Prefabrication for Architects

Considerations in Designing Mass Timber Buildings

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Module 1: Introduction and Project Planning for Optimizing Design

Objectives:

Introduce the prefabrication process of mass timber and early design considerations to optimize design.

- Introduction to mass timber
- Advantages to Prefabrication
- Early considerations for optimizing design
- Project planning


Regenerative

Image of a CLT Panel in the fabrication process. Photo by: Veronica Madonna

Mass Timber

- Engineered products made from dimensional lumber
- Laminated together through the elimination process
- Forms large structural elements
- Lamination occurs through adhesive, nails, screws, or dowels

Cross Laminated Timber
Glulam
Dowel Laminated Timber
Nail Laminated Timber
Mass Plywood

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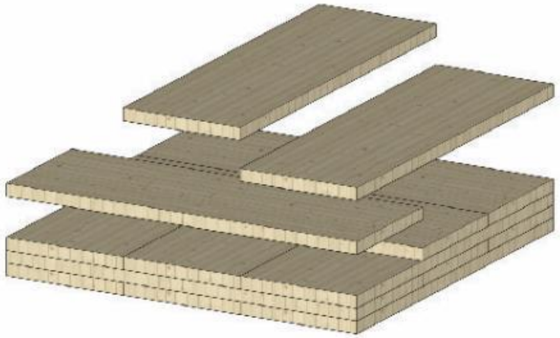
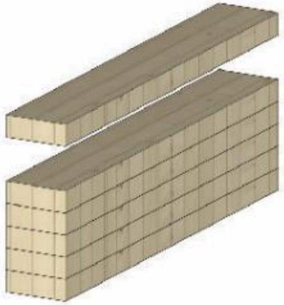
Mass Timber Products

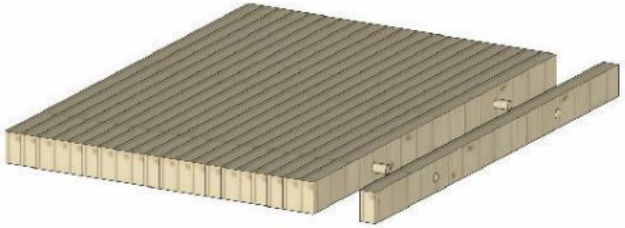


Cross Laminated Timber



Glued Laminated Timber

Nail Laminated Timber



Dowel Laminated Timber

Mass Plywood Panel

Laminated Veneer Lumber

Glulam and Glulam Panels (GLT)

Image of a glulam beam structure and decking. Source: StructureCraft

Dimensional Lumber stacked parallel to each other
Long spans and strength

Cross Laminated Timber (CLT)

The Cube in Hamburg, Germany, is constructed using CLT panels for floor and wall structure. Photo credit IBA Hamburg, Martin Kunze.

Dimensional lumber stacked crosswise
Strength, dimensional stability and rigidity

Nail Laminated Timber (NLT)

NLT consists of dimensional lumber placed on edge with individual pieces mechanically fastened together by nails or screws

The interior of 80 Atlantic Avenue in Toronto, Ontario architectural designed by BPN Quadrangle (formerly Quadrangle Architects Ltd.) utilizes a nail-laminated timber floor deck. Photo credit: Doublespace Photography.

Dowel Laminated Timber (DLT)

Like NLT, except it is fastened together using wood dowels rather than metal screws or nails

Image of the DLT floor structure at 111 East Grand Office. Source: StructureCraft

Mass Plywood Panels (MPP)

Veneer-based engineered panel comprised of multiple veneers pressed and adhered together

Image of a mass plywood pavilion. Source: Lever Architecture.

Advantages of Mass Timber

Construction Advantage

Prefabrication on components provide greater precision and quality control.

Reduced on-site construction.

Aesthetic Advantage

Aesthetic and experiential benefits often make mass timber buildings desirable to tenants as well as aiding in biophilic benefits.

Ecological Advantage

Building represent close to 40% of the greenhouse gas emissions.

