KL&A Engineers & Builders

MASS TIMBER COMPARATIVE LIFE CYCLE ASSESSMENT SERIES

COMPARING THE EMBODIED CARBON IMPACTS AND COST OF MASS TIMBER BUILDINGS TO FUNCTIONALLY EQUIVALENT BUILDINGS

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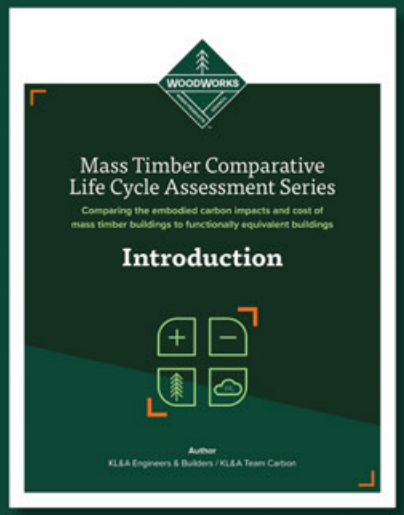
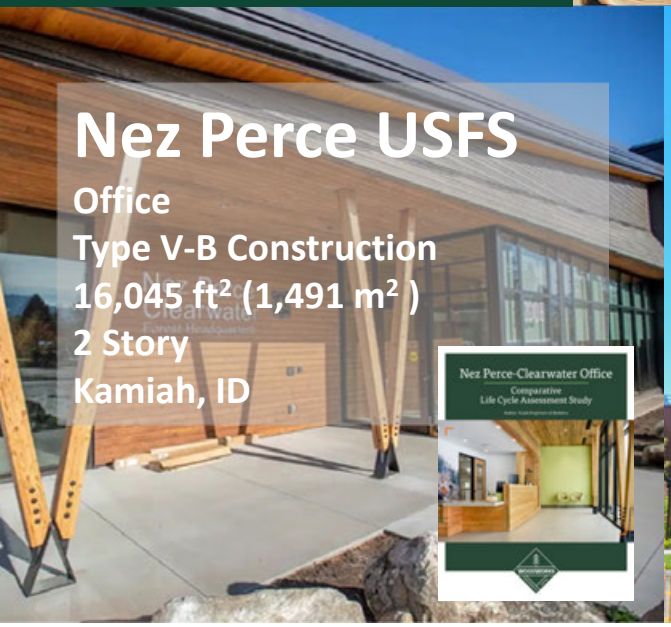
Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.

Photo Credit: JC Buck

WoodWorks, KL&A Team Carbon, USDA U.S. Forest Service, Softwood Lumber Board


WOODWORKS
Mass Timber Comparative
Life Cycle Assessment Series
Comparing the embodied carbon impacts and cost of
mass timber buildings to functionally equivalent buildings
Introduction
Author
KL&A Engineers & Builders / KL&A Team Carbon


Return to Form
Multifamily / Retail
Type IV-B Construction
139,000 ft² (12,900 m²)
12 Story
Denver, CO
Return To Form
Comparative
Life Cycle Assessment Study


Nez Perce USFS
Office
Type V-B Construction
16,045 ft² (1,491 m²)
2 Story
Kamiah, ID
Nez Perce-Clearwater Office
Comparative
Life Cycle Assessment Study

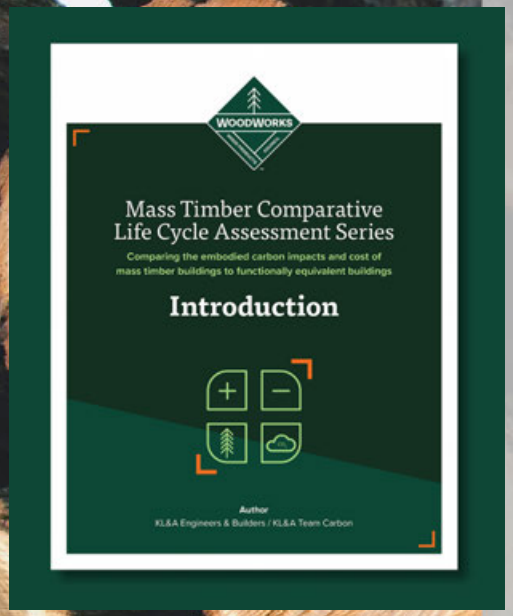

Burwell Center
Office / Higher Ed
Type III-B Construction
22,990 ft² (2,136 m²)
3 Story
Denver, CO
Burwell Center
Comparative
Life Cycle Assessment Study


Denver Office
Office / Higher Ed
Type III-A Construction
98,280 ft² (9,130 m²)
4 Story
Denver, CO
Denver Office
Comparative
Life Cycle Assessment Study

OUTLINE

- **Building Study Methodology**
- **Building Study Results (GWP/m² & Cost)**
  - Denver Office Building (4 Story Office/Higher Ed)
  - Return to Form (12 Story Multifamily)
  - Nez Perce-Clearwater National Forests Office (2 Story Office)
  - Burwell Center for Career Achievement (3 Story Office/Higher Ed)
- **Building Study Trends (GWP/m² & Cost)**

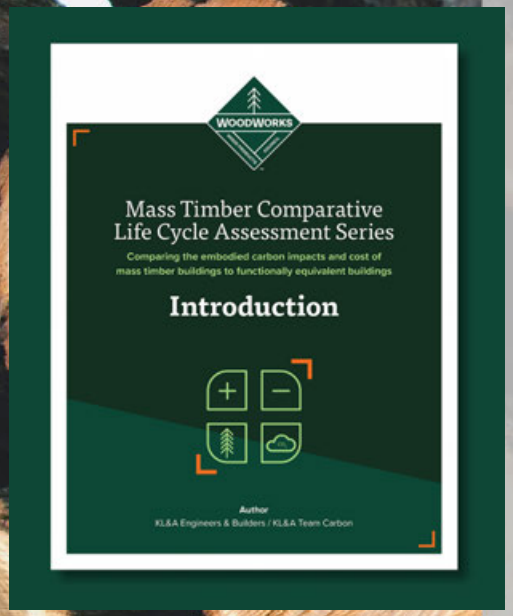
BUILDING STUDY METHODOLOGY



- **Comparative WBLCA**
  - TallyLCA
  - Scope
    - Structure
    - Enclosure – Vertical and Horizontal
    - Fire Resistance
    - Acoustic
    - Ceiling Finishes
  - Cradle-to-Grave (A-C, plus Module D)
  - Includes Biogenic Carbon (-1/+1, 32% Permanent Storage)
  - Data: Methodology, Assumptions, End-of-Life, Uncertainty

- **Comparative Cost & Speed of Construction**
  - Normalized Material & Labor Costs

Photo by Aleksandar Radovanovic on Unsplash



- **Comparative Design**
  - Functionally Equivalent (ISO 14044 4.2.3.7 & ASTM E2921)
  - Construction Type
    - Fire Resistance Rating
  - Design Efficiencies & Considerations
    - Framing Scheme
    - Span Lengths
    - Grid Layout → Eliminate Transfer Podiums
    - Floor Assembly Thicknesses → Building Height
    - Building Weight → Foundations, Lateral System
    - Acoustic Assembly
    - Ceiling Assembly

BUILDING STUDY METHODOLOGY

Photo by Aleksandar Radovanovic on Unsplash

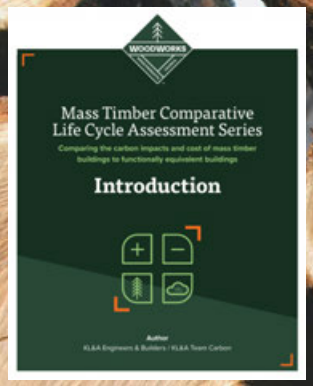
CRADLE TO GRAVE + MODULE D

CRADLE TO GRAVE

CRADLE TO GATE

Production			Construction		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	Transportation	Manufacturing	Transportation	Construction/Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction/Demolition	Transportation	Waste Processing	Disposal	Reuse	Recycling	Energy Recovery

Note that the stages and information modules shown here deviate slightly from the naming convention used in ISO 21930. However, this series generally uses terminology consistent with ISO 21930.



Sustainable Sourcing

- ISO 21930 7.2.11

+1/-1 Static Accounting

- ISO 21930 7.2.7

TallyLCA EOL Allocation

- 32% Permanently Stored

Material	Incineration	Landfill	Recycling / Recovery	Accounting Method
Concrete		45%	55%	Recycled into aggregate, credited for avoided burden of production of aggregate, considers impact of grinding energy
Steel & Reinforcement		2%	98%	Recycled virgin material is credited for avoided burden of production (net scrap), considers processing impacts
Mass Timber	22%	63.5%	14.5%	Incineration is credited for energy recovery, landfill considers 50% decomposition and release of biogenic carbon (with credit for energy recovery due to landfill gas capture) and 50% is permanently stored, recycling is credited as avoided burden, considers impact of grinding energy
Glass		100%		
Gypsum Board		100%		
Plastic		100%		
Insulation		100%		

Image by WoodWorks

BIOGENIC CARBON METHODOLOGY

Photo by Aleksandar Radovanovic on Unsplash

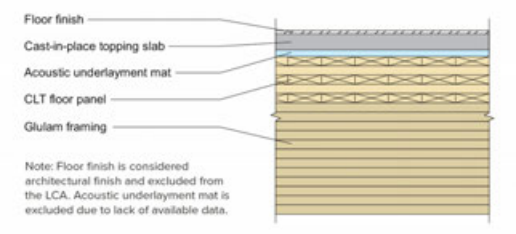
Office / Higher Education
Type III-A Construction
98,280 ft² (9,130 m²)
4 Story
- Foundations: Spread Footings
- No below grade
- L1: Concrete Slab on Grade
- L2 – Roof: CLT Panel & Glulam

Lateral: Precast Concrete Core Walls + Glulam Brace
Grid: 20’ X 34’

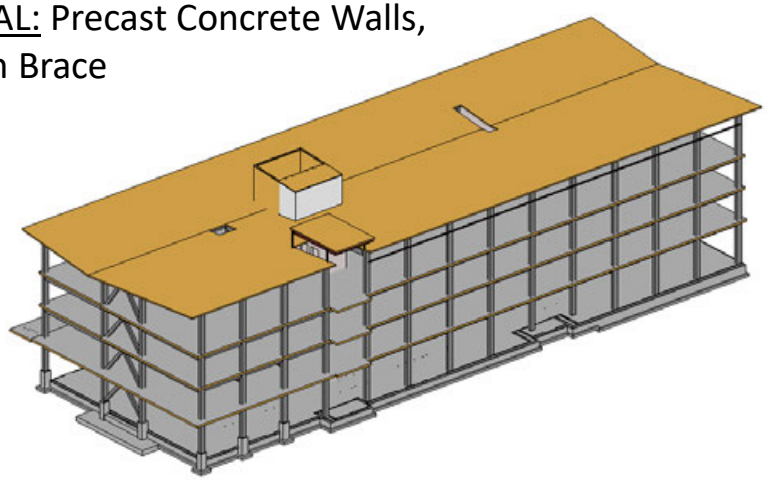
Architect: Shears Adkins Rockmore
Engineer: KL&A
Contractor: PCL

Denver Office Building

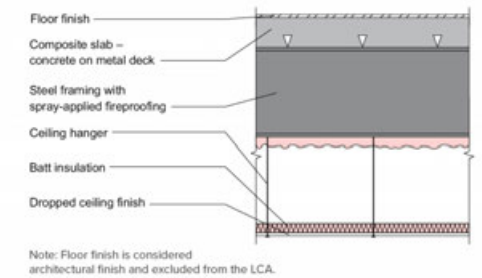
Denver, Colorado



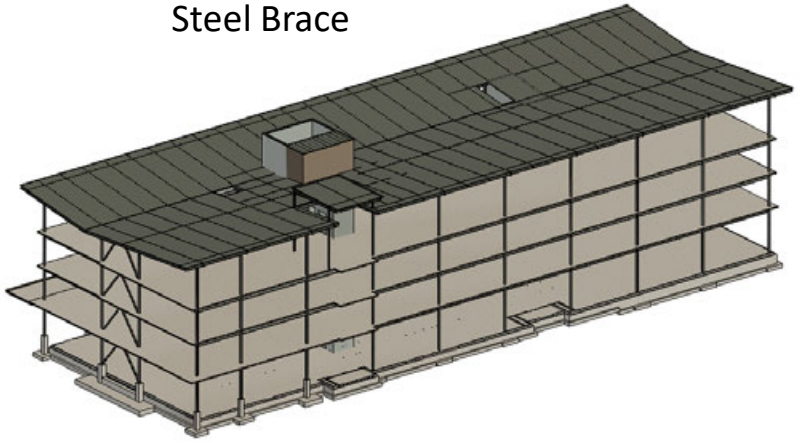
- FLOOR: 5ply CLT Floor, Concrete Topping Slab, Glulam Framing
- ROOF: 5ply CLT, Glulam Framing
- LATERAL: Precast Concrete Walls, Glulam Brace



MASS TIMBER
(AS DESIGNED)



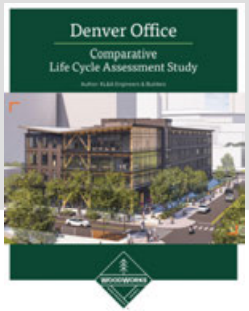
- FLOOR: Concrete on Metal Deck, WF Framing
- ROOF: Metal Deck, WF Framing
- LATERAL: Precast Concrete Walls, Steel Brace



