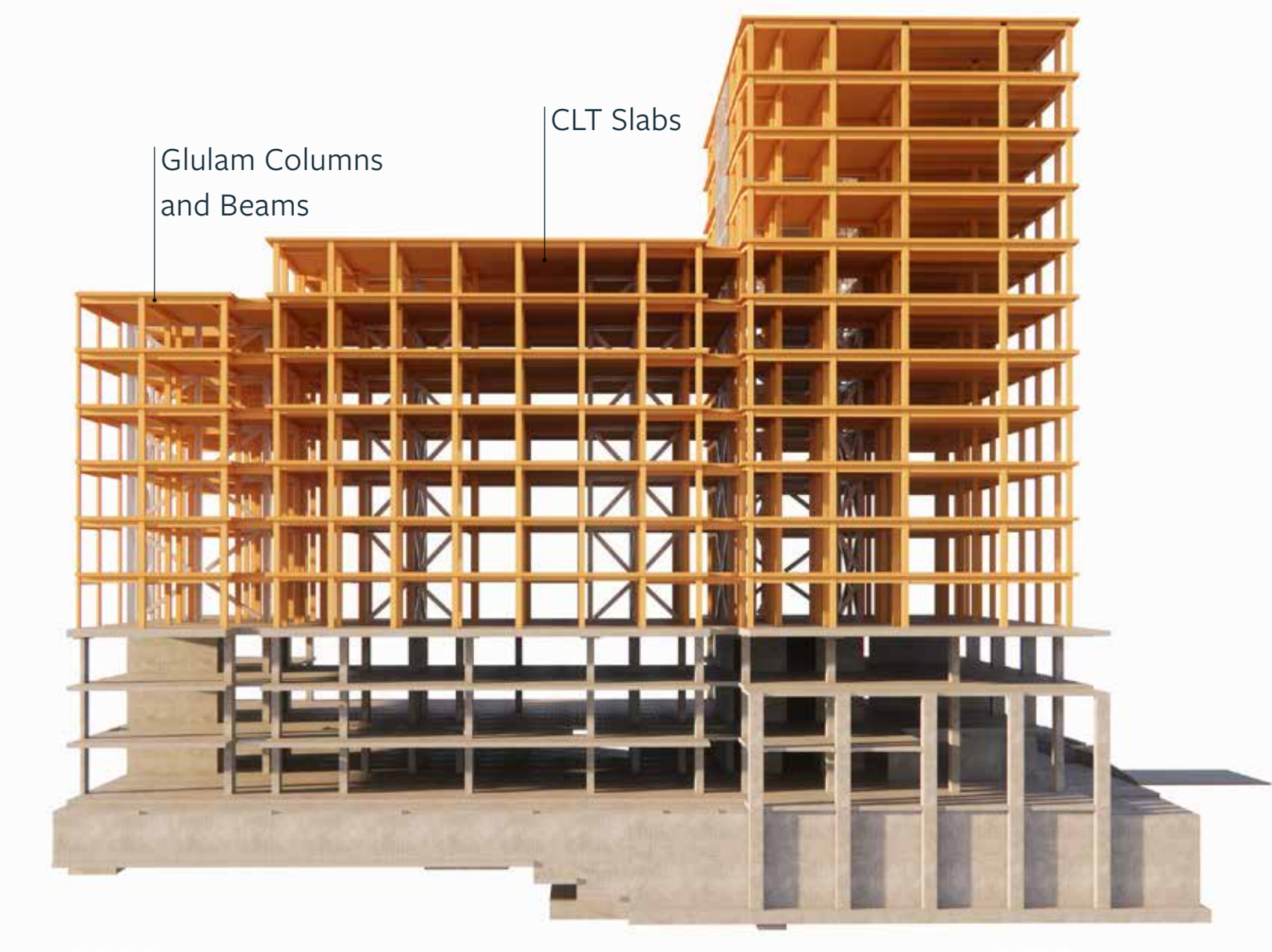
Mass Timber And Steel Hybrid

DESCRIPTION
The original building design, currently under construction.
FLOOR-TO-FLOOR HEIGHT
10'-9"
FLOOR SLAB
The design used a CLT slab made of KLH 180mm Austrian Spruce with an addition of 2" gypcrete and a 5/16" sound mat on top for acoustic purposes.
BEAMS
The design uses Hasslacher Nordic Spruce glulam beams (Grade 24F-1.8E).
FRAMING
The design assumes steel framing using a combination of A992 W sections and A500 Gr C HSS sections.
FIREPROOFING
The project was pursuing Type VI-B construction under 2021 IBC code, and requested a variance to increase mass timber exposure to 60%. The 2024 IBC code provisions allow for 100% ceiling exposure.
LATERAL SYSTEM
The lateral system comprises a braced steel frame (HSS A500 Gr C brace sections and W shapes A992 grade material columns and beams) above the concrete podium with a system of reinforced concrete shear walls below.
PODIUM AND FOUNDATION
The podium and foundations below comprise of post tensioned slabs supported on reinforced concrete columns and shear walls.