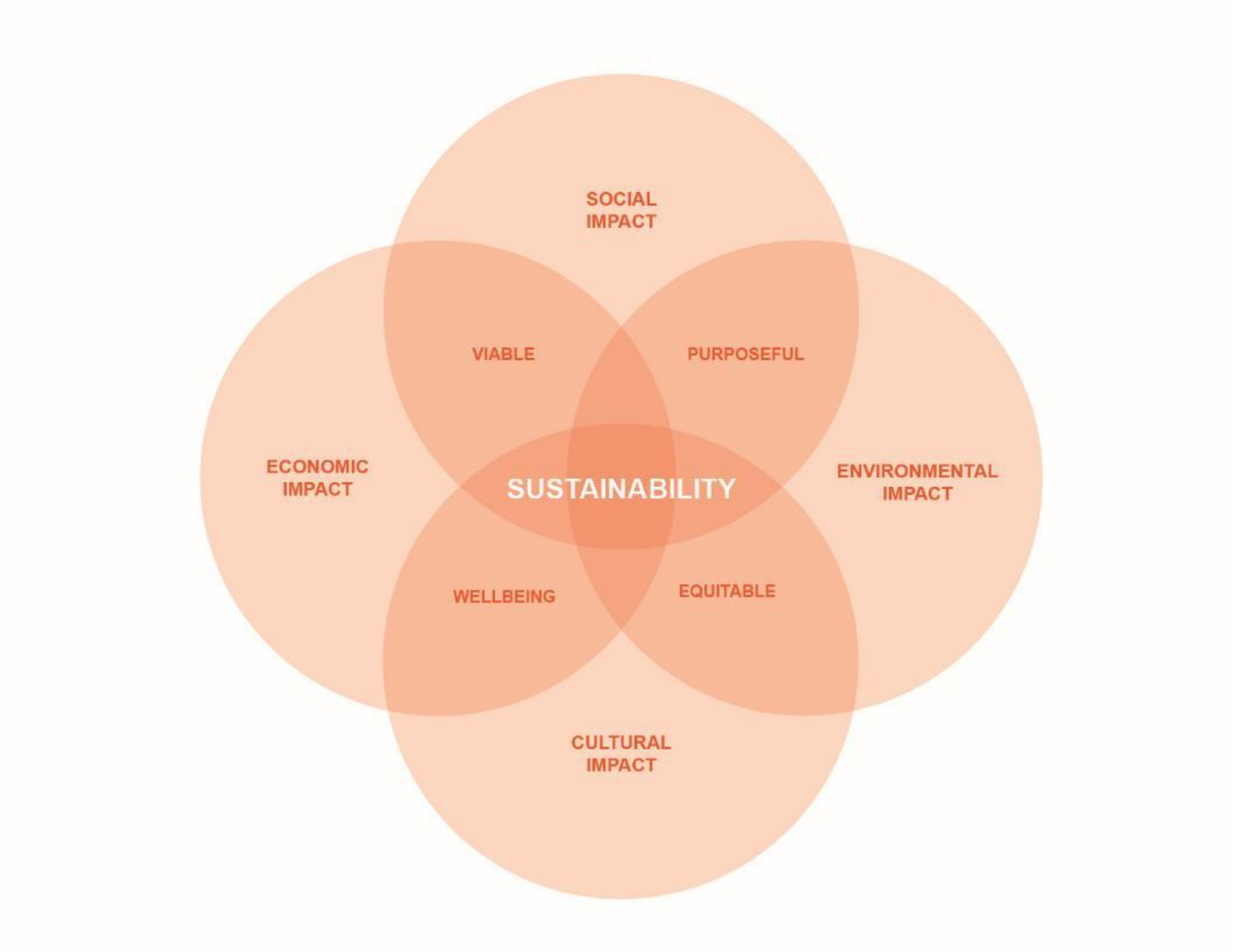
Wood has the ability to sequester carbon, and is a low embodied carbon building product.