STEEL

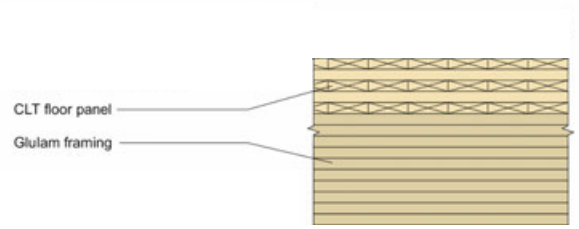
FUNCTIONAL EQUIVALENCY

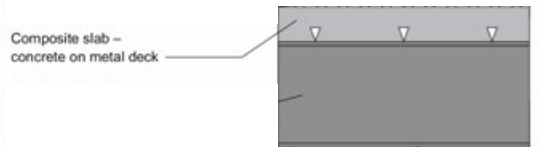
Denver Office Building



Goal: Design & Component Specifications to achieve Functional Equivalency

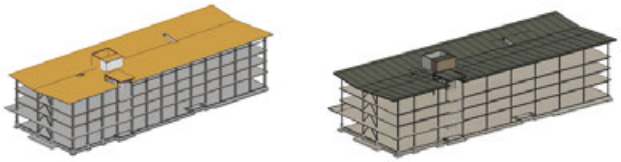
- Construction Type
  - Fire Resistance Rating
- Design Efficiencies & Considerations
  - Framing Scheme
  - Span Lengths
  - Grid Layout
  - Floor Assembly Thicknesses → Building Height
  - Building Weight → Foundations, Lateral System
  - Acoustic Assembly
  - Ceiling Assembly
- Component Specifications





Floor Elevations and Building Height			
Structural System	**Floor-to-Floor Height**	**Floor to Ceiling***	**Total Building Height**
Mass Timber	13'-4"	10'-3"	63'-7"
Steel	14'-0"	10'-0"	65'-7"

Concrete Mix Property Assumptions	
Element	**Concrete (psi, SCM%)**
SOG	4000, 20% FA
Columns	5000, 20% FA
Pilasters	5000, 40% FA
Mat Slabs	5000, 40% FA
Footings	5000, 40% FA
Foundation Walls	5000, 40% FA
Precast Shear Walls	6000, 40% FA
Slab on Metal Deck	4000, 20% FA
Topping Slabs	4000, 20% FA



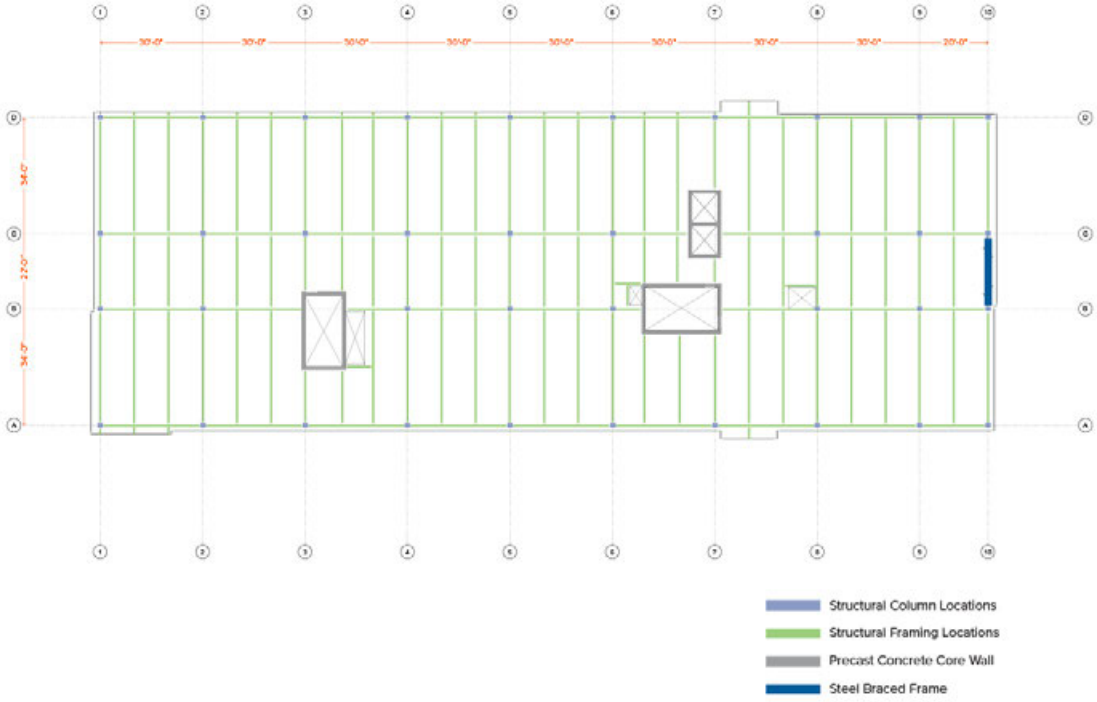
KL&A

FUNCTIONAL EQUIVALENCY

DENVER OFFICE

Mass Timber Typical Floor Plan

Steel Typical Floor Plan

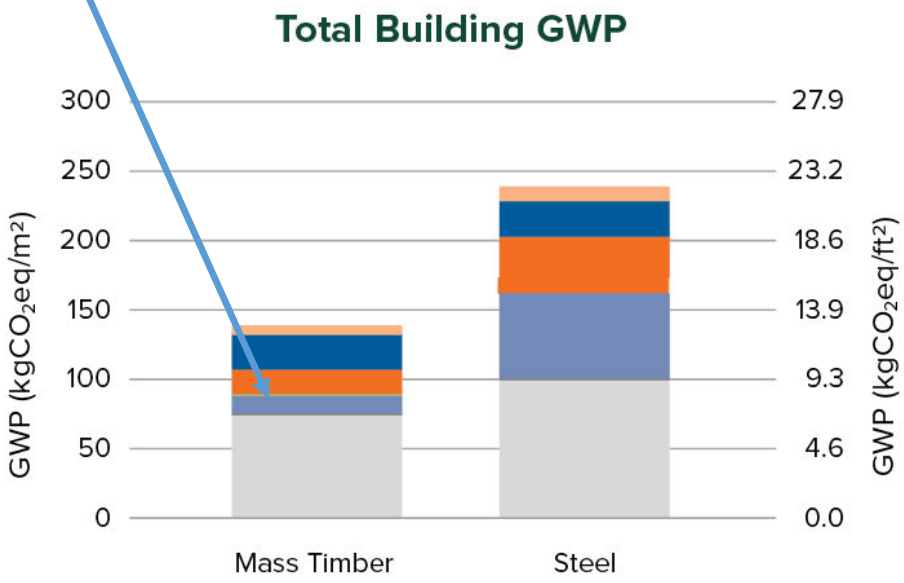


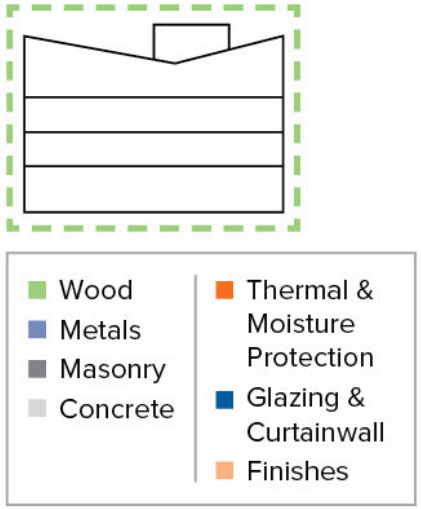
42% TOTAL REDUCTION

32% ARCH REDUCTION

46% STRUCTURAL REDUCTION

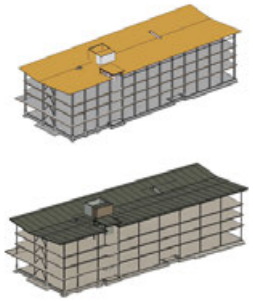
Mass timber material contributes 0.5% to superstructure GWP



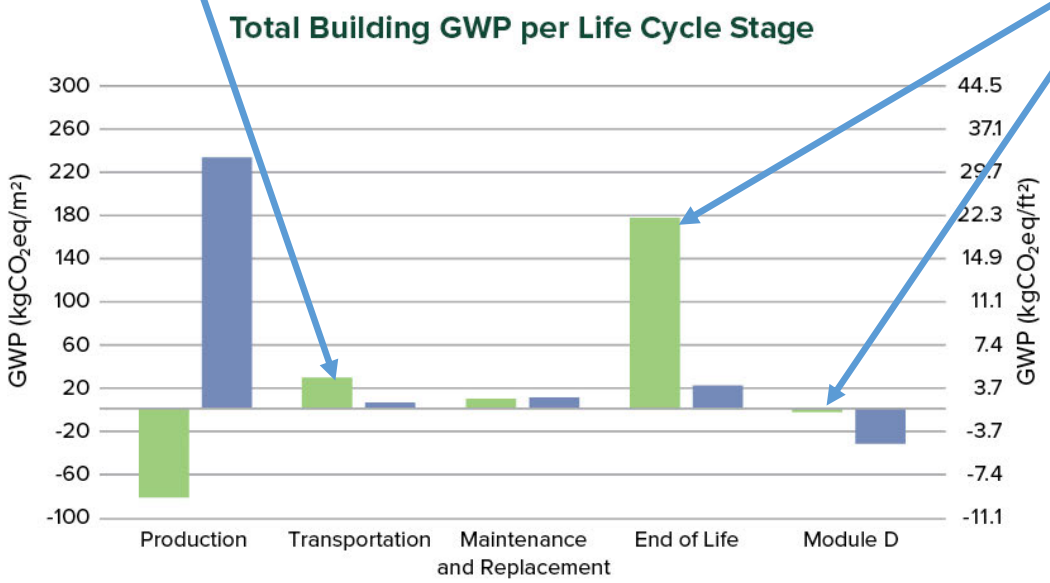


DENVER OFFICE – TOTAL GWP

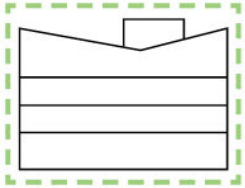
DENVER OFFICE – LCA STAGES



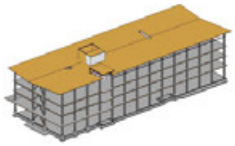
3,940 km (2,450 miles)



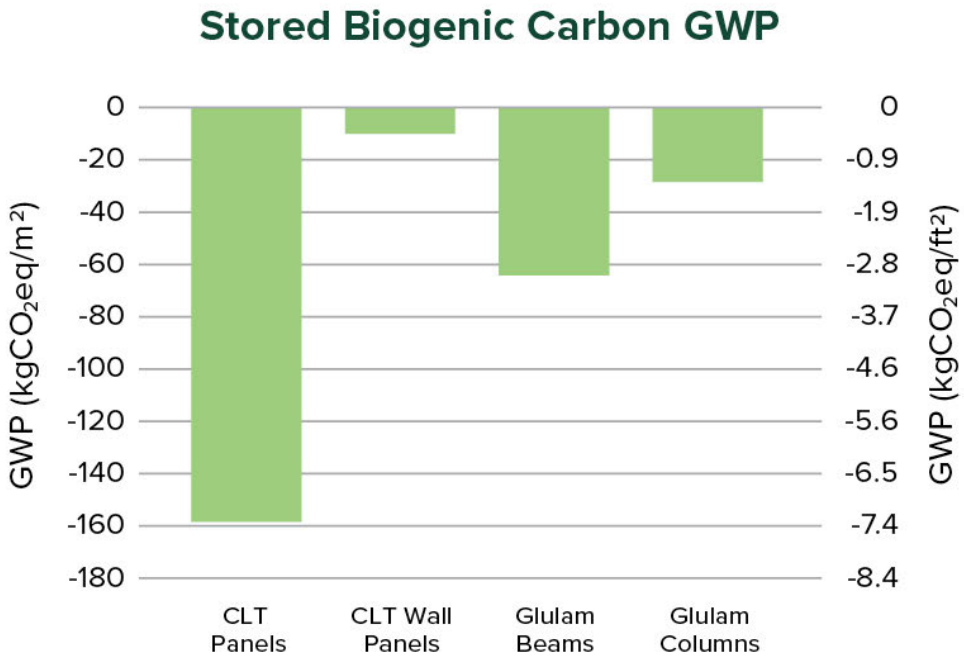
Mix Assumptions for Wood:
32% Permanently Stored
- 63.5% Landfill
- 22.0% Incineration
- 14.5% Recycle