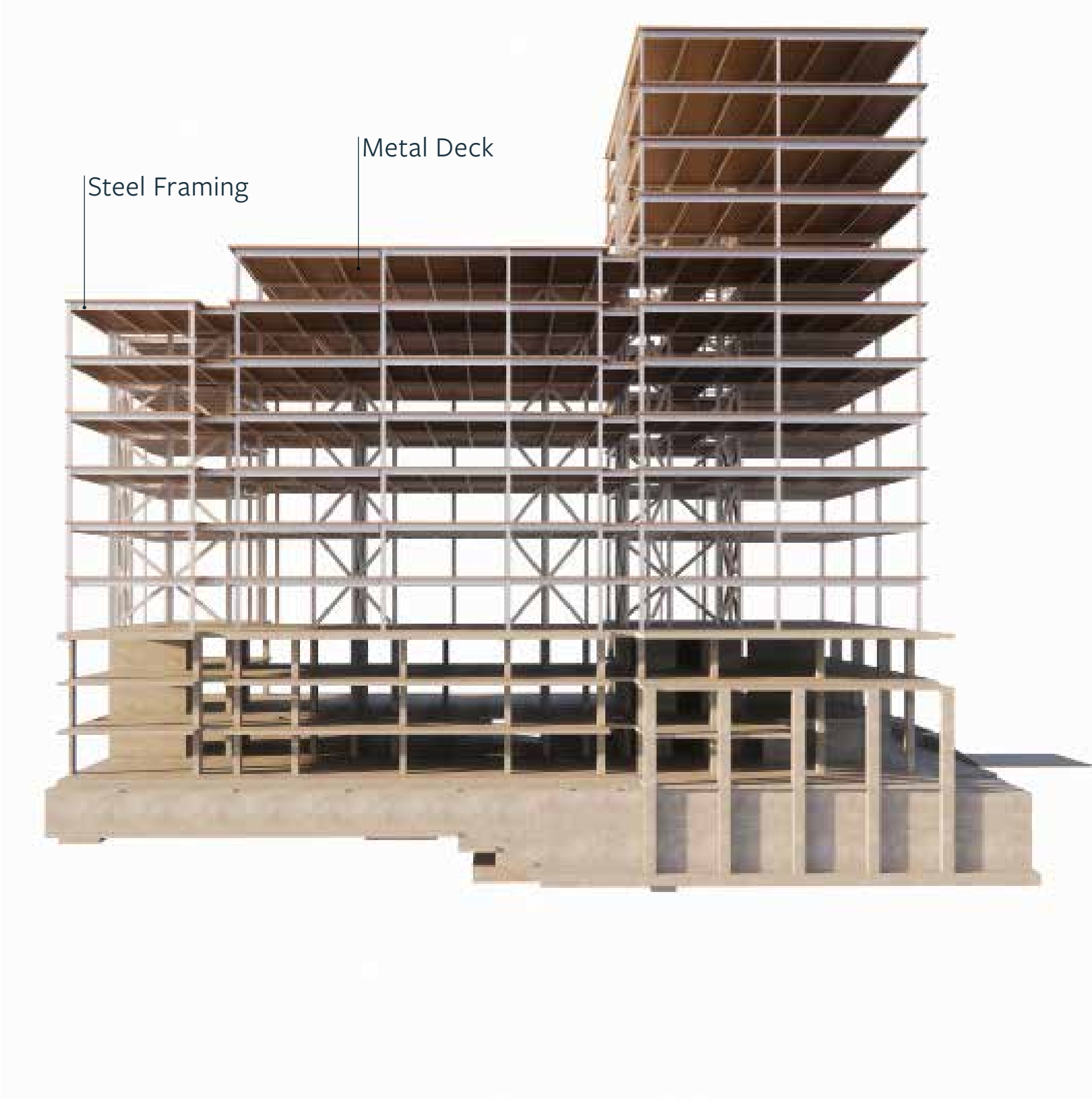
Timber

DESCRIPTION
For the full mass timber option, Equilibrium has kept the same framing layout as the real building scheme. This is appropriate because the CLT floor plates are unchanged and beams were already laid out to be relatively short spanning and efficient.
FLOOR-TO-FLOOR HEIGHT
10'-9" (same as baseline).
FLOOR SLAB
The scheme uses the same floor slab as the baseline: a CLT slab made of KLH 180mm Austrian Spruce with an addition of 2" gypcrete and a 5/16" sound mat on top for acoustic purposes.
BEAMS
Outside of the braced frames, steel elements have been replaced with glulam Hasslacher Nordic Spruce Grade GL 28h.
FRAMING
The design assumes the use of A36 plate steel for columns and Ricons by Knapp beam end connections of various sizes.
FIREPROOFING
This scheme assumes Type VI-B construction under 2021 IBC code, similarly to the baseline scheme, with only 20% ceiling exposure. It's important to note that the 2024 IBC code provisions allow for 100% ceiling exposure.
LATERAL SYSTEM
The lateral system comprises locally inserted braced steel frames (HSS A500 Gr C brace sections and W shapes A992 grade material columns and beams) above the concrete podium with a system of reinforced concrete shear walls below.
PODIUM AND FOUNDATION
The mass timber scheme has the same requirements for the podium and foundation as the baseline hybrid scheme as the weight of the structure in two schemes is very similar.



Steel

DESCRIPTION
For the steel option, Equilibrium has placed columns on a roughly 30'x30' grid while respecting the baseline unit layouts. The structure was formed from a composite slab-on-metal deck between composite filler beams, which span to girders and then to W columns.
FLOOR-TO-FLOOR HEIGHT
12'-4" (higher than the baseline).
FLOOR SLAB
The Steel structural scheme uses a slab-on-metal deck: a 3 1/2" layer of 3000 psi lightweight concrete on top of 3" 20 ga. composite steel deck. The resulting floor slab thickness is 6 1/2".
BEAMS
The beams in the Steel scheme assume ASTM A992 grade steel with additional A36 plate steel for connection details.
FRAMING
The steel columns assume W12 shapes with A992 grade material.
FIREPROOFING
This scheme would require spray-applied fireproofing on steel framing members to achieve the fire rating.
LATERAL SYSTEM
The lateral system assumes braced frames (W shapes A992 grade material) similar to the baseline design, but stretched vertically to accommodate the taller floor-to-floor heights.
PODIUM AND FOUNDATION
The total gravity load to the podium structure and foundations is about 30% greater in this scheme compared to the baseline. The layout is quite different, however, with far fewer columns, each carrying substantially higher load. The design of the Steel scheme assumed a full transfer slab.



Concrete

DESCRIPTION

For the concrete option, Equilibrium has envisioned a scheme with post-tensioned flat plate slabs supported by reinforced concrete columns. Lateral support is provided by reinforced concrete shear walls.

FLOOR-TO-FLOOR HEIGHT

9'-7 1/2" , this is less than the baseline scheme because this scheme doesn't require dropped beams to support the floor slab.

FLOOR SLAB

The all Concrete scheme assumes 5000 psi of a high early strength mix concrete with rebar intensity of 1.75 psf and post-tensioning intensity of 0.8 psf.

BEAMS

N/A

FRAMING

In this scheme, the columns were placed to limit disruption to baseline unit plans while achieving optimal spans for a post-tensioned concrete system of (25' to 30'). The rebar intensity in columns was assumed at 300 lb/yd³. The required strength ranged from 5,000 psi on the top levels to 10,000 psi below 7th level.