Speed and cost
Human connection
sustainability

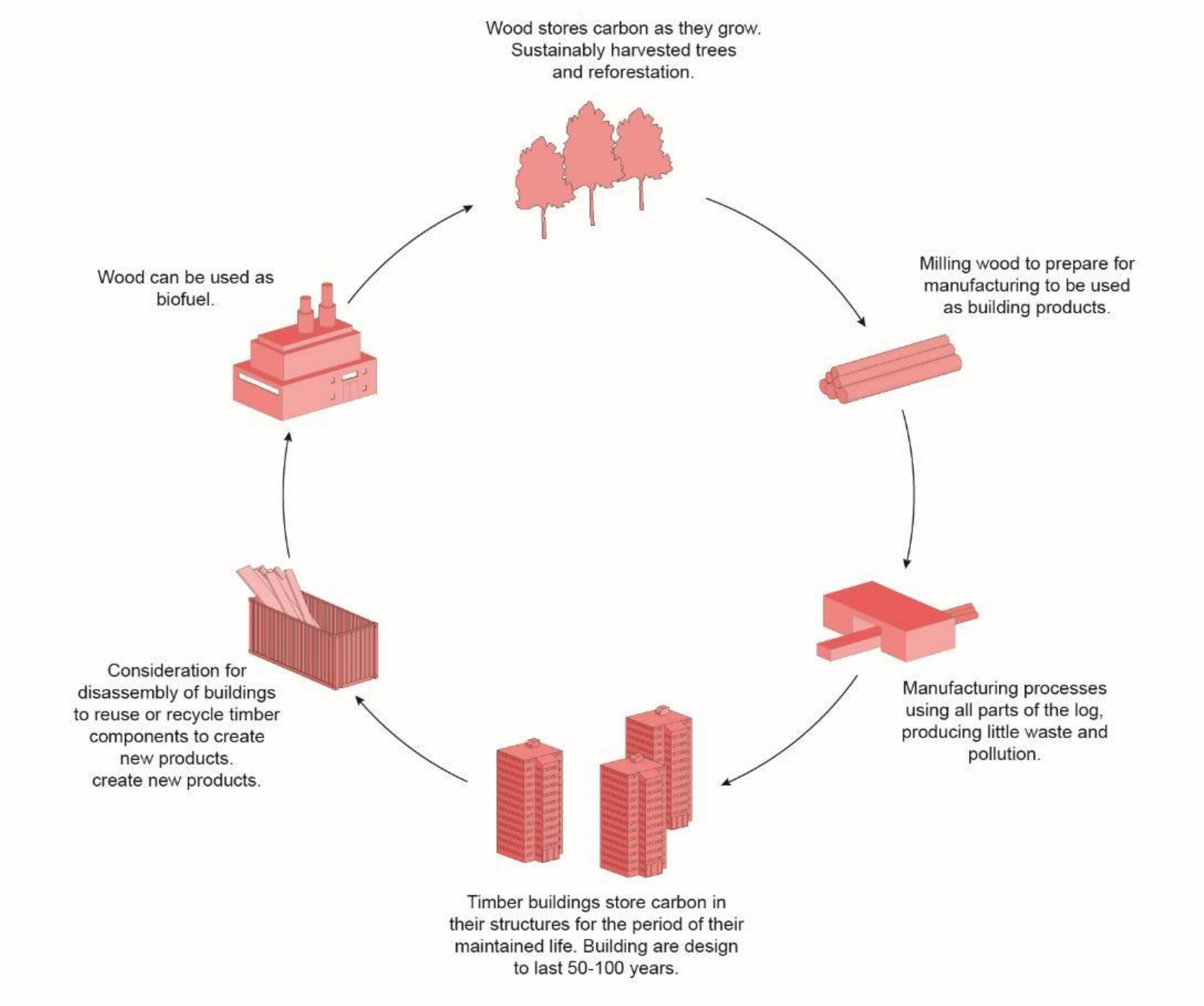
Additional Advantages

- Proven Performance and Safe
- Light-weight and Low Embodied Carbon Material
- Efficient, Cost-Saving Construction
- Thermal and Health Benefits

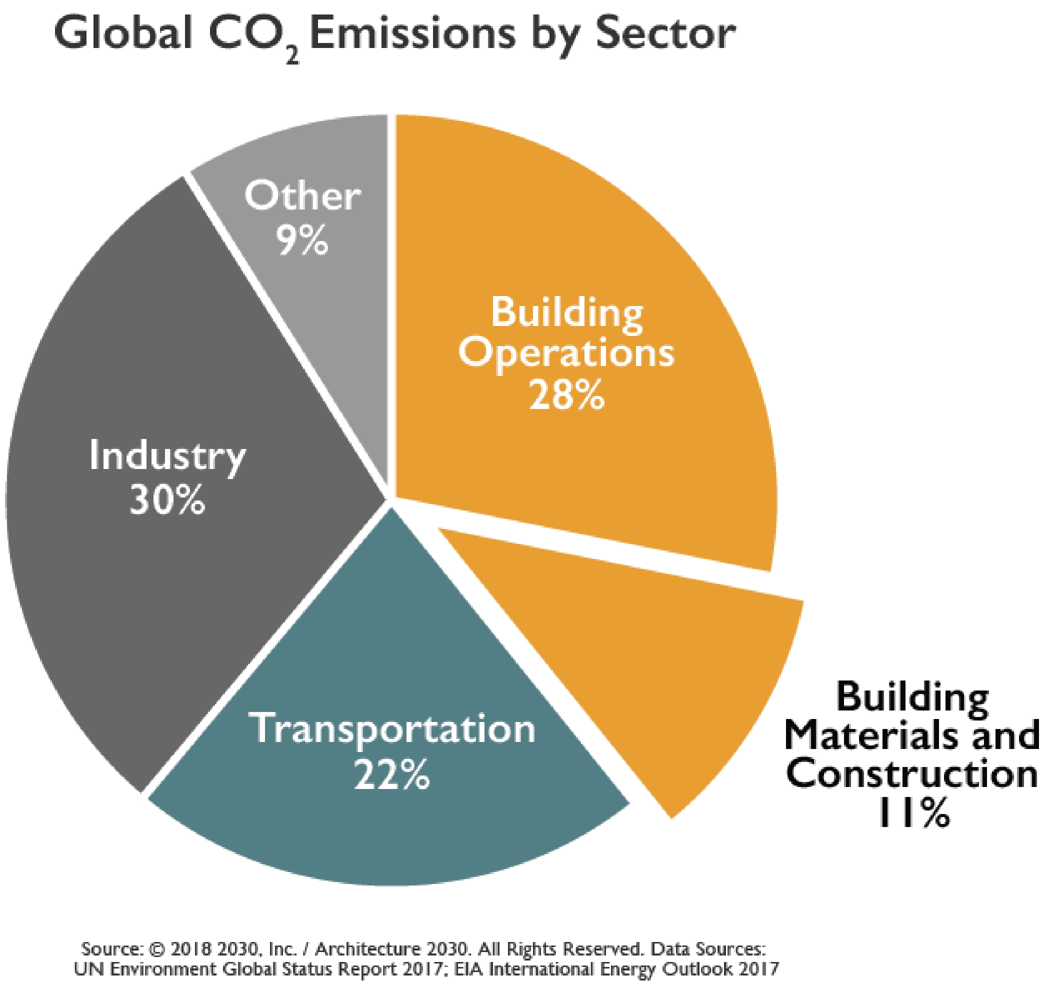
Social, Economic, Environmental and Cultural Benefits