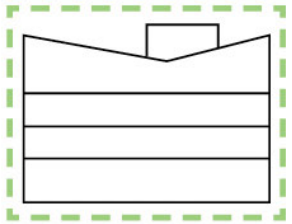


A4 GWP = 35% of Stored Biogenic Carbon

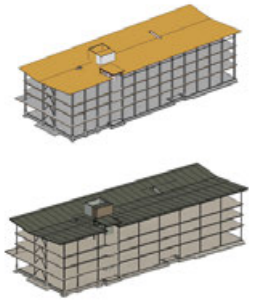


-256 $kgCO_2eq/m^2$
vs
140-239 $kgCO_2eq/m^2$



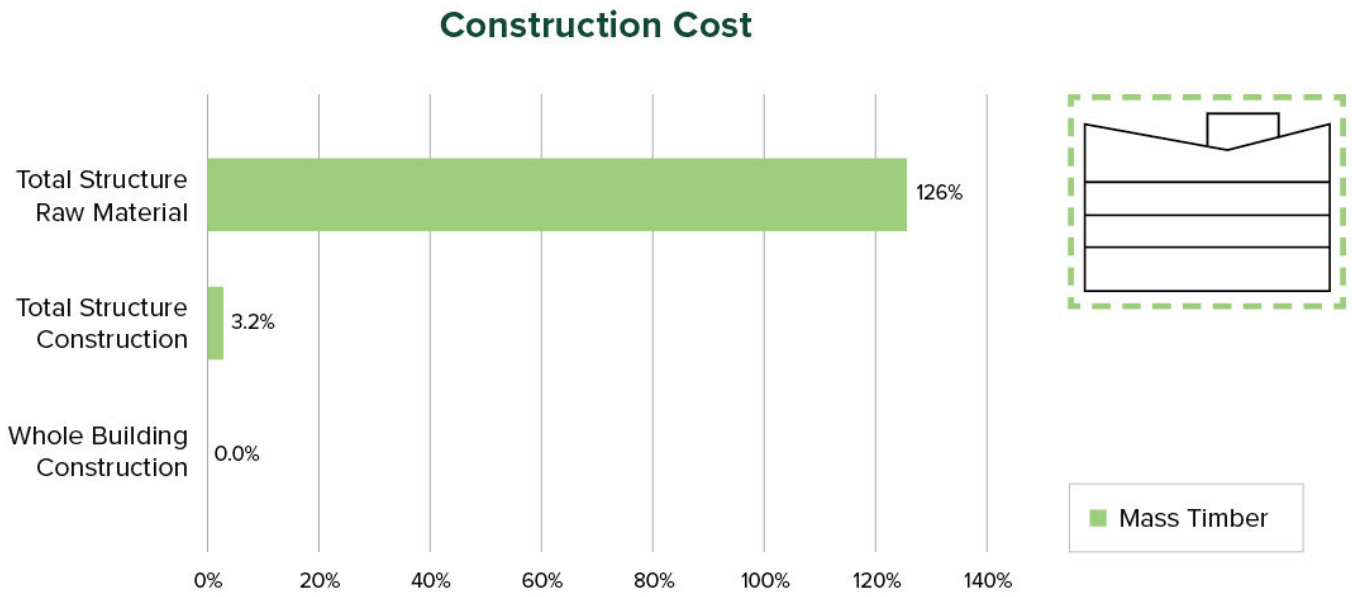


DENVER OFFICE – BIOGENIC CARBON



2.5 Months Faster

0% $ Premium



DENVER OFFICE – COST & SCHEDULE

Return To Form

Comparative Life Cycle Assessment Study

Author: KL&A Engineers & Builders

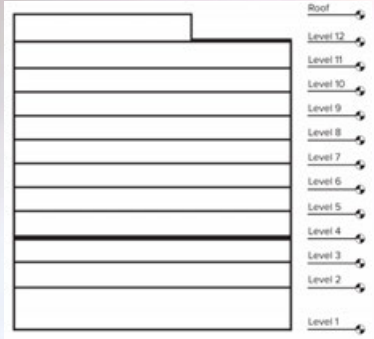
WOODWORKS
WOOD PRODUCTS COUNCIL

Image by WoodWorks

Multifamily / Retail
Type IV-B Construction, IBC 2018 with Denver Amendments (2024 IBC)
139,000 ft^2 (12,900 m^2)
12 Story
- Foundations: Drilled Piers
- No below grade
- L1: Concrete Slab on Grade
- L2-L4: Concrete Slabs
- L5 - Roof: CLT Panel & Glulam

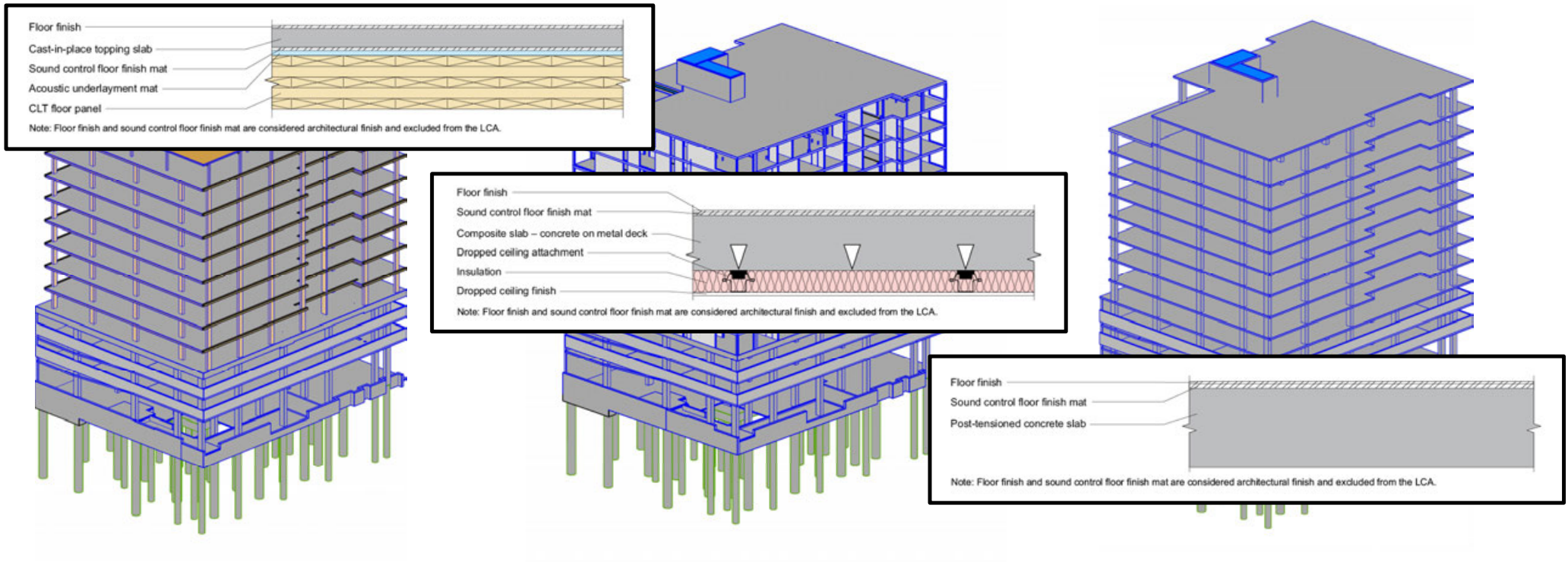
Lateral: Concrete Cores
Grid: 20’ x 20’

Owner: Katz Development
Architect: tres birds
Engineer: KL&A
Contractor: Swinerton



RETURN TO FORM

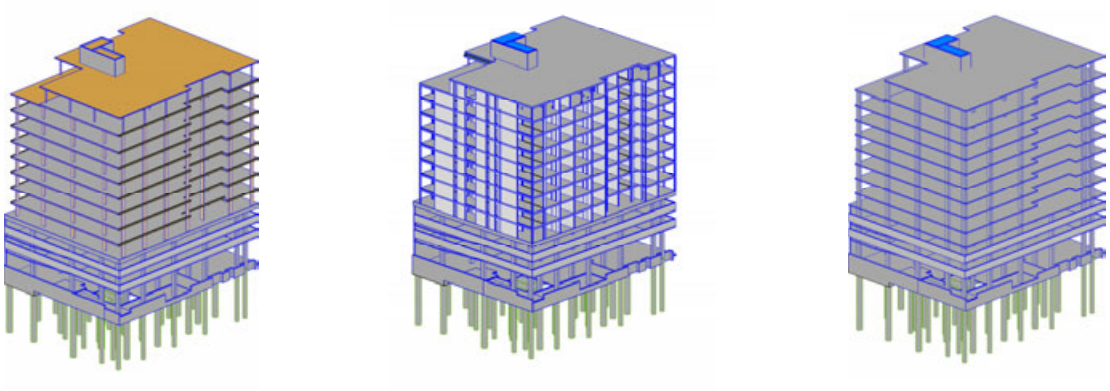
Denver, Colorado



MASS TIMBER
(AS DESIGNED)
Type IV-B

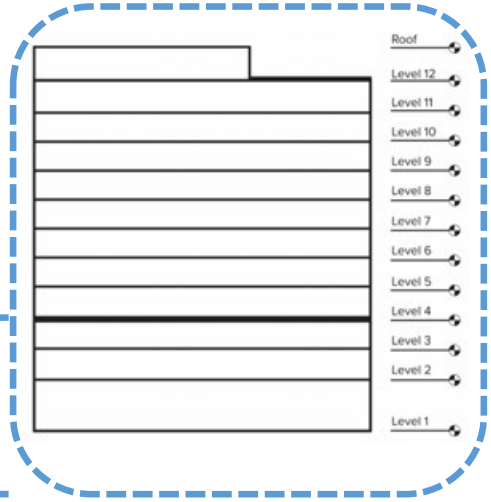
STEEL “CFS”
(CFS & DECK)
Type I-B

CONCRETE
(PT)
Type I-B

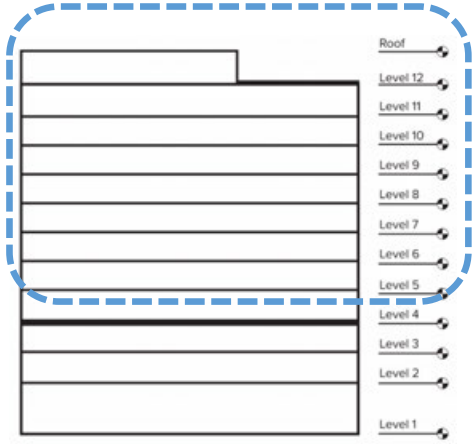


Concrete Volume:

MT 23% Reduction
CFS 11% Reduction

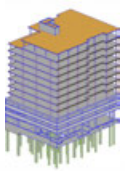


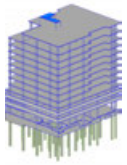
Building GWP is dominated by Concrete at Level 4 Podium & Below



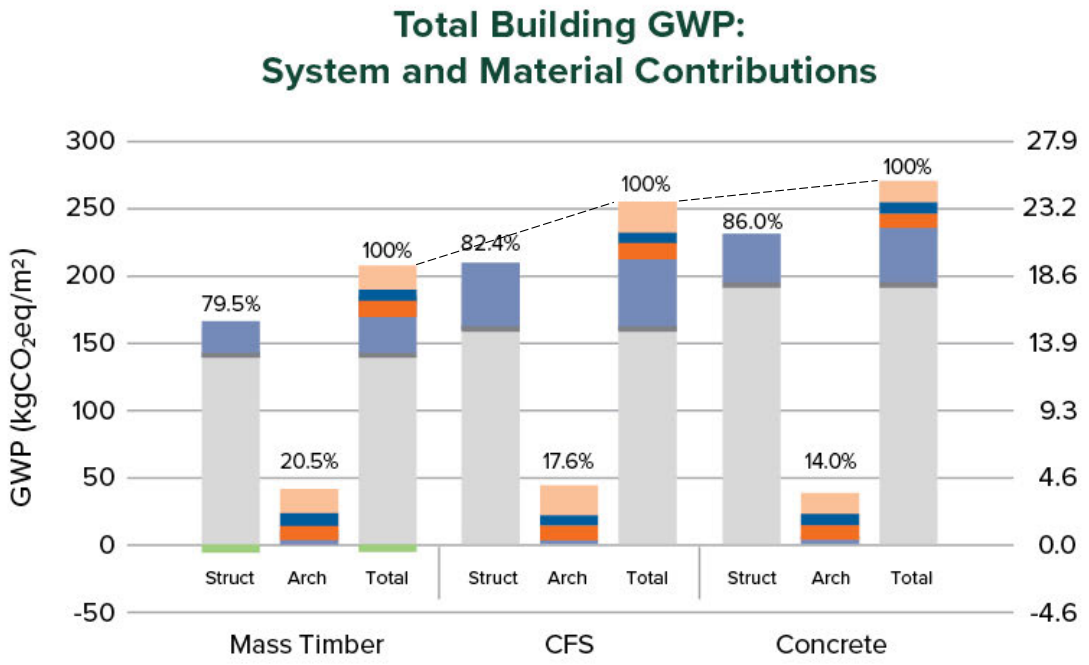
"Above Podium"
(GWP/m^2)