FIREPROOFING

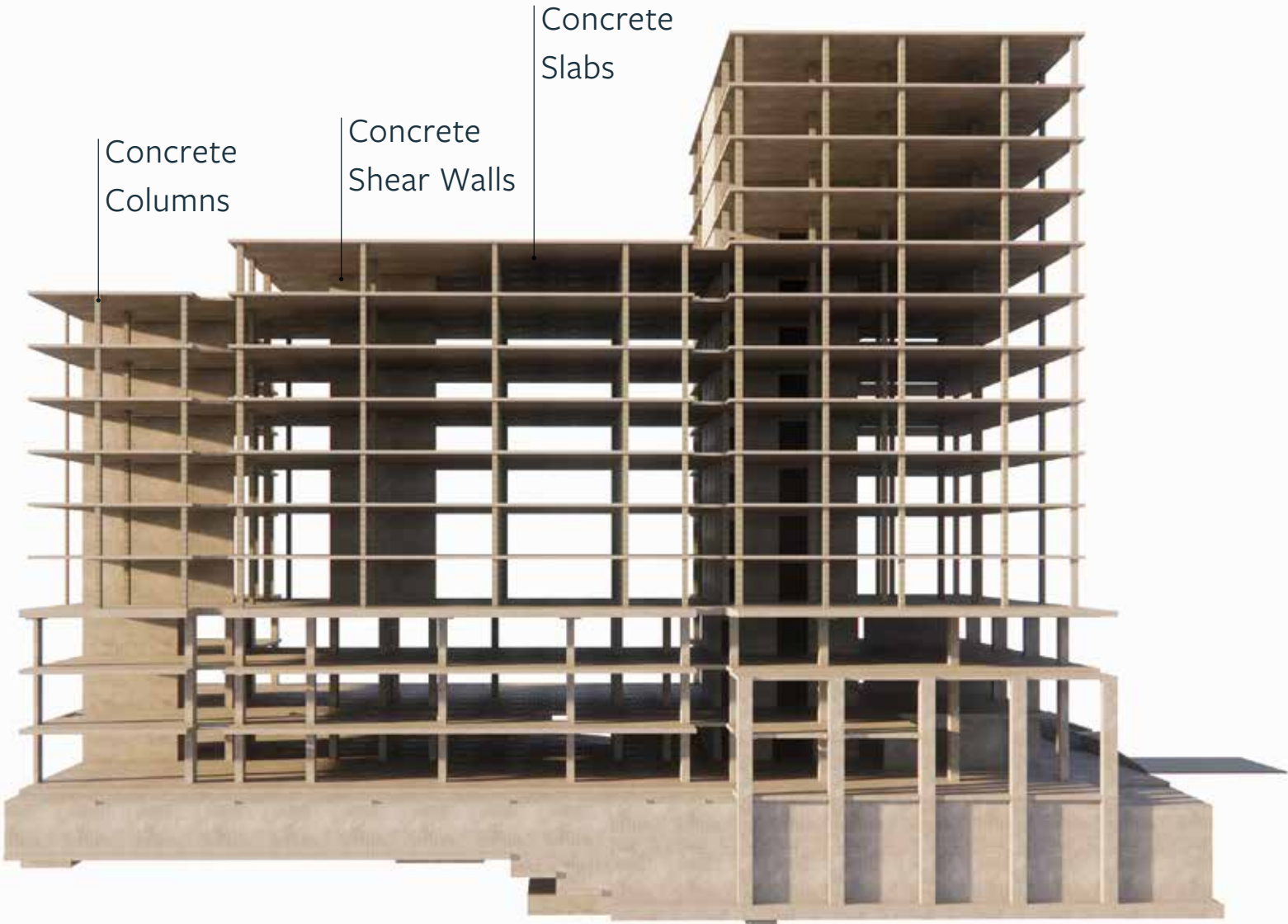
Concrete is naturally a fire retardant material. This scheme assumed one layer of gypsum over the concrete for added fireproofing. The basis of design for this structure is Type I-A under 2021 IBC.

LATERAL SYSTEM

The lateral system in this scheme assumed the same concrete strength as for the columns with a rebar intensity of 200 pcy.

PODIUM AND FOUNDATION

The total gravity load to the podium structure and foundations is about 55% greater in this scheme compared to the baseline. The layout is quite different, however, with far fewer columns each carrying substantially higher load. The design assumes discrete transfer beams at the fourth level in lieu of a full transfer slab.



Structural Comparison

SCHEME	ADVANTAGES	DISADVANTAGES
Mass Timber-Steel Hybrid (Baseline)	• Lower weight compared to all concrete scheme • Part of labor moved off site	• Requires complex coordination between different trades for each level erection • Not common for residential construction
All Mass Timber	• Lower weight compared to all concrete scheme • Part of labor moved off site	• Not common for residential construction in much of the country
All Steel	• Part of labor moved off site	• Not common for residential construction in much of the country
Post-Tensioned Concrete	• The standard way to build a residential structure • Less coordination between trades to erect it	• Largest amount of on site labor required of all schemes • Requires the largest foundation • Can be difficult to modify in the future • Heaviest structure



⁰³ Cost & Schedule Analysis

Method

C.D. Smith Construction produced a schedule of values for each proposed system that outlines the estimated costs per square foot and months required to construct each structure using the following assumptions:

All pricing in this construction analysis is based on Q3, 2023.

The All Steel scheme pricing is based on the same steel column layout as what is included in the baseline hybrid structure.

Additionally, all schemes, including All Mass Timber are based on the same fire-resistance rating as the baseline hybrid scheme.

All other assumptions and considerations are based on the structural narrative, found in Section 2 of this report.

Findings

The results of this cost and schedule comparison reveal that the Post-Tensioned Concrete scheme is the cheapest structure to build while the All Steel structure has the fastest construction time. This illustrates why traditional developments that predominantly optimize for cost reduction have historically favored concrete and steel structures.

Currently, the Mass Timber-Steel Hybrid Structure costs less than the All Mass Timber scheme, but takes longer to build due to a relatively more complex coordination of trades. Mass timber use in buildings is an emerging technology. It would be able to compete with steel and concrete when it could reach similar economies of scale.

Additionally, these estimates don't take into account the income side of the development equation, where mass timber structures have a potential for rent premiums that could offset some of the relatively higher costs.

SCHEME	TIME TO BUILD	COST PER SF
Mass Timber-Steel Hybrid	26.5 months	\$263
All Mass Timber	26 months	\$271
All Steel	25 months	\$262
Post-Tensioned Concrete	25.5 months	\$247



⁰⁴ Embodied Carbon Life Cycle Assessment

Method

The Neutral Project retained Priopta to conduct a Life Cycle Assessment (LCA) of the Bakers Place development project using One Click LCA software.