Life Cycle Overview of Mass Timber



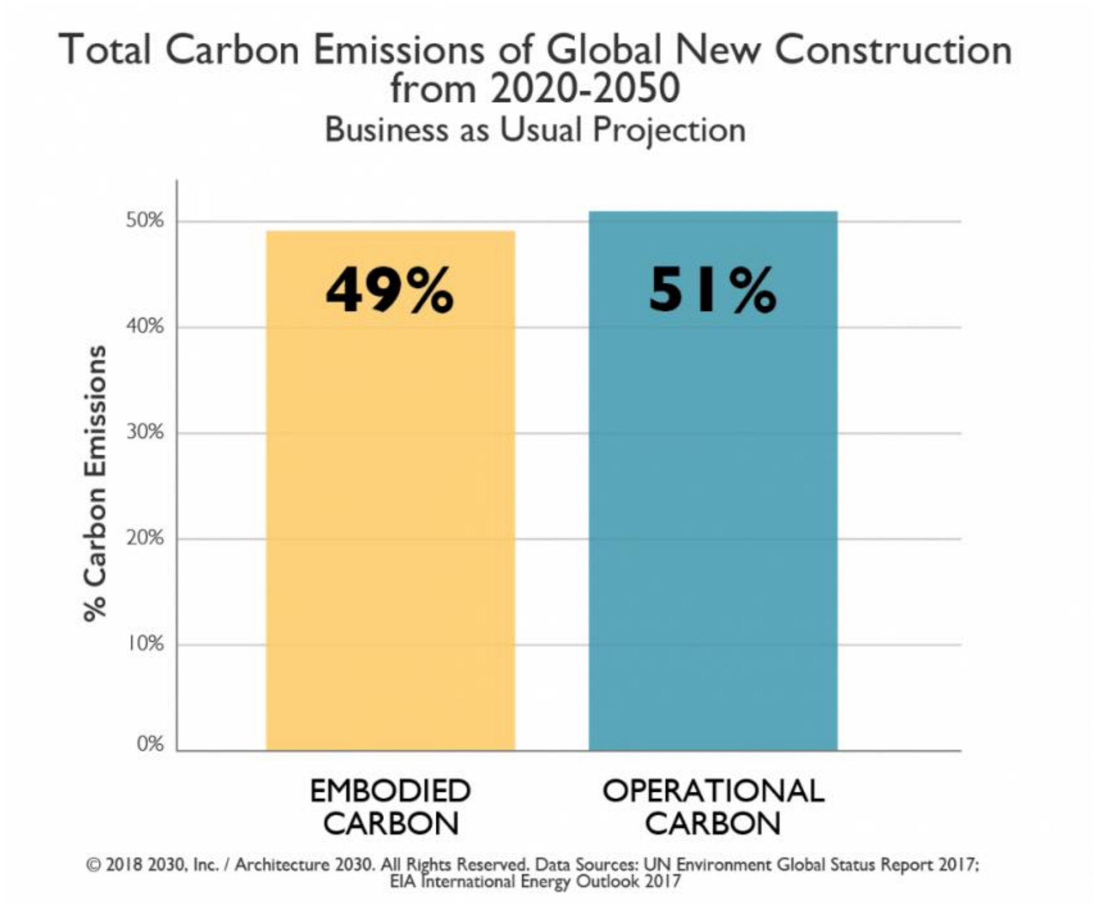
Carbon Emissions



- **Buildings contribute to over 40% of the total green house emissions globally**
- **Annually, embodied carbon is responsible 11% of global GHG emissions and 28% of global building sector emissions.**

Source: Architecture 2030

Embodied vs. Operation Carbon



- **Embodied carbon will be responsible for *almost half* of total new construction emissions between now and 2050.**
  - Unlike operational carbon emissions, which can be reduced over time with building energy efficiency renovations and the use of renewable energy, embodied carbon emissions are locked in place as soon as a building is build. It is critical that we get a handle on embodied carbon now if we hope to phase out fossil fuel emissions by the year 2050.