= Above Podium GWP / Above Podium Floor Area

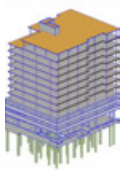


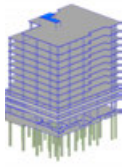


MT < CFS < CONC
21%-25%
REDUCTION

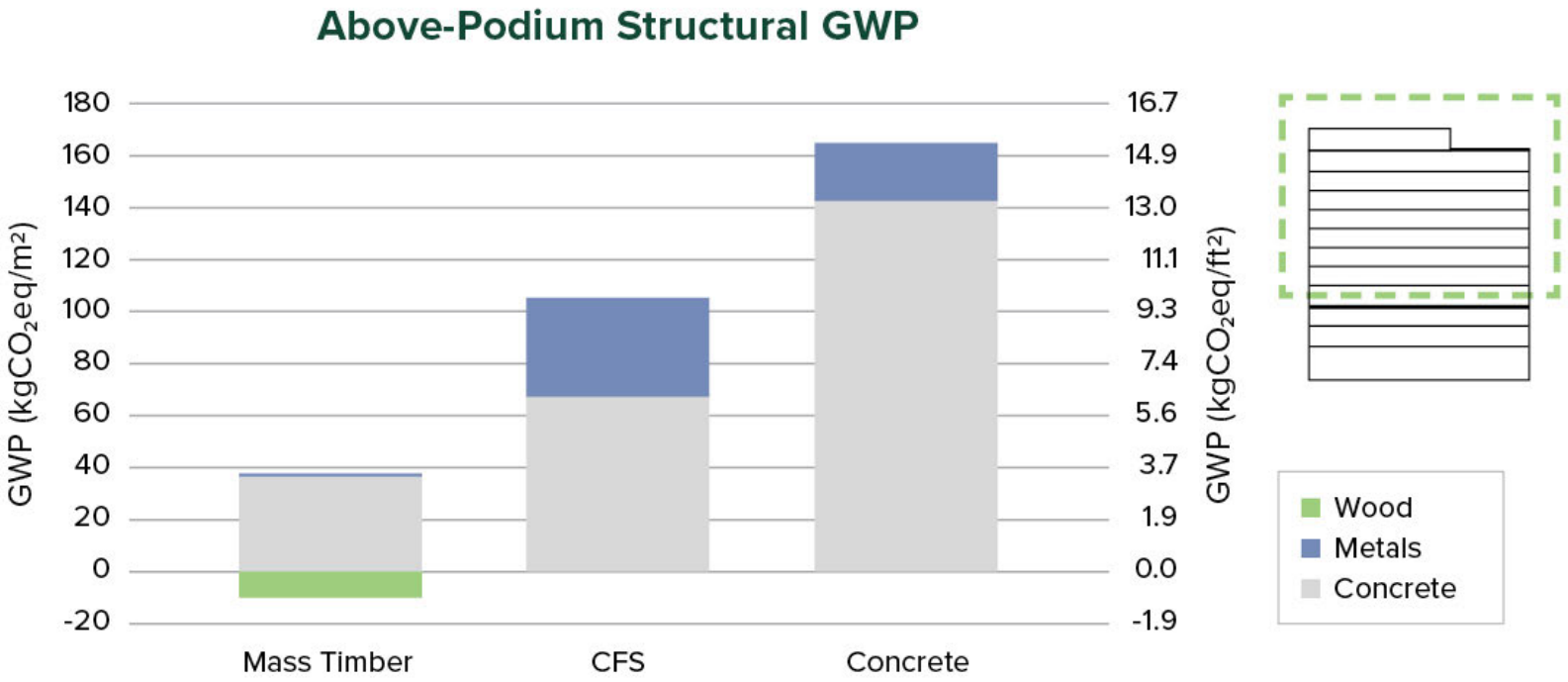


RTF – TOTAL GWP

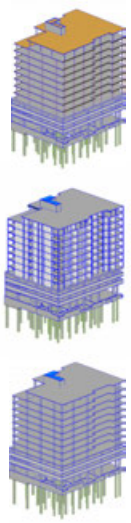




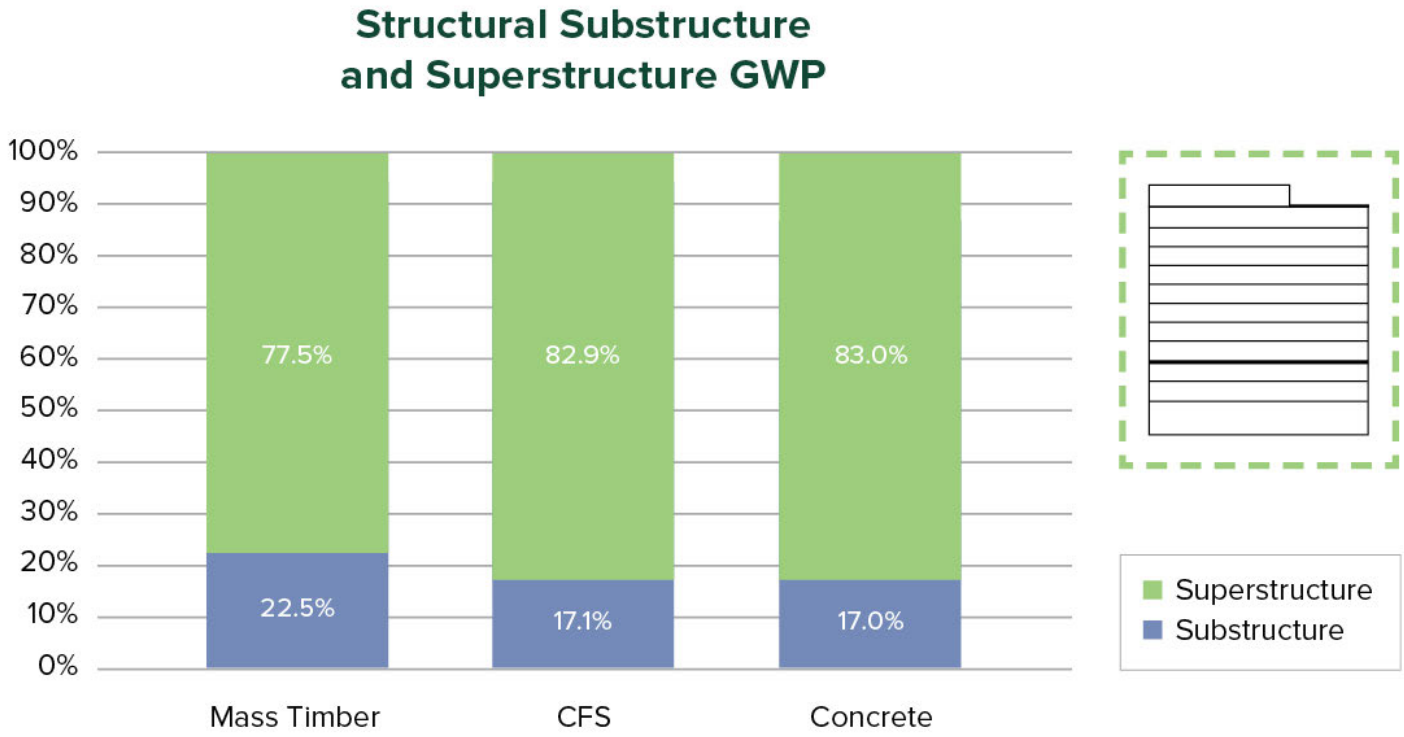
MT < CFS < CONC
73%-83%
REDUCTION



RTF – STRUCTURE ABOVE PODIUM



~20% Foundation Impact



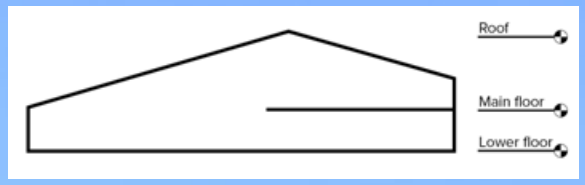
RTF – SUBSTRUCTURE vs SUPERSTRUCTURE

NEZ PERCE-CLEARWATER NATIONAL FORESTS SUPERVISOR'S OFFICE

KAMIAH, ID

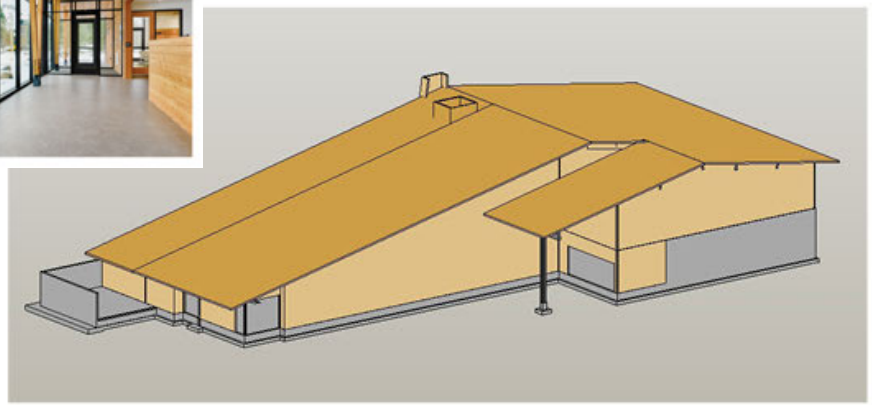
Office
Type V-B Construction
16,045 ft^2 (1,491 m^2)
2 Story
- Foundations: Spread Footings
- Partial Below Grade
- L1: Concrete Slab on Grade
- L2: Partial, Light Frame Wood & MT Hybrid
- Roof: CLT Panel & Glulam

Lateral: Light Frame Wood Shear Walls
CLT Elevator Walls



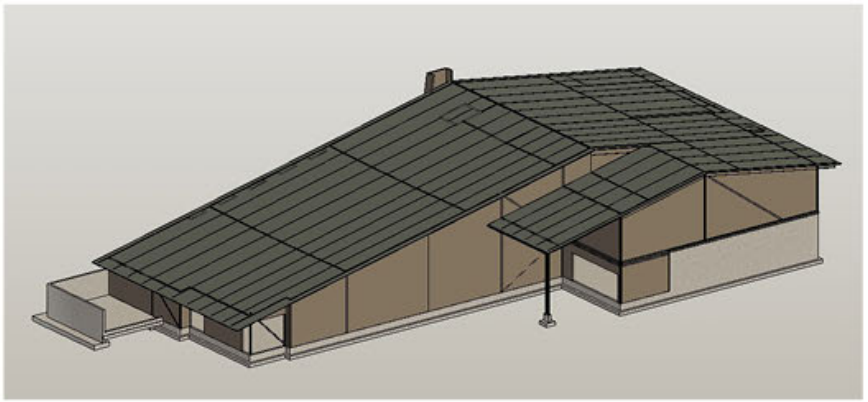
Owner: U.S. Forest Service
Architect: Mosaic Architecture
Engineer: Morrison-Maierle
Contractor: Quality Contractors

MASS TIMBER – LIGHT FRAME HYBRID (AS CONSTRUCTED, 2021)

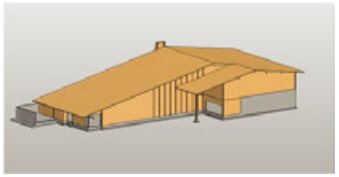


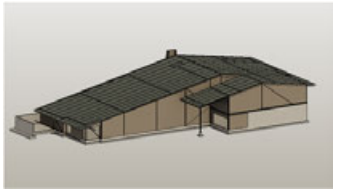
- FLOOR: Plywood Sheathing, I-Joists, Glulam Beams (No Topping Slab)
- ROOF: 4ply CLT, Glulam Beams & Columns
- WALLS: Light Frame Wood Walls & CLT Elevator Walls

STEEL

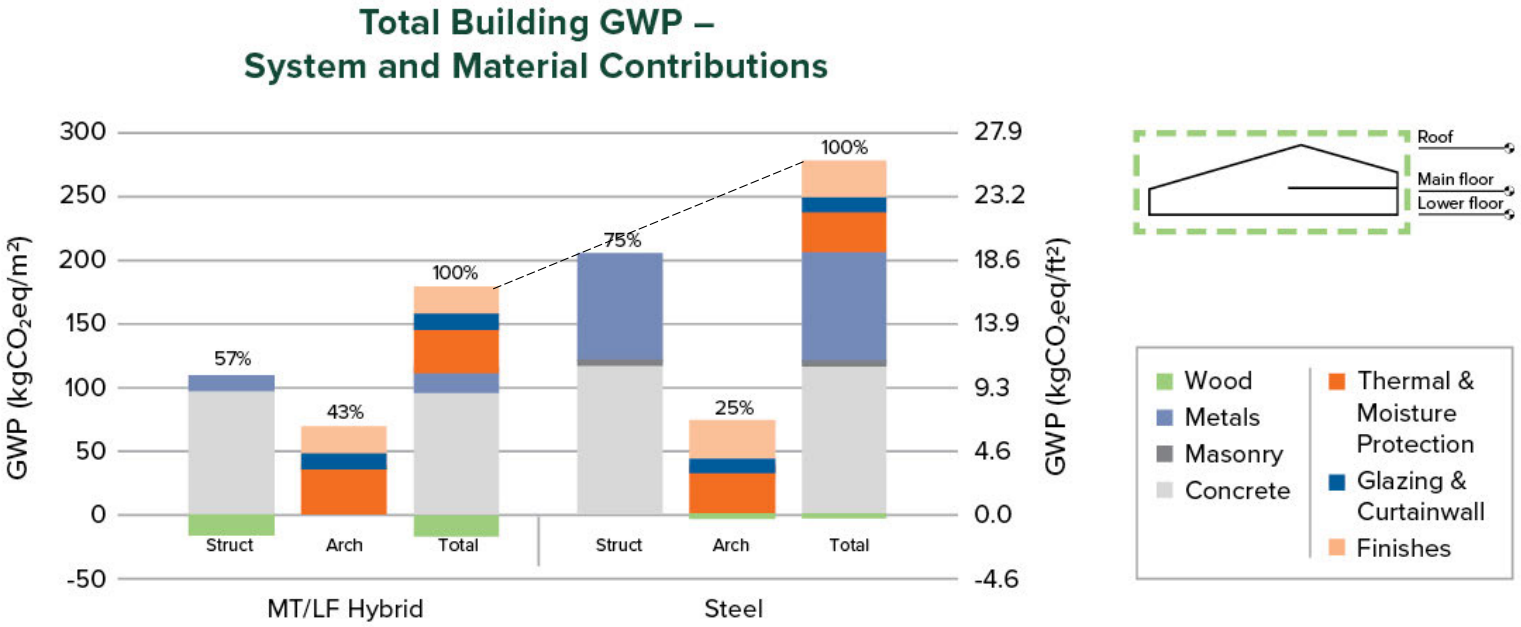


- FLOOR: Concrete on Metal Deck, WF Beams
- ROOF: Metal Deck, Steel Bar Joists, WF Beams
- WALLS: CFS Stud Walls & CMU Elevator Walls