Priopta modeled four different structural frame options for Bakers Place based on quantity takeoffs from the models created by EQUILIBRIUM. Carbon reduction was calculated based on a baseline of a traditional concrete building that produces 289 kilograms of CO₂e equivalent per square meter.

The results are measured in Global Warming Potential (GWP) Intensity, which is denoted as kilograms of carbon dioxide equivalent per square meter (kgCO₂e/m²).

Additionally, the USDA Forest Products Lab (FPL) used the same material take-offs as inputs to different Life Cycle Assessment tools, such as Athena Impact Estimator, Tally, and SimaPro LCA. FPL's objective was to evaluate potential differences in LCA software outputs. The FPL research is still in progress as of the writing of this report.

Assumptions

- This study only addresses the structural frame and does not include materials associated with the enclosure or other building elements.
- The embodied carbon of the Post-Tensioned Concrete scheme was used as a reference point, from which reductions in embodied carbon of other schemes were measured.
- All four structural frame options primarily impact the upper levels above the concrete podium. While the podium remains largely consistent, some schemes impacted the concrete/rebar volumes associated with the columns and foundation.
- The floor area definition used for calculating GWP Intensity (kgCO₂e/m²) only references above-grade floor area. However, the below-ground materials were included in the impact analysis.
- The LCA conducted for the purposes of this study was executed using One Click LCA software, for which it is standard practice to report values with and without biogenic carbon separately. This results in a conservative estimate of the potential for carbon reduction. A note on biogenic carbon accounting and related carbon reduction potential is provided at the end of this section.

LCA Findings

The Life Cycle Assessment (LCA) conducted by Priopta illustrated superior environmental performance of both All Mass Timber and Mass Timber-Steel Hybrid compared to the All Steel and Post-Tensioned Concrete schemes.

The All Mass Timber structure has the largest carbon footprint reduction of nearly 20% compared to the concrete reference. The Mass Timber-Steel hybrid structure achieves a 16% carbon reduction. The steel structure achieves up to 3% reduction in carbon emissions.

Consistently, the component of every structure that produces the most carbon emissions is the ready-mix concrete in the building’s podium. Additionally, Priopta’s analysis illustrated the adverse environmental effect of adding fire-rated gypsum board (GWB) to the underside of the CLT. When added, GWB reduced the carbon reduction of the Mass Timber-Steel Hybrid Scheme to 11% and that of the All Mass Timber to 15% compared to the concrete reference.

The USDA Forest Products Lab (FPL) Life Cycle Assessments are still a work-in-progress, but preliminary results have yielded similar findings to the work done by Priopta.

Carbon Comparison Summary

SCHEME	GWP	CARBON REDUCTION
Mass Timber-Steel Hybrid	244 kgCO ₂ e/m ²	- 15.5%
All Mass Timber	232 kgCO ₂ e/m ²	- 20%
All Steel	282 kgCO ₂ e/m ²	- 2.5%
Post-Tensioned Concrete	289 kgCO ₂ e/m ²	0%

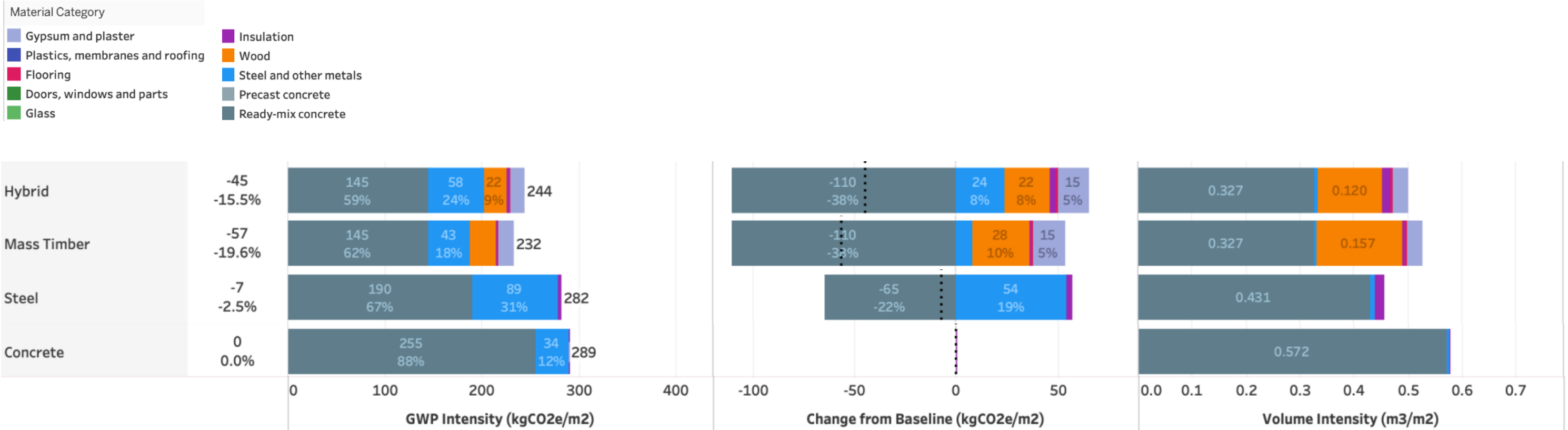
GWP by Material Type

In the following graph, the GWP results are broken down by material type, represented by the different colors (e.g. gray for ready-mix concrete, blue for steel and other metals, and orange for wood). Within each bar, the top label represents GWP intensity (kgCO₂e/m²) and the bottom text label represents the percentage of total GWP for each material type.

The leftmost column of results shows the GWP intensity for each scheme. The middle column shows the change in GWP intensity relative to the concrete baseline scenario and how these reductions are achieved by material.

For example, for the full mass timber scheme, we see that the GWP of concrete compared to the baseline concrete scheme is 110 kgCO₂e/m² lower (due to less concrete volume), but it also increases the wood by 28 kgCO₂e/m², steel by 9 kgCO₂e/m², and gypsum concrete by 15 kgCO₂e/m² (classified as gypsum and plaster). The net effect is represented by the dotted black line, representing a reduction of 57 kgCO₂e/m² or close to 20% reduction relative to the concrete baseline.