Source: Architecture 2030

Activity – Understanding Mass Timber

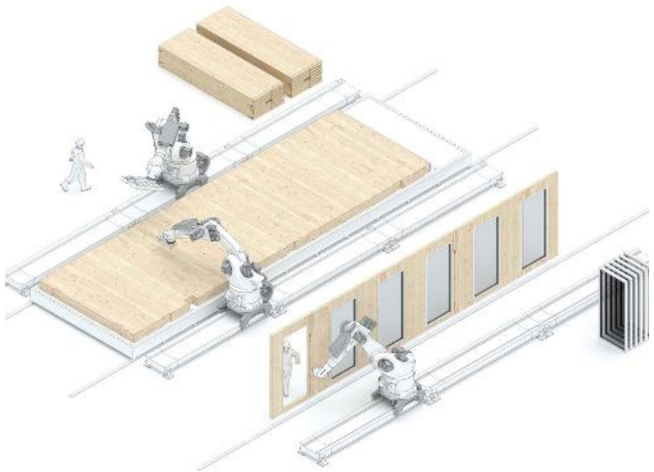
1. *Name three mass timber products and how they compare.*

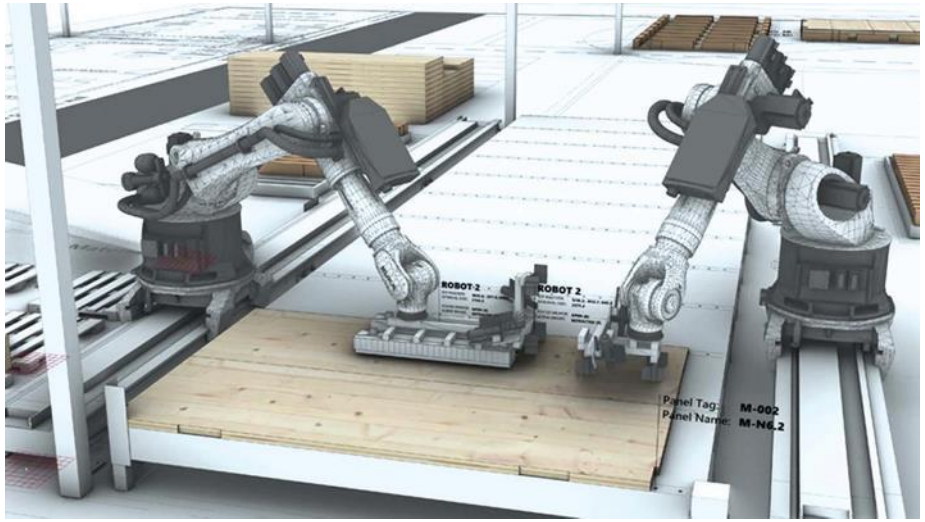
2. *What are three advantages of mass timber?*