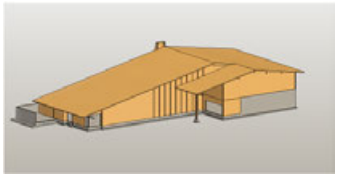


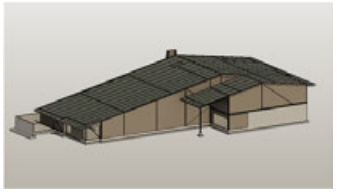


MT < STEEL
43% REDUCTION



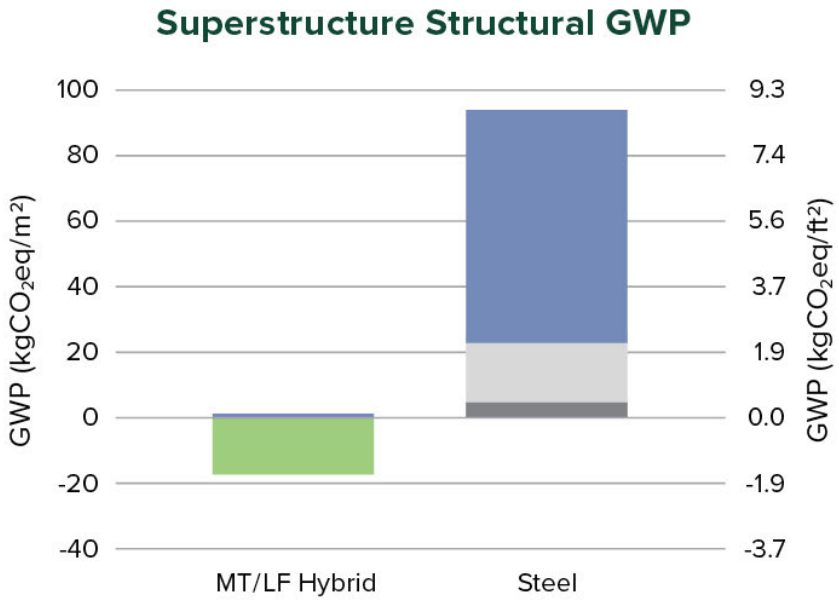
NP – TOTAL GWP

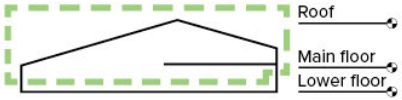


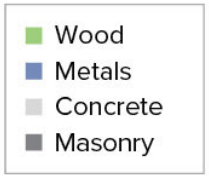


69% SUPERSTRUCTURE REDUCTION

118% STRUCTURAL REDUCTION



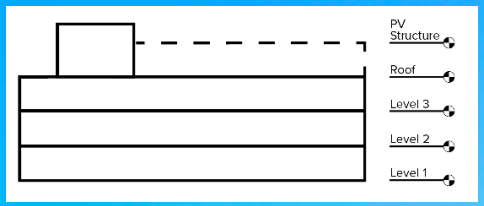




NP – SUPERSTRUCTURE GWP

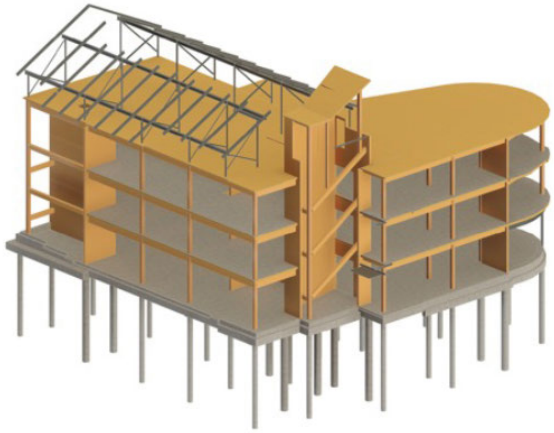
Office / Higher Education
Type III-B Construction
22,990 ft² (2,136 m²)
3 Story
Foundations: Drilled Piers
No below grade
L1: Concrete Slab on Grade
L2 – Roof: CLT Panel & Glulam
Lateral: CLT Panel Walls at Core
Grid: 11’ X 24’

Owner: University of Denver
Architect: Lake Flato, Shears Adkins Rockmore
Engineer: KL&A
Contractor: PCL



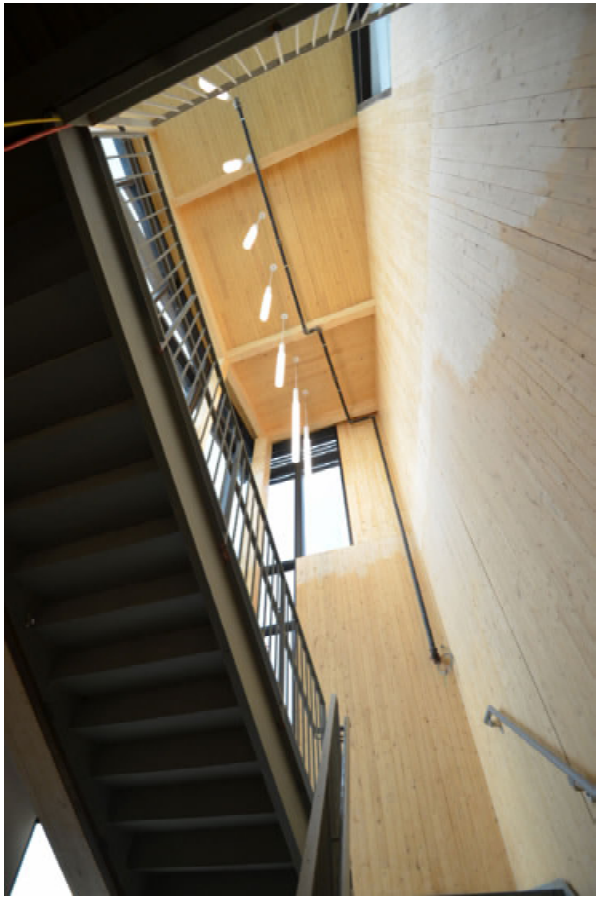
Burwell Center for Career Achievement

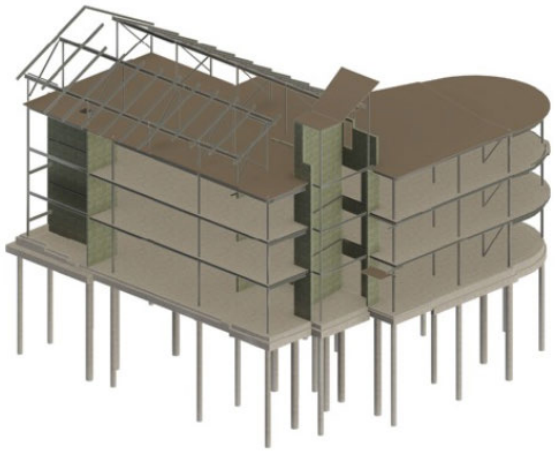
Denver, Colorado



MASS TIMBER
(AS CONSTRUCTED, 2020)

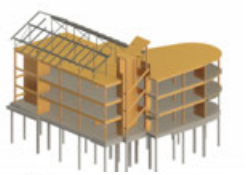
- <u>FLOOR:</u> 3ply CLT Floor, Concrete Topping Slab, Glulam Framing
- <u>ROOF:</u> 3ply CLT, Glulam Framing
- <u>LATERAL:</u> 5ply CLT Core Walls

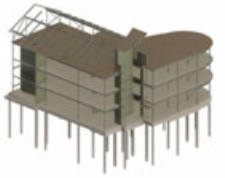




STEEL

- <u>FLOOR:</u> Concrete on Metal Deck, WF Framing
- <u>ROOF:</u> Metal Deck, WF Framing
- <u>LATERAL:</u> CMU Core Walls & Steel Brace