The third column shows volume intensity (m³/m²), which is a way of visualizing the total material quantities across all materials. Note that if this data were given on a mass basis (kg/m²), the graphs would be significantly different due to the different densities (kg/m³) of different materials.

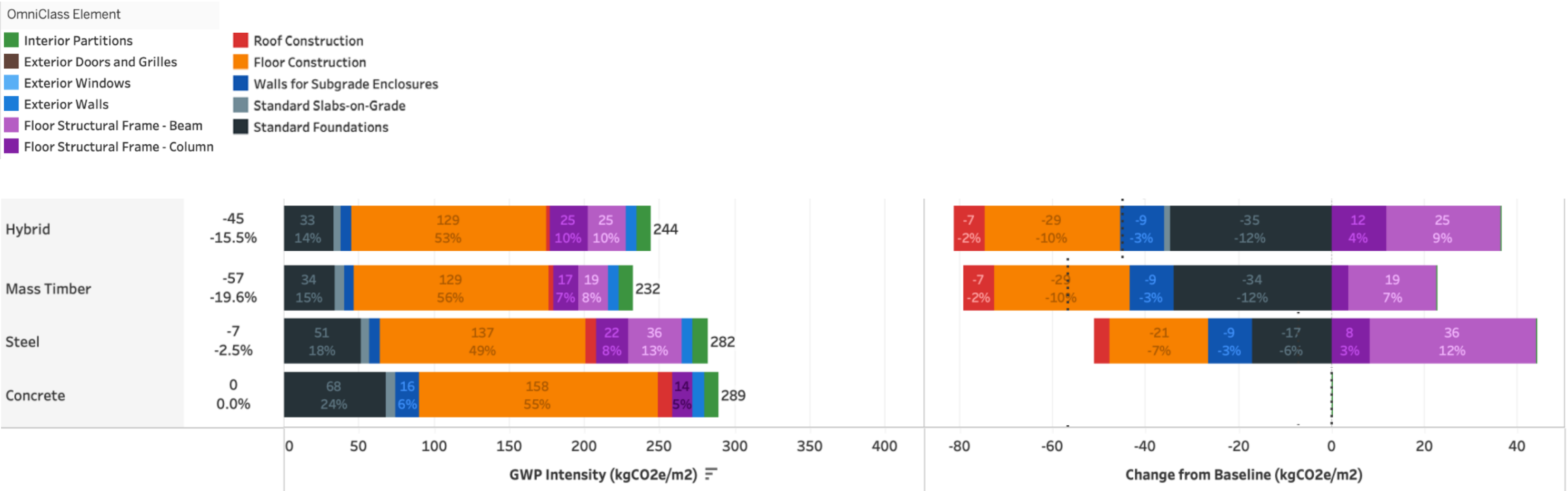


GWP by Building Element

The following graph shows the breakdown in Global Warming Potential results by Building Elements according to OmniClass classification.

For all structural schemes, the building elements with the highest GWP are Floor Construction (49%-57%), followed by foundation (24%-13%), then Columns (5%-10%) and Beams (0%-13%).

Notably, the portion of carbon footprint stored above ground is close to half of the total global warming potential across all schemes. The above ground part of the All Mass Timber scheme accounts only for 48% of the structure's total GWP footprint. While the above ground part of the structure accounts for 55% GWP of the Mass Timber-Steel Hybrid scheme.



Biogenic Carbon in WBLCA

Biogenic carbon is all carbon stored in, sequestered by, or emitted through organic matter. As such, biogenic carbon storage refers to carbon stored in organic matter, like wood, temporarily or indefinitely (Hoxa et al. 2020)¹.

Typical LCA calculations involving wood products only account for the fossil-fuel-related impacts (e.g. emissions for logging, transport, manufacturing/processing), but do not account for biogenic carbon fluxes happening in the forest. The results presented thus far do not account for biogenic carbon.

Methods of accounting for biogenic carbon storage fall primarily into two categories, static and dynamic temporal approaches.

In static approaches, LCA studies may try to account for the stored biogenic carbon in wood products by quantifying the total carbon stored in the wood, converting that to a CO₂ equivalent number (CO₂e), and multiplying that by a -1. The idea is to quantify the benefits of temporarily storing the biogenic carbon of wood in a building over the lifespan of the building. Multiplying this figure by -1 may be considered an overly optimistic assumption, based on the latest research around dynamic biogenic carbon modeling.

An alternative dynamic approach to modeling biogenic carbon storage is called “GWPbio”, which aims to not only quantify the benefit of product carbon storage (the longer the wood is stored, the better), but also the impact of forest rotation period (i.e. how long the replanted trees take to grow and sequester this biogenic carbon). Dynamic approaches account for when and at what rate the biogenic carbon is emitted or sequestered, both in the forest (i.e. forest rotation period) and in the product (i.e. product storage period).

¹ Hoxha, E., et al. (2020). *Biogenic carbon in buildings: a critical overview of LCA methods*. *Buildings and Cities*, 1(1), pp. 504–524. DOI: <https://doi.org/10.5334/bc.46>

While dynamic approaches tend to be more robust and transparent, they are currently only used for academic purposes, due to the complexity and non-standardized approach to dynamic LCA modeling (Pak 2020)¹. Static approaches are more standardized for use in Whole Building Life Cycle Assessments and current ISO standards (ISO 14040:2006) require static accounting-based reporting.