3. *Describe the four benefits to utilizing mass timber.*

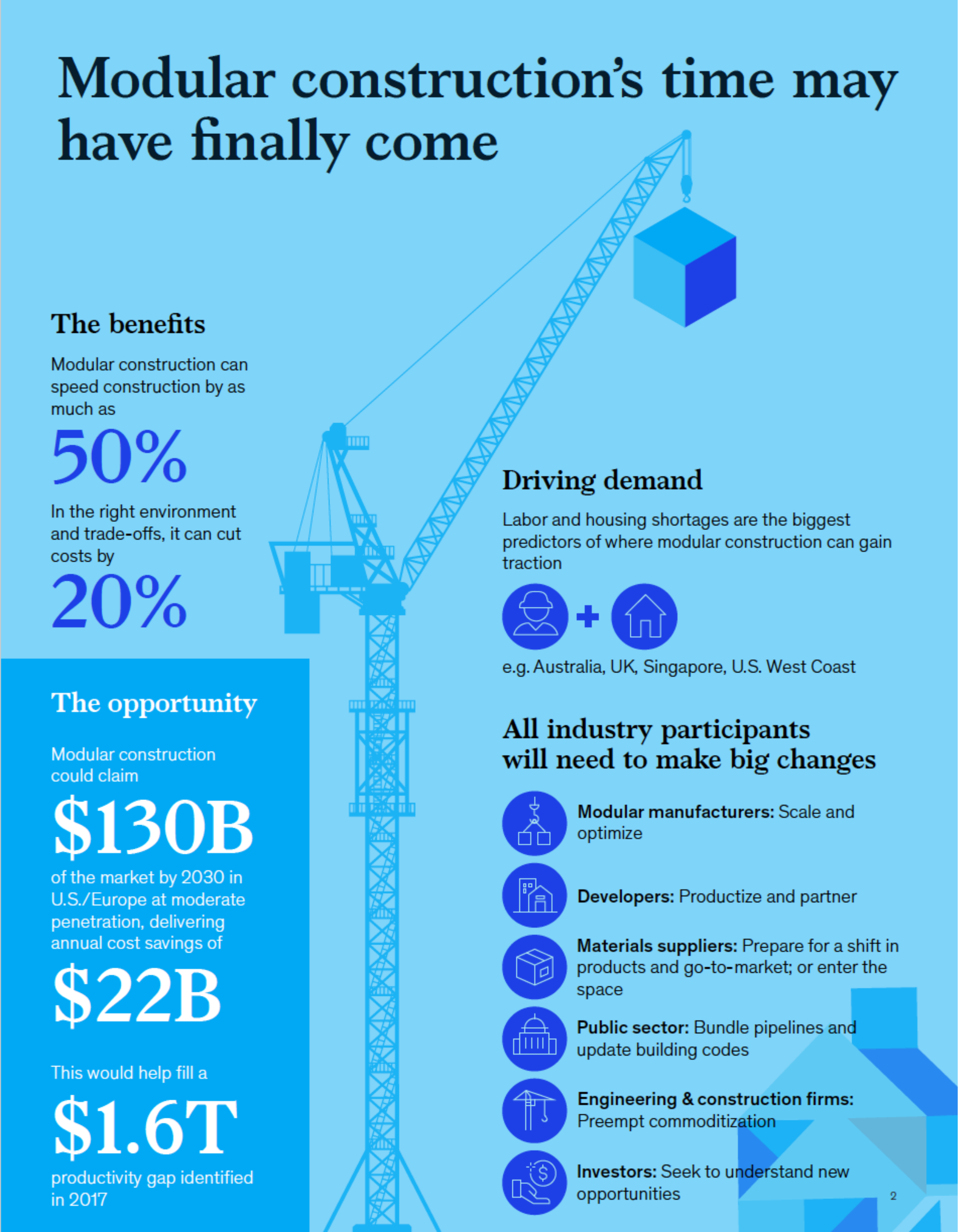
Advantages of Prefabrication

Mass Timber and Prefabrication





https://www.canadianarchitect.com/home-products-r-hauz-toronto-ontario-and-intelligent-city-vancouver-british-columbia/



Benefits of Modular Construction

20-50% increase speed of construction

Potential cost savings of 20%

Big changes are required

- Modular manufacturers
- Developers
- Suppliers
- Regulations
- Design & Engineering
- Investments

Source: McKinsey & Company . (2019, June). *Modular Construction: From Projects to Products.* Retrieved from McKinsey & Company

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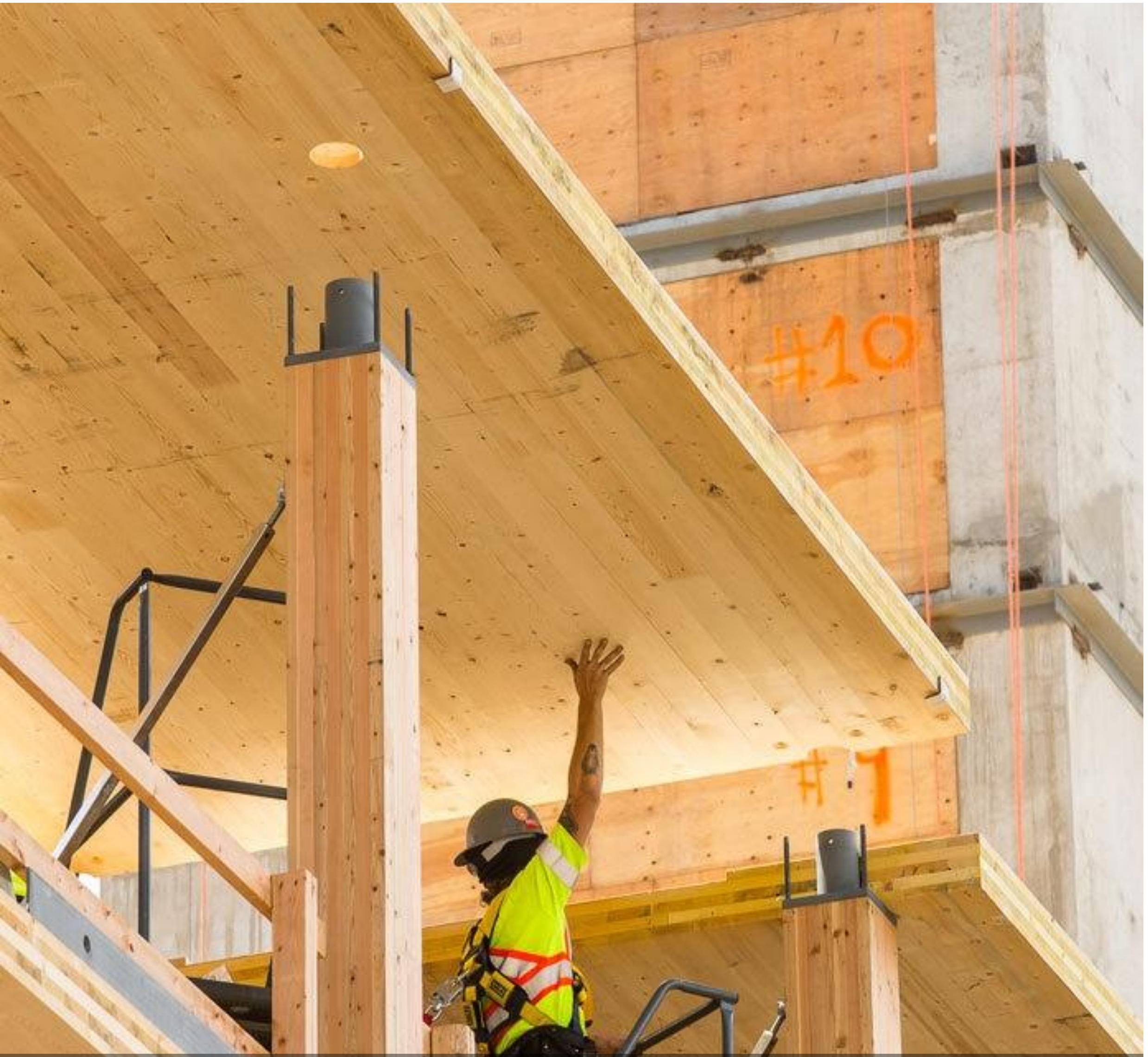
Construction Advantage