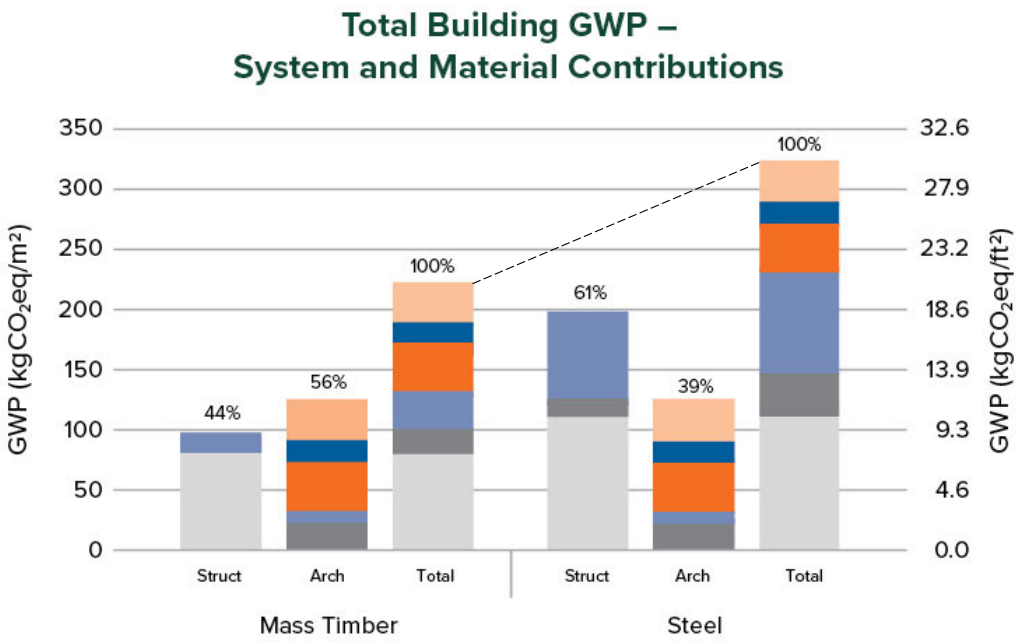


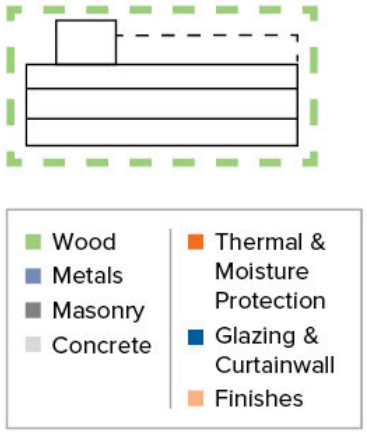


MT < STEEL
31% TOTAL REDUCTION

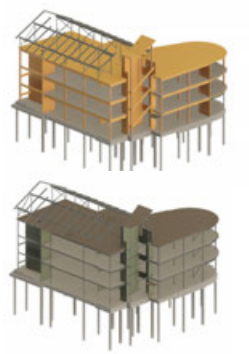
SUPERSTRUCTURE
40% REDUCTION

SUPERSTRUCTURE
STRUCTURE
79% REDUCTION

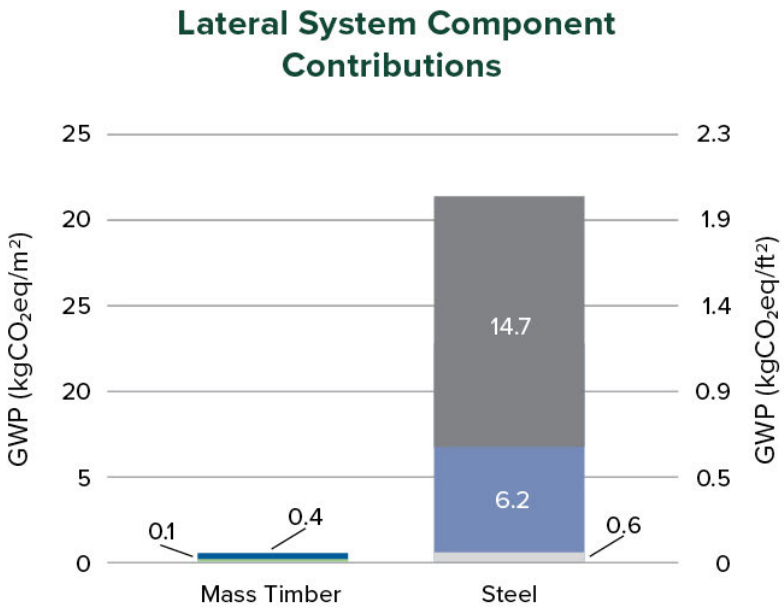




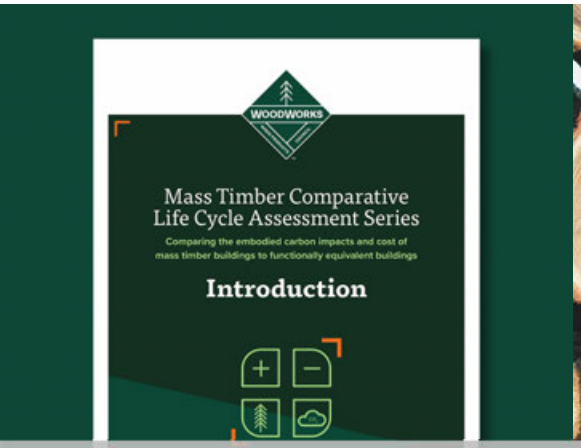
BURWELL – TOTAL GWP



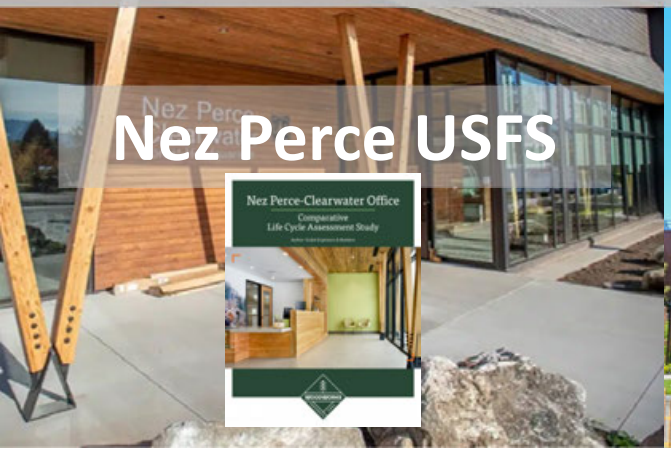
MT < STEEL
98% REDUCTION

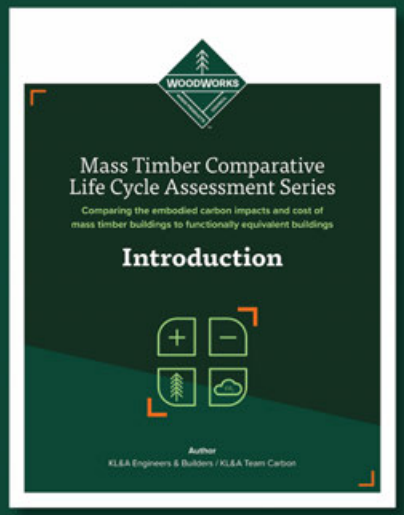


BURWELL – LATERAL SYSTEM

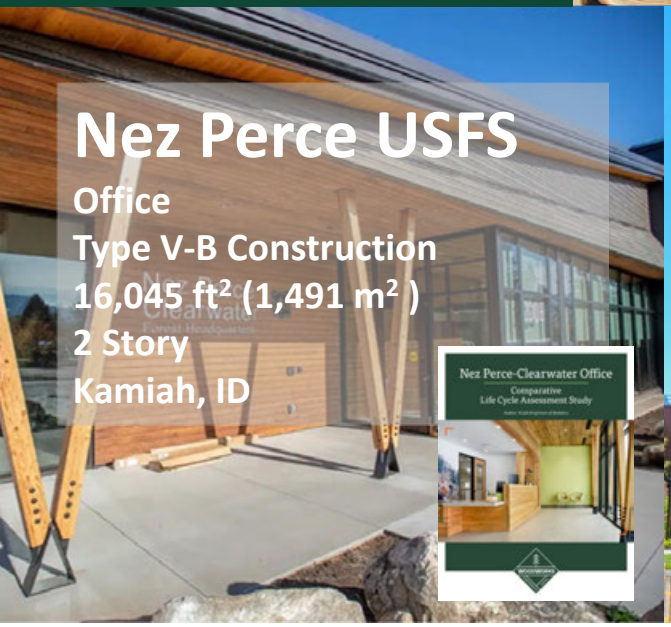


STUDY TRENDS



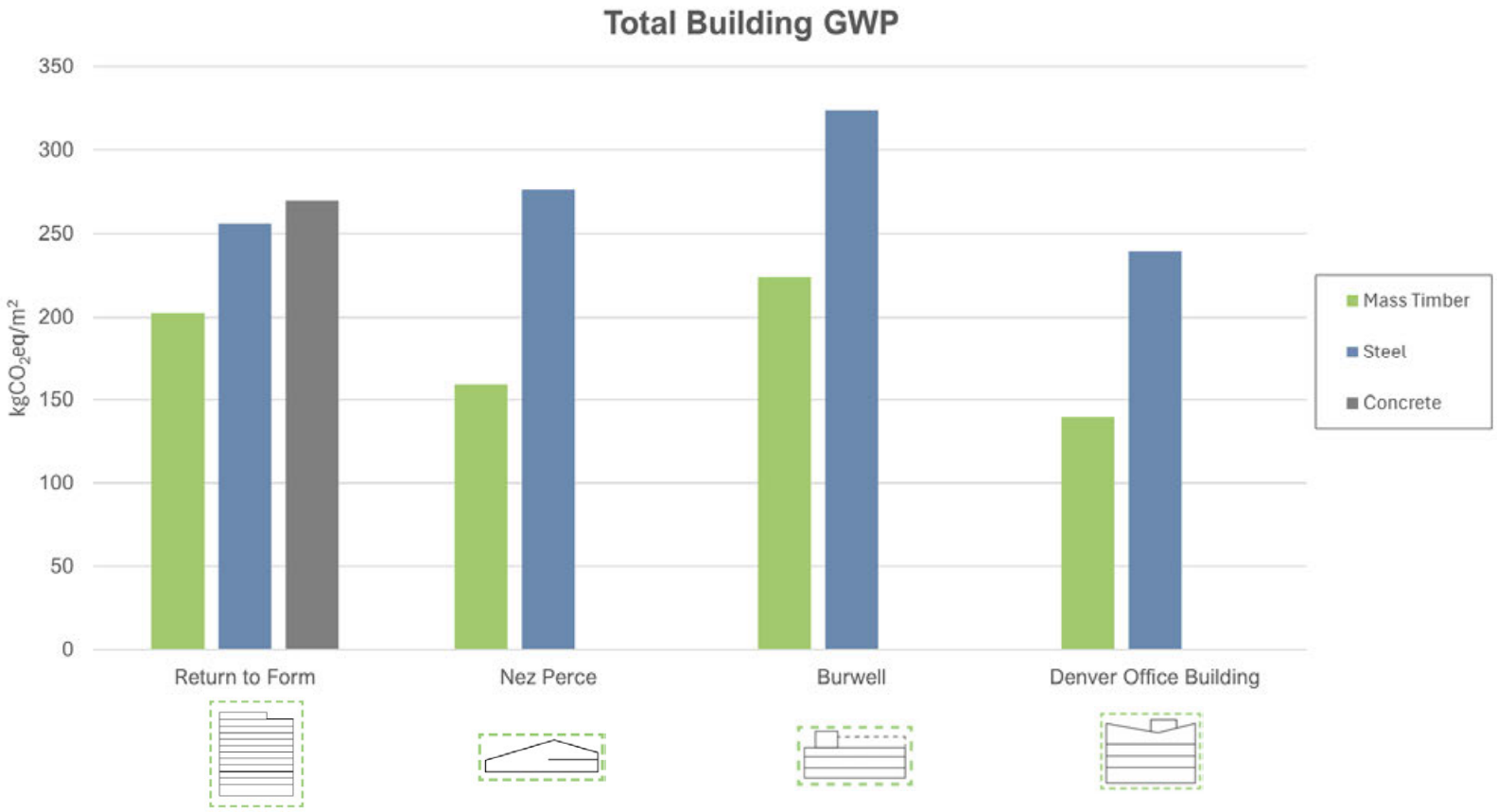

WOODWORKS
Mass Timber Comparative
Life Cycle Assessment Series
Comparing the embodied carbon impacts and cost of
mass timber buildings to functionally equivalent buildings
Introduction
Author
KL&A Engineers & Builders / KL&A Team Carbon


Return to Form
Multifamily / Retail
Type IV-B Construction
139,000 ft² (12,900 m²)
12 Story
Denver, CO
Return To Form
Comparative
Life Cycle Assessment Study


Nez Perce USFS
Office
Type V-B Construction
16,045 ft² (1,491 m²)
2 Story
Kamiah, ID
Nez Perce-Clearwater Office
Comparative
Life Cycle Assessment Study


Burwell Center
Office / Higher Ed
Type III-B Construction
22,990 ft² (2,136 m²)
3 Story
Denver, CO
Burwell Center
Comparative
Life Cycle Assessment Study


Denver Office
Office / Higher Ed
Type III-A Construction
98,280 ft² (9,130 m²)
4 Story
Denver, CO
Denver Office
Comparative
Life Cycle Assessment Study