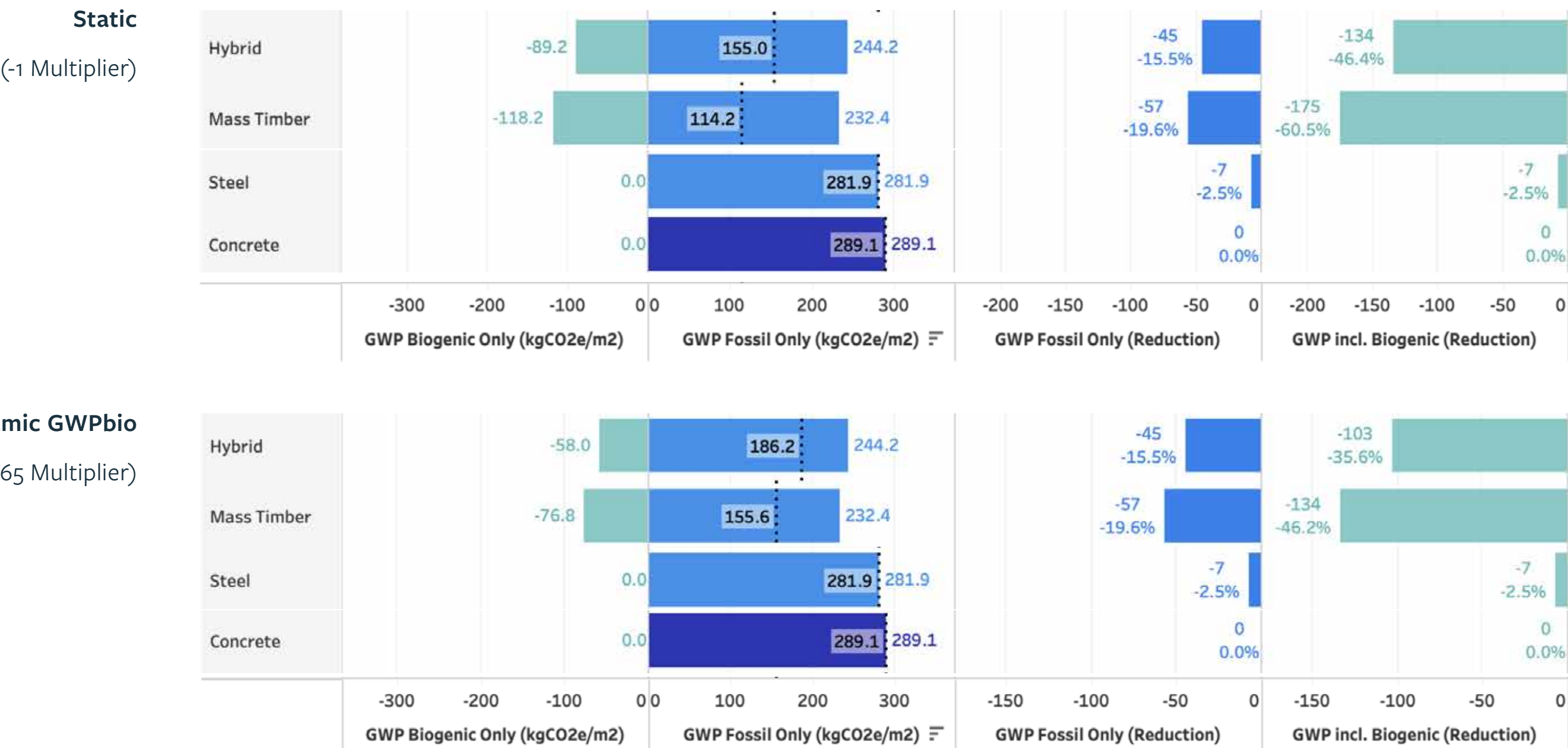
Whether a static or dynamic approach is used, end-of-life assumptions can have a drastic impact on the results of a carbon assessment. Various LCA softwares use different end-of-life assumptions, typically including a mixture of: incineration, recycling, and landfill of the wood product. Incineration causes biogenic carbon to be emitted back into the atmosphere but has the benefit of creating energy that can offset fossil fuel use. Placement into a landfill results in a portion of the biogenic carbon being permanently stored, as the majority of landfilled wood products do not decay (LCA tools make assumptions on the process of decomposition). Recycling partially extends the life of the wood, which means that the sequestered carbon remains sequestered. Secondly, it displaces the need for and use of a new material.

¹ Pak, A. (2020) *Biogenic Carbon Accounting of Wood Products in Whole Building LCA*. November 27th, 2020. Available at: <https://www.youtube.com/watch?v=7XTzKESNGEU>. (Accessed: August 29th, 2023)

Biogenic Carbon In Schemes

The LCA results presented throughout the case study thus far omitted biogenic carbon to provide a more conservative comparison of the structural schemes. However, accounting for the biogenic carbon, both the Mass Timber-Steel Hybrid and All Mass Timber schemes have an even greater potential to reduce Global Warming Potential compared to All Steel and Post-Tensioned Concrete

The Mass Timber-Steel Hybrid scheme results in a 46% GWP reduction using the Static accounting method and over 35% using the Dynamic accounting method. The All Mass Timber achieves up to 60% carbon reduction emission compared to an Post-Tensioned Concrete scheme using Static accounting method.





⁰⁵ Other Considerations

Building Codes

Approval Under IBC 2021 Type IV-B

The Neutral Project decided the best strategy for using mass timber in Bakers Place was to gain approval for the use of the 2021 International Building Code (IBC). That edition of the IBC was the first to include the primary provisions associated with the three new types of mass timber construction.

The City of Madison required developers to submit a Petition for Variance to formalize its approval. At the same time, the State Commercial Building Code allowed the use of the 2021 IBC upon publication,

Bakers Place prepared a variance application for the building plan to be submitted and reviewed by the City of Madison under the 2021 ICC suite of codes, including the 2021 IBC Type IV-B provision. The City Of Madison Building Code, Fire Code, Conveyance Code, and Licensing Appeals Board approved the building to use the 2021 IBC Type IV-B code for Bakers Place in the middle of 2021.

Variances for Exposure

After gaining approval to use the 2021 IBC, The Neutral Project started a variance application for an increase in exposed area of mass timber (to 60%) and reduced area of fire-rated gypsum board to the underside of the CLT (ceilings) in the residential units.

The City initially indicated that this variance could be supported, but ultimately rejected the application despite extensive 3rd-party fire safety testing.

The draft variance submission for the exposed area was based on extensive fire testing at RISE (Sweden), previous extensive fire testing at ATF and NIST, and the Canadian tests at NRC Canada. The Neutral Project also proposed conducting fire testing at the USDA Forest Products Lab in Madison to prove the exposed area of mass timber of approximately 60% of the floor area would be sufficiently safe.

Based on the Madison Fire Department (MFD) concern, The Neutral Project agreed to a series of NFPA 286 tests (a referenced test standard in the IBC and is recognized as the standard for testing to determine if theoretical flashover occurs) to show how the flame spread differed between that of exposure conditions allowed by the 2021 IBC and that of a ceiling exposure amount closer to that expected to exist within Bakers Place. The NFPA 286 testing at the USDA Forest Products Laboratory in Madison showed that an exposed timber area at 60% of the ceiling does not result in flashover conditions, as determined by the NFPA 286 criteria.