Brock Commons Tall Wood House during construction. Architect: Acton Ostry, Structural Engineer: Fast+Epp. Photo by: KKLaw

Construction speed

- Potential 25% quicker than traditional material like concrete
- 90% reduction in truck deliveries
- 75% fewer works on active deck

Light Weight Structure

- Can reduce foundation sizes

Prefabrication = Less Waste

- Precision in fabrication process
- Greater quality and quality control

Modular Construction

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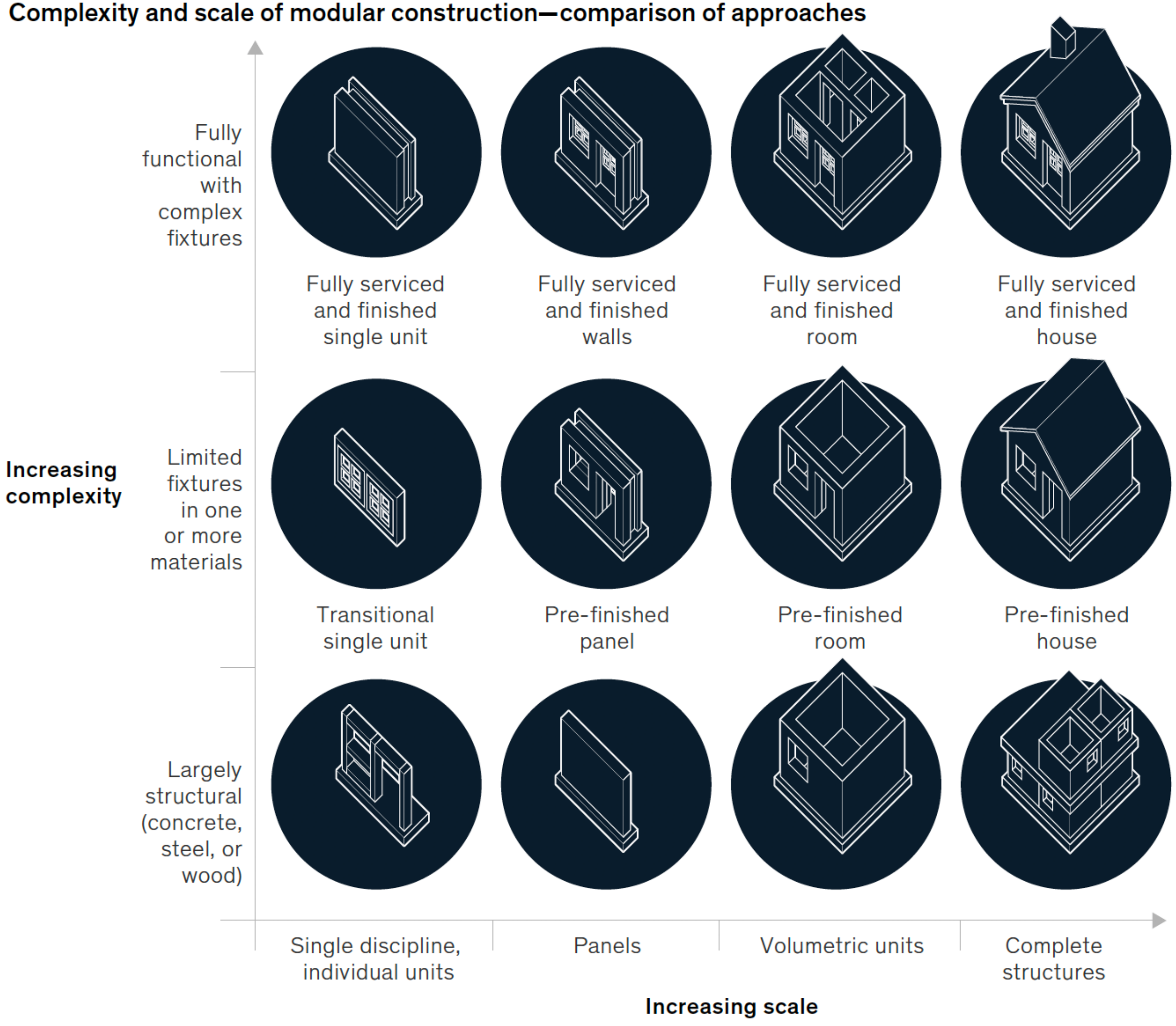
Modular construction covers a broad set of approaches.