21% – 43% Reduction

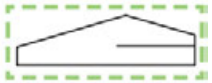
TOTAL BUILDING TRENDS

COMPARATIVE STUDY SERIES

Return to Form – Steel

165

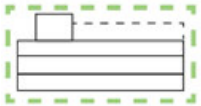
137



Return to Form – Concrete

207

171



Nez Perce

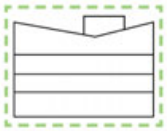
48

40

Burwell

51

42



Denver Office Building

217

180

= about 10 homes; = about 10 cars

EQUIVALENT TRENDS

COMPARATIVE STUDY SERIES

Total Building

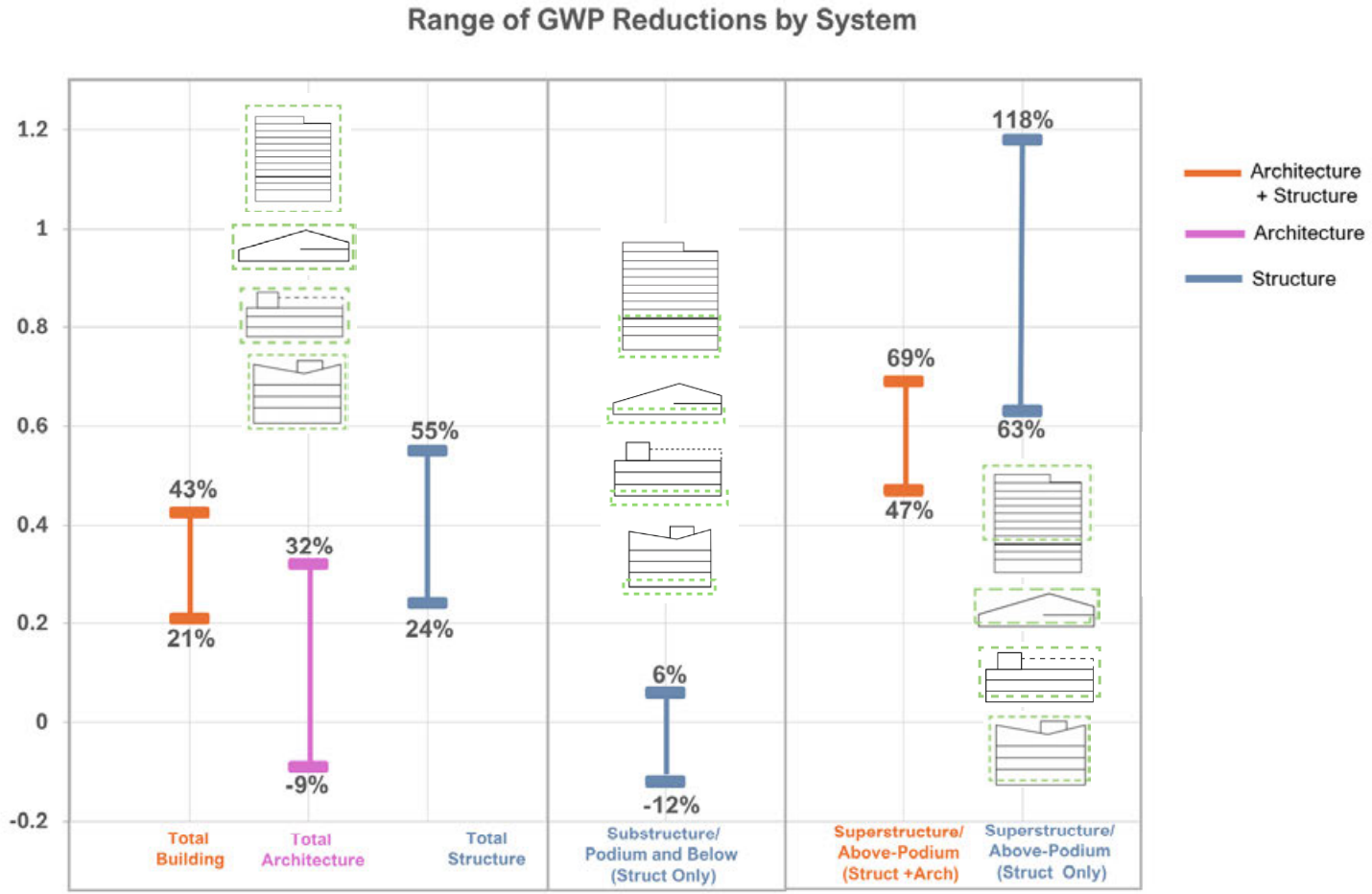
21% – 43% Reduction

Total Structure

24% – 55% Reduction

Total Architecture

32% Reduction – 9% Increase



SYSTEM TRENDS

COMPARATIVE STUDY SERIES

Total Building

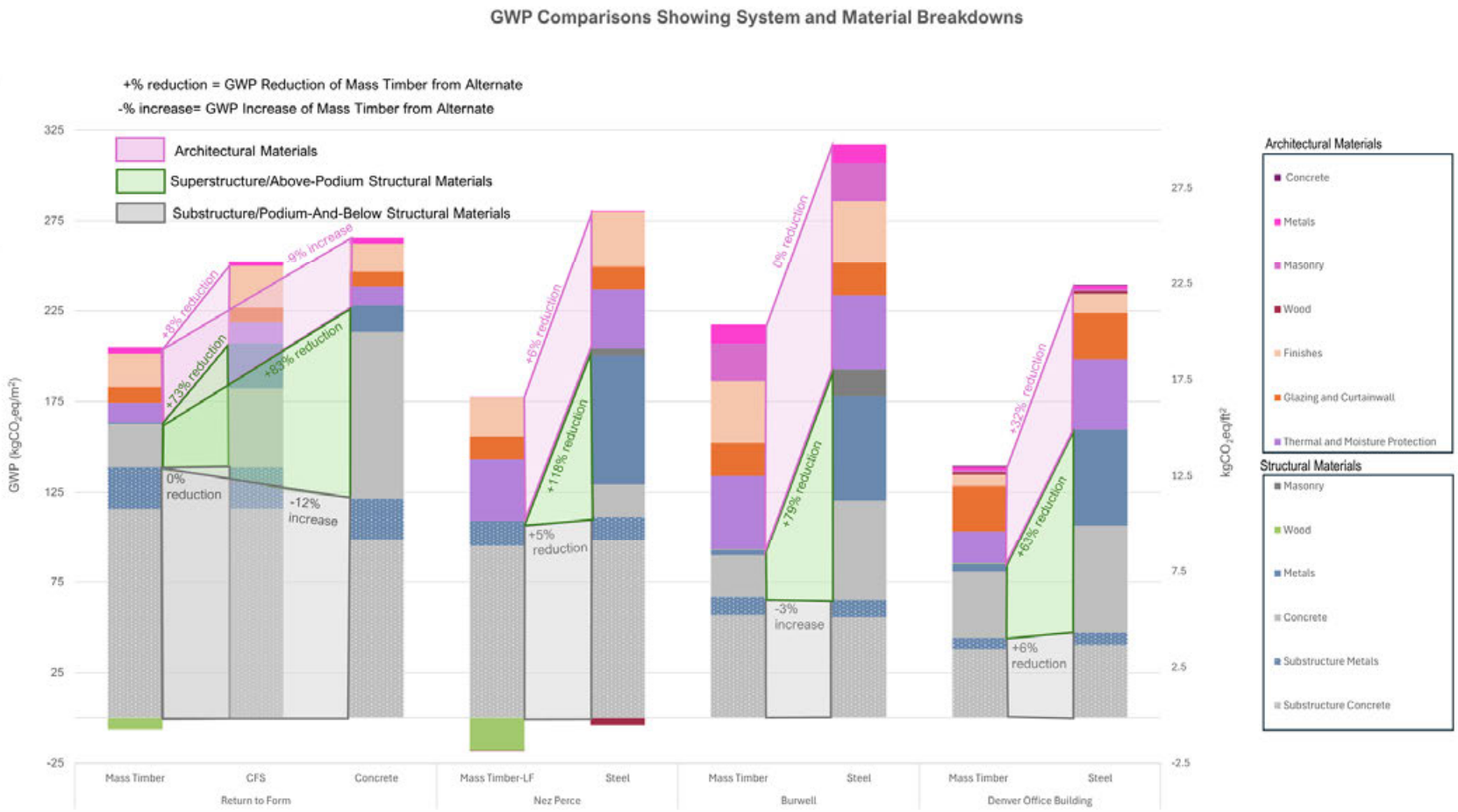
21% – 43% Reduction

Total Structure

24% – 55% Reduction

Superstructure Structure

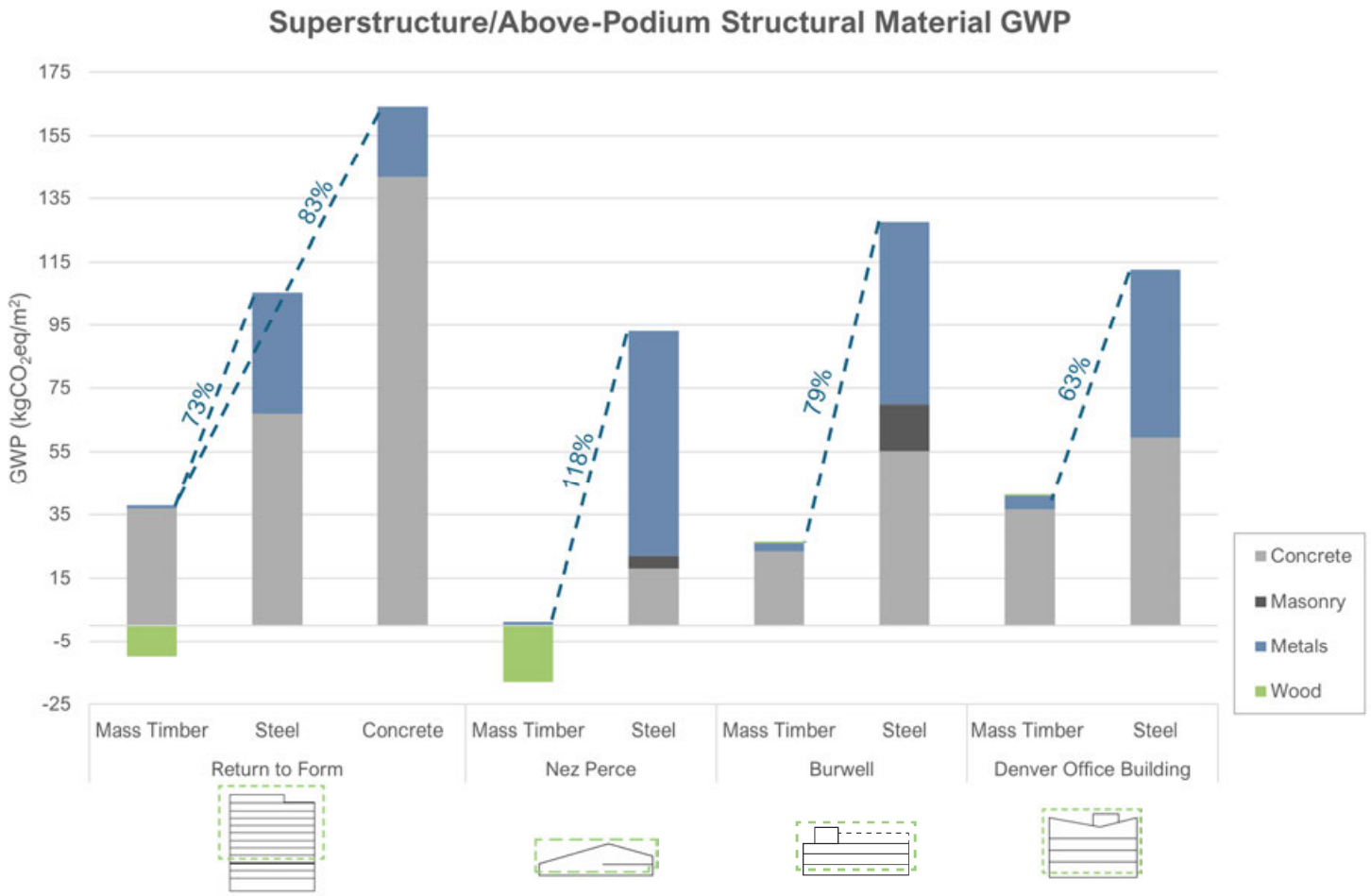
63% – 118% Reduction



SYSTEM TRENDS

COMPARATIVE STUDY SERIES

63% – 118% Reduction



SUPERSTRUCTURE STRUCTURAL TRENDS

COMPARATIVE STUDY SERIES

-165 to -256 $kgCO_2/m^2$

Stored Biogenic Carbon

Equivalent to

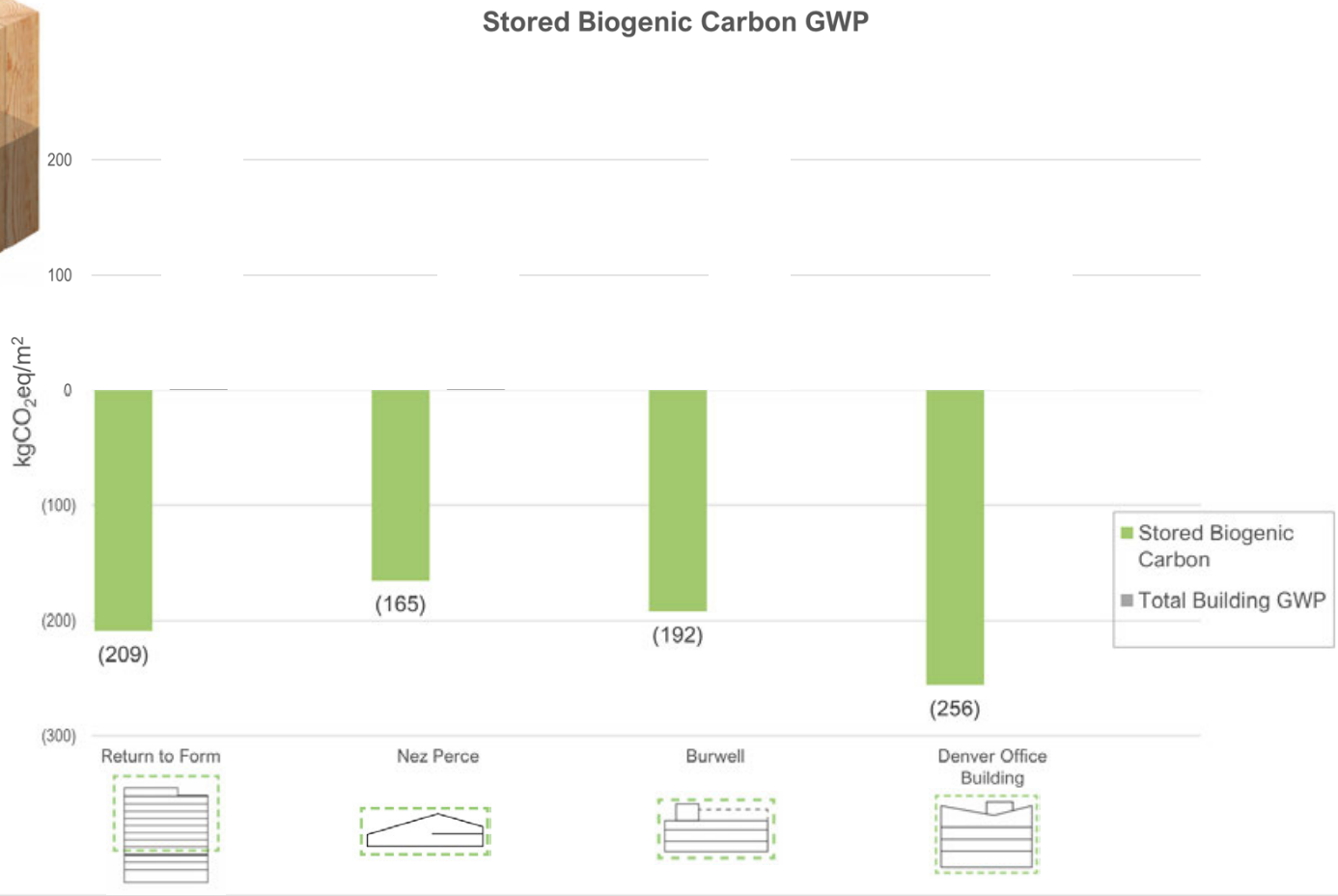
221,700 ft^2 (20,600 m^2) New Construction