Despite these consistent safety results, the City of Madison Board of Appeals denied the second variance based on MFD objections. The Neutral Project appealed the City of Madison's decision to the State of Wisconsin Department of Safety and Professional Services (DSPS). This appeal was unsuccessful.

Implications of 2024 IBC

The 2024 edition of the IBC includes a change that allows Type IV-B construction to have 100% of the mass timber ceilings exposed. That change was approved without any additional requirements due to the extensive fire testing that had taken place at RISE as a continuation of the limited testing that occurred leading up to the approval of the 2021 IBC provisions.

During the Bakers Place review process, The City of Madison Fire Department (MFD) stated that they were reluctant to base a variance on any consideration of a part of the 2024 IBC that would allow 100% ceiling exposure. MFD indicated that they disagreed with the ICC decision to allow 100% exposure and indicated that their disagreement was due to the reduced time to flashover reflected when comparing the earliest test information to that of the 2021 RISE testing. MFD also stated that they would not support any future Wisconsin code changes to permit more than 20% of the exposed area of mass timber for Type IV-B construction.

The reluctance of local authorities to adopt 2024 IBC provisions as well as recognize supporting fire test results is likely to serve as a limiting factor for mass timber adoption in North American construction, as well as stifle the efforts to reduce the embodied carbon of the built environment.

Mass Timber Bidding

The project team solicited bids from the following manufacturers: Binderholz, Structurlam, Smartlam, Mercer, Kalesnikoff, and KLH / Wiehag. The European manufacturers' bid was roughly ~16% lower in total cost (inclusive of shipping) than the closest North American manufacturers' bid.

Due to budgetary constraints of the project, The Neutral Project was compelled to select KLH for CLT and Wiehag for glulam production. However, the project team was concerned about the increase in carbon emissions from transportation due to shipping from Austria instead of the northwest of North America.

As illustrated in the following chapter, these concerns were unfounded as the carbon emissions from domestic and international shipping were nearly equivalent.

Mass Timber Shipping Analysis

The Neutral Project's team decided to study the impact of shipping from Austria versus Northwest America to address potential environmental concerns. In a rather surprising outcome, the two shipping scenarios had a very similar carbon footprint despite a massive difference in distance.

Shipping from Austria:

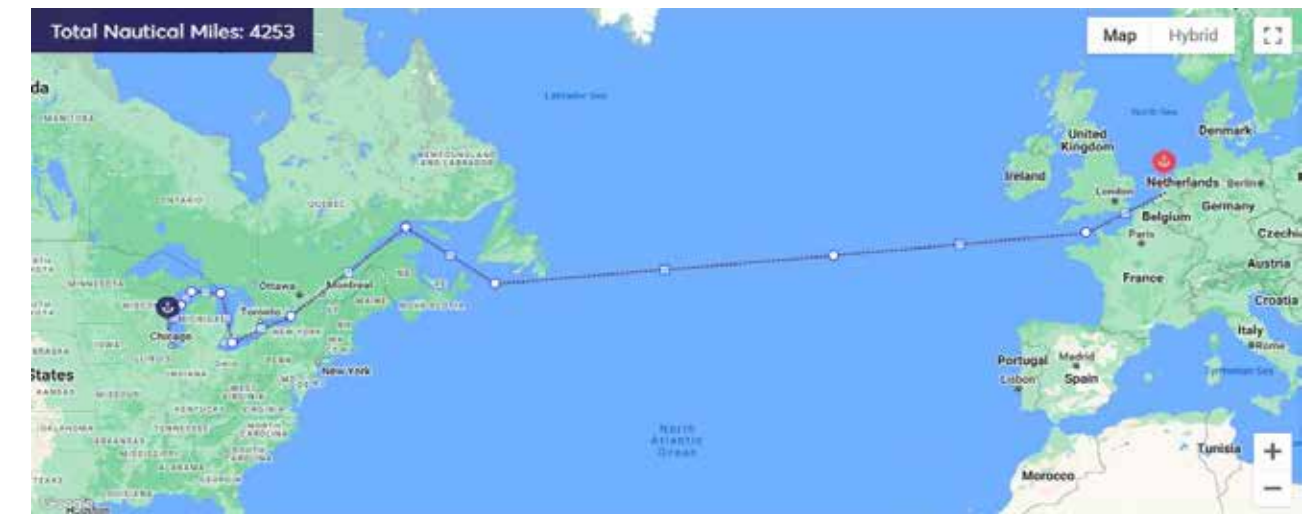
- A total distance of 9,110 kilometers.
- 487,000 kilograms of carbon dioxide equivalent (kgCO_2e).

Shipping from the nearest factory in Spokane, Washington:

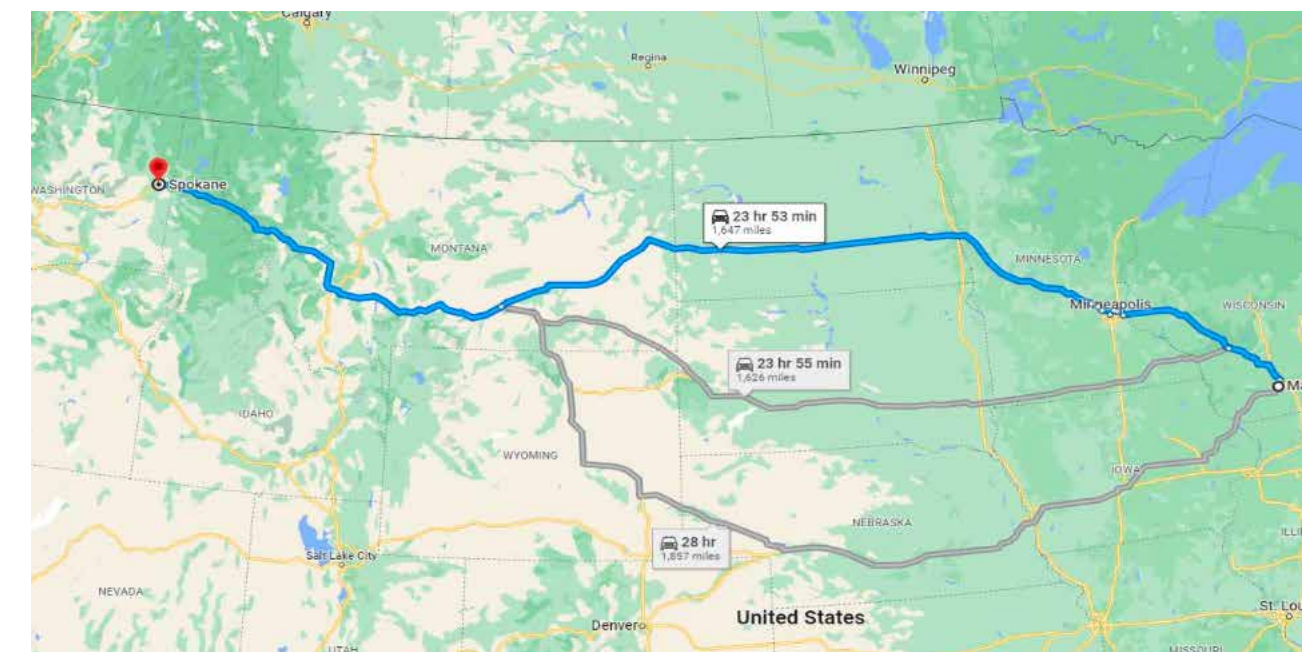
- A total distance of 2,650 km.
- 467,000 kgCO_2e .

The main reason why these scenarios yielded a similar carbon footprint is the means of transportation. Mass timber traveling from the production facility in Teufenbach, Austria is traveling a total of 1,230km by truck and 7,880km by ship from the Port of Rotterdam directly to the Port of Milwaukee. Whereas, the shipment from the nearest manufacturer to the site in North America would happen fully by truck.

Shipping route from Austria:



Shipping route from Washington State:



Moisture Protection

Unlike concrete or steel structures, mass timber structures need extensive moisture management during and after the assembly on site. For Bakers Place, an extensive moisture management plan (“MMP”) was developed by RDH, the project’s building science and waterproofing consultancy. The following areas were in need of special moisture management treatment:

- Areas with no roof above with precipitation expected during exposure duration,
- Areas with roof above but open perimeter with wind-driven precipitation expected during exposure duration, and
- Areas with extended exposure timeline that increase the risk of wetting potential.
- Slab edge detailing on every floor of mass timber.

Special sealants and tapes are applied to areas requiring treatment. In the specific case of Bakers Place, a combination of Rothoblaas tape and MasterSeal AWB 660 was specified.

While concrete and steel structures do not require this type of moisture management, they still require quite significant supplemental installation procedures, e.g. heat blankets used for concrete placement during cold outside temperatures. These are typically gas-powered, and add to the fossil fuel usage during the construction process. For steel structures on-site rust prevention requires the use of cold galvanizing sprays or paints.

Insurance

The Neutral Project has been working with Woodworks and The Wood Products Council on a Mass Timber Insurance playbook to take lessons learned from insuring Bakers Place and apply them to future mass timber projects. The playbook is planned to be published in Q1 2024.



⁰⁶ The Neutral Project

The Neutral Project is a sustainability-focused real estate development company founded by Nate Helbach in 2020. The company has headquarters in Madison, WI and the Bay Area, CA.

The Neutral Project team of real estate, finance, engineering, design, and technology professionals is integrating cutting-edge products and technologies in its projects with the objective of building and operating the most sustainable, efficient, and comfortable buildings in North America.

The company's development pipeline includes: Bakers Place, a mixed-use development in Madison, WI; The Edison in Milwaukee, WI, slated to be the tallest mass timber building in the United States upon completion. The Neutral Project has started work on a sustainable low-rise industrialized product line with a goal to address the shortage of missing middle housing. The company plans to launch the product line later in 2024.

You can get in touch with The Neutral Project by emailing us at marketing@theneutralproject.com

Learn more at:

theneutralproject.com



The Edison

Milwaukee, WI

Program: Mixed Use, Multifamily

Building GFA: 377,339 ft²

Stories: 32

Status: Pre-Development;
Construction start in 2024



Vanilla

Madison, WI

Program: Multifamily

Building GFA: 24,619 ft²

Stories: 4

Structure: Mass timber hybrid

Status: Pre-development.
Construction start in 2024



The Bloom

Monona, WI

Program: Multifamily

Building GFA: 93,665 ft²

Stories: 4

Status: Sold

Acknowledgements

The Neutral Project wishes to recognize that this case study was only possible with the help of funding from the United States Department of Agriculture (USDA) Wood Innovations Grant Program in 2021 and funding support from the Softwood Lumber Board (SLB).

We would like to extend our utmost gratitude to the individuals and organizations that made this case study possible through their assistance and expertise in this process:

- Matt Kantner at Equilibrium for his technical support in this process, producing great models and corresponding narratives for our structural comparisons.
- Anthony Pak and his team at Priopta for guidance through the life cycle assessment (LCA).
- Michael Green and his team at MGA | Michael Green Architecture for the design and architectural work to create a community with sustainable-focused design.
- David Barber and the whole Arup team for their work on fire protection and fire testing in collaboration with the USDA Forest Products Laboratory.
- Graham Finich and the whole RDH Building Science team.
- Dane Bernau at CD Smith for the analysis of the cost and scheduling implications of each building structure.
- Ashley Cagle and Ricky Mclain at Woodworks-Wood Products Council for their support in using and reporting on wood products throughout the entire process. We are grateful for the passion for sharing information and spreading knowledge that their team shares with ours.
- Finally, a special thank you to Dr. Hongmei Gu, Jocelyn Lam, Marco LoRicco, and the team at the USDA Forest Service Forest Products Laboratory.

We would like to thank everyone else that directly and indirectly supported this process, especially those that dedicated their time to peer-reviewing and adding commentary to our final case study.

Case Study Team Links

The Neutral Project	https://theneutralproject.com
Wood Innovations US Forest Service	https://www.fs.usda.gov/science-technology/energy-forest-products/wood-innovation
Michael Green Architecture	https://mg-architecture.ca/
Equilibrium	https://eqcanada.com/
RDH Building Sciences	https://www.rdh.com/
Priopta	https://www.priopta.com/
WoodWorks	https://www.woodworks.org/
Angus Young	https://www.angusyoung.com/
Arup	https://www.arup.com/
C.D. Smith	https://www.cdsmith.com/

Bakers Place Case Study

A comparative exploration into mass timber and
conventional construction methods

USDA Wood Innovations Grant Program
www.theneutralproject.com

2024