Equivalent to

1135+ Flights, Roundtrip Denver to London

16 Minutes

Regrow the Wood of All 4 Buildings



BIOGENIC CARBON TRENDS

COMPARATIVE STUDY SERIES

Structure Raw Material

8 – 126% Premium

Structure Construction

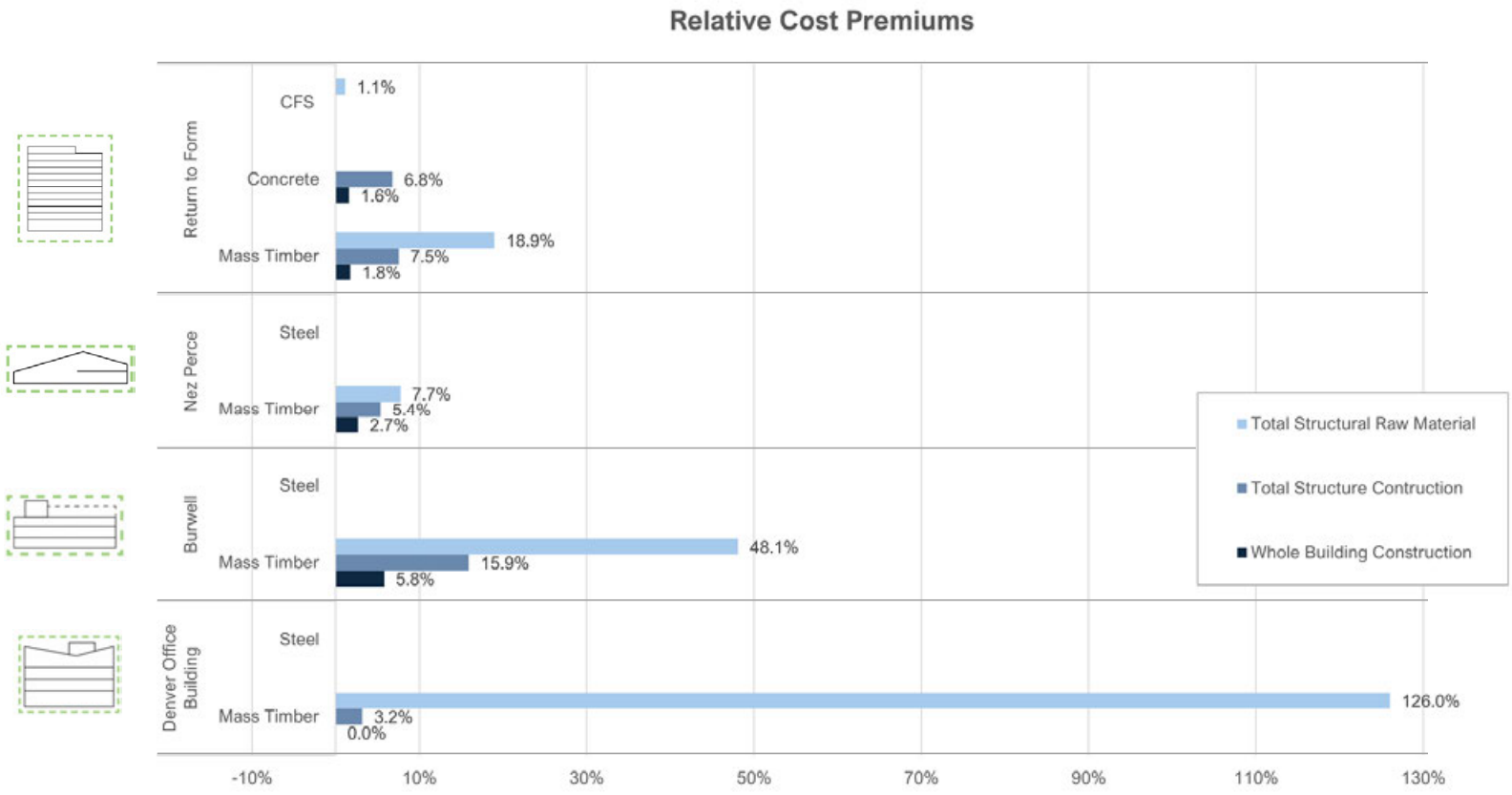
3 – 16% Premium

Whole Building Construction

0 – 6% Premium

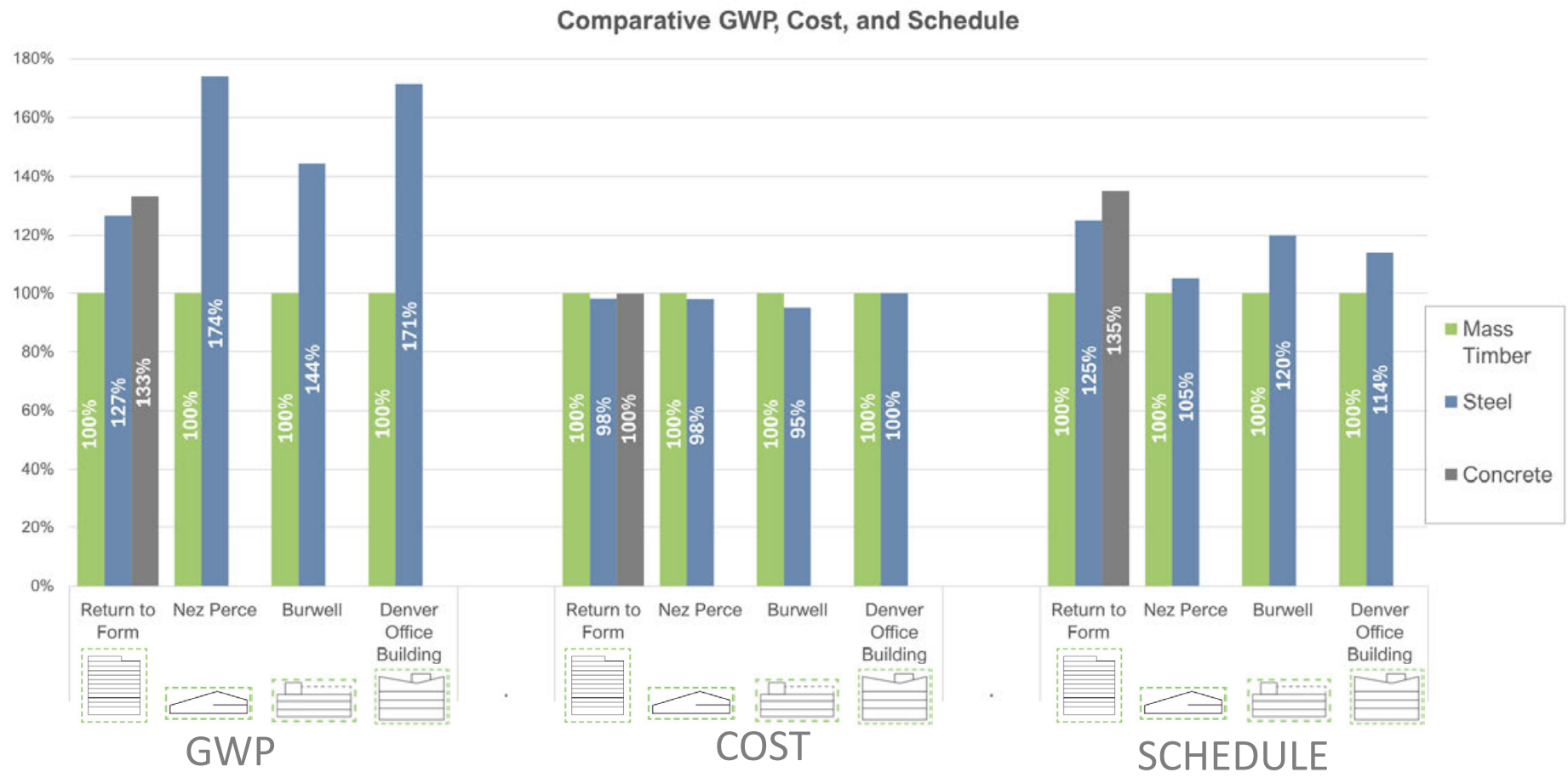
Schedule

16% Average Savings



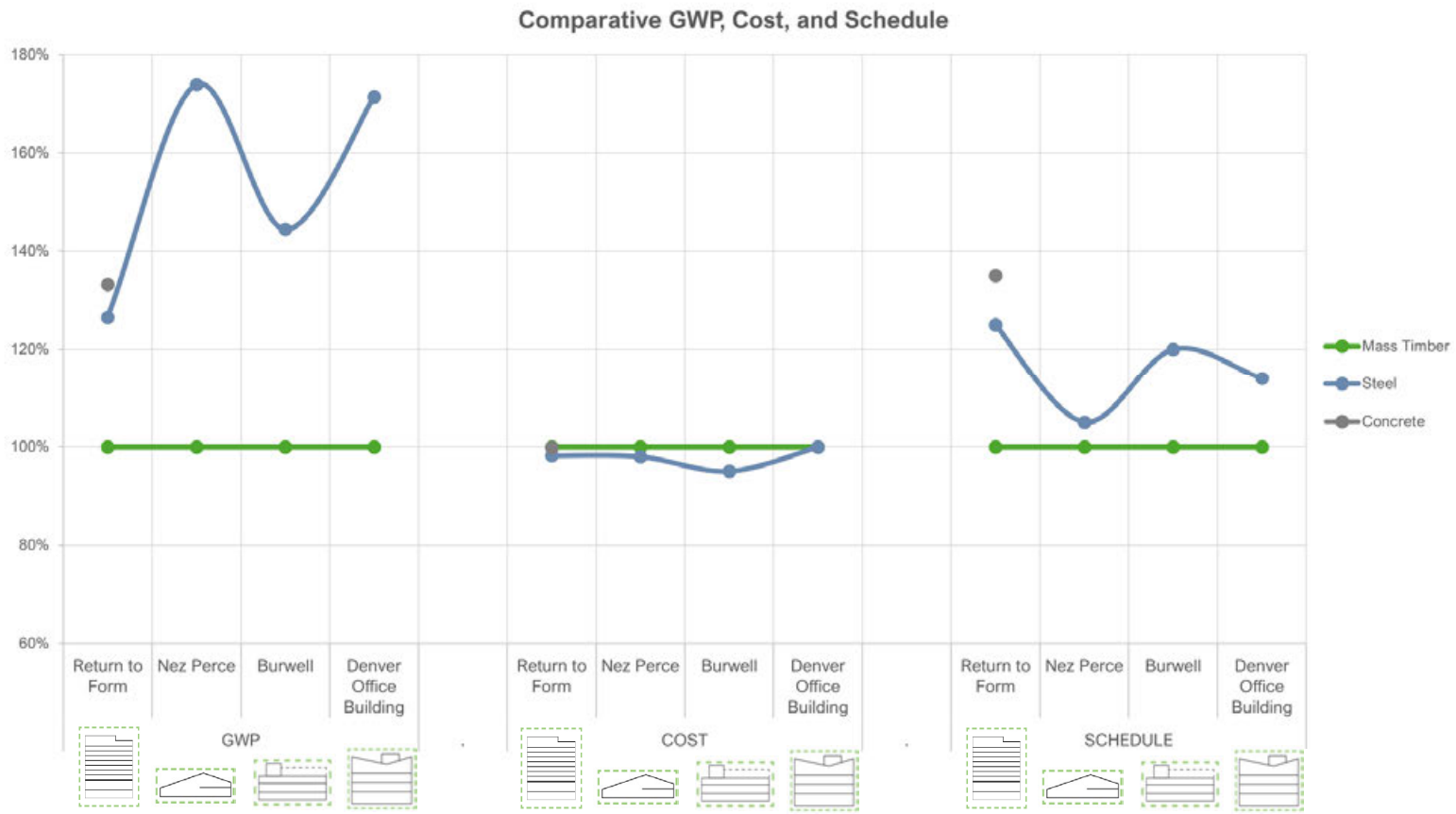
COST TRENDS

COMPARATIVE STUDY SERIES



TOTAL BUILDING TRENDS

COMPARATIVE STUDY SERIES



TOTAL BUILDING TRENDS

COMPARATIVE STUDY SERIES

- MASS TIMBER STRUCTURAL SYSTEMS HAVE CLEAR EMBODIED CARBON BENEFITS (SOURCE RESPONSIBLY & STAY INFORMED)
- GWP vs COST BALANCE
- SPEED OF CONSTRUCTION
- RESPECT STORED BIOGENIC CARBON
- DESIGN FOR DECONSTRUCTION & EASY RECOVERY
- EMBODIED CARBON AT CONCEPT DESIGN

Photo by Aleksandar Radovanovic on Unsplash

Photo Credit: JC Buck

This concludes The American Institute of Architects Continuing Education Systems Course.

THANK YOU

KL&A
Engineers & Builders

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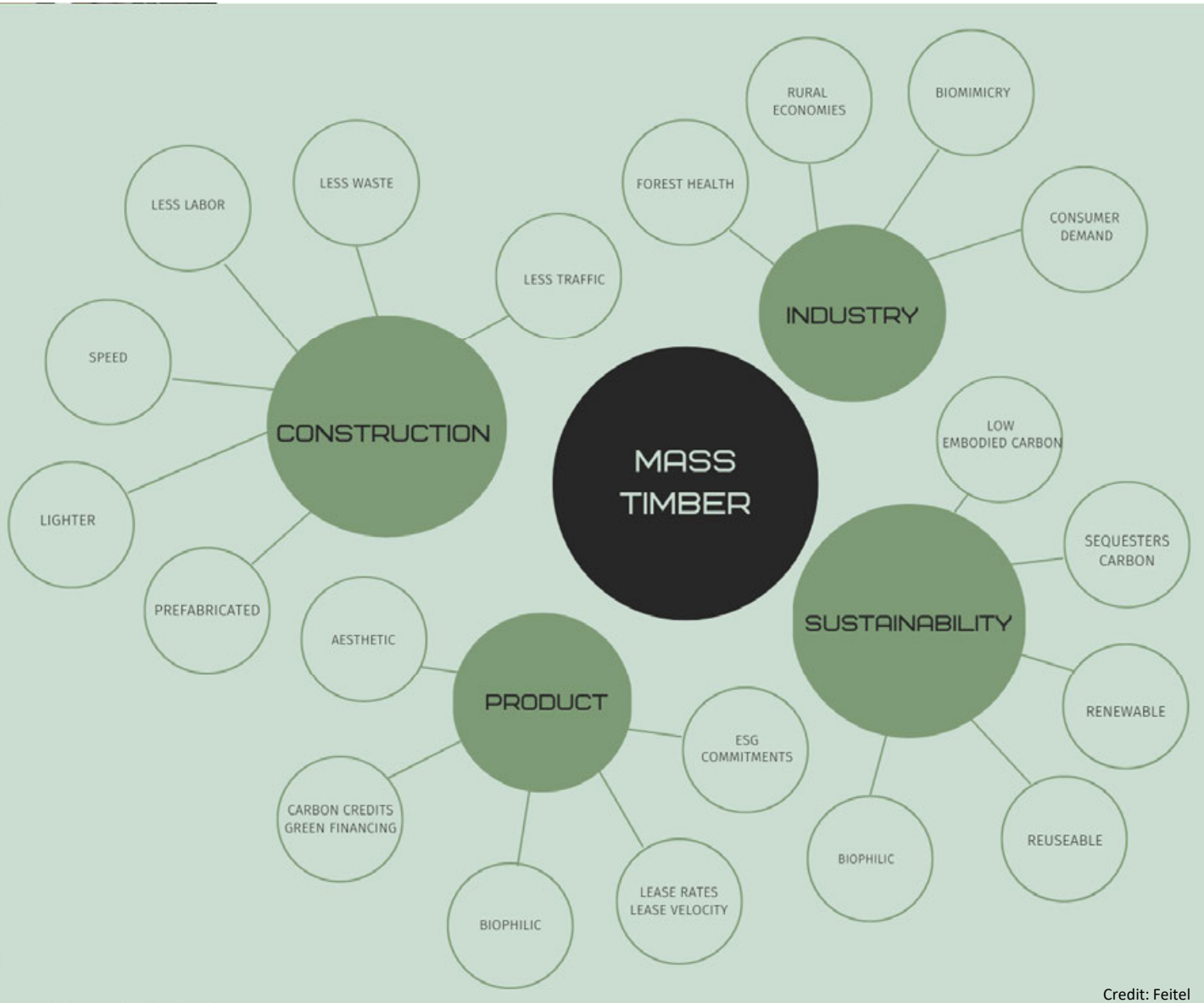
Anli Ni
ani@klaa.com



Credit: Feitel