Complexity and scale of modular construction—comparison of approaches



Source: Case studies; interviews; McKinsey Capital Projects & Infrastructure

Various Approaches to Prefabrication

Source: McKinsey & Company . (2019, June). *Modular Construction: From Projects to Products.* Retrieved from McKinsey & Company

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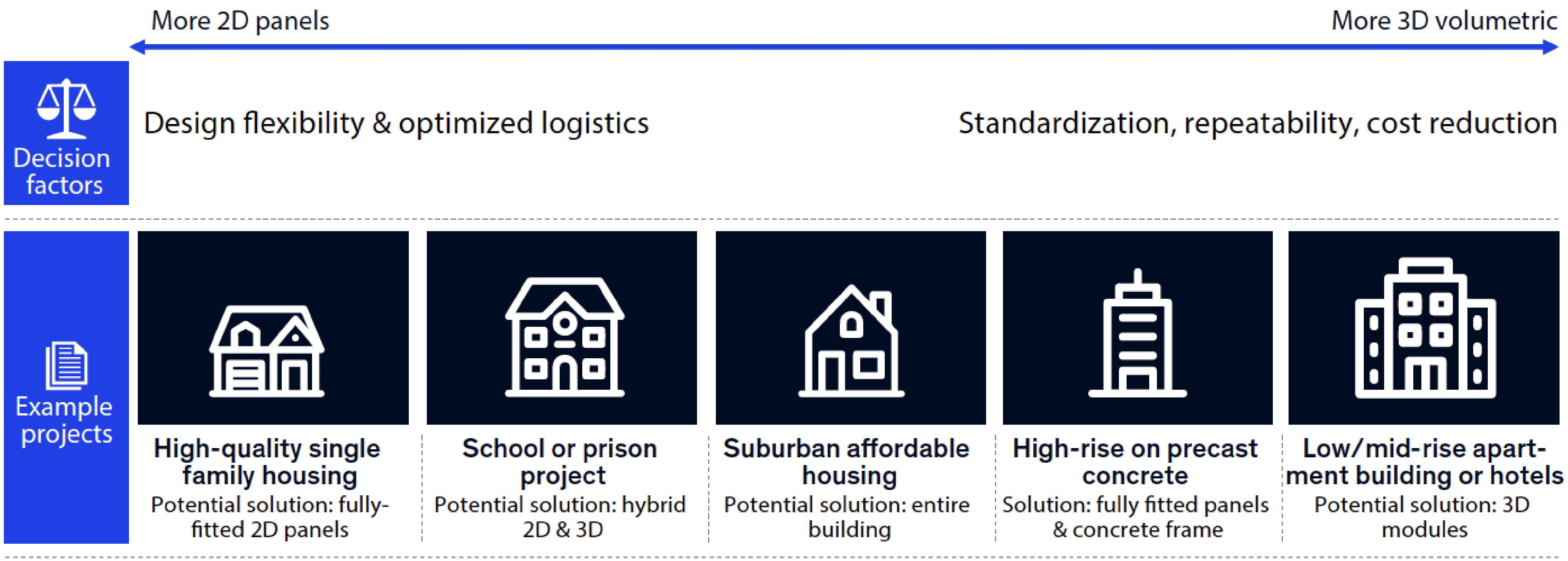
Prefabrication and Potential Scenarios

A project's specific requirements will determine the choice of modular system.



Source: McKinsey & Company . (2019, June). *Modular Construction: From Projects to Products.* Retrieved from McKinsey & Company

3D Volumetric Prefabrication

- Fully Assembled Units
- Maximize productivity benefits and efficiencies
- However, limitation include transportation
  - Typically, 3.5m wide for non-police escort
- Compartmentalized plans
  - Hotels
  - Student Residence
  - Affordable Housing

Source: 3D Volumetric Construction of Hotel Jakarta in Amsterdam.
https://www.derix.de/en/referenzen/X-LAM/hoteljakarta

2D Panelized

Albina Yard in Portland Oregon by LEVER Architecture. Photo by: Jeremy Bittermann

- Panels prefabricated off-site and assembled on site
- Flat packed for shipping, more economic shipping costs than 3D Volumetric
- However, longer times on site than 3D Volumetric
- Permits flexibility for open plan design, ie. Offices

Early Considerations For Optimizing Design

Project Planning

Project Planning and Time Distribution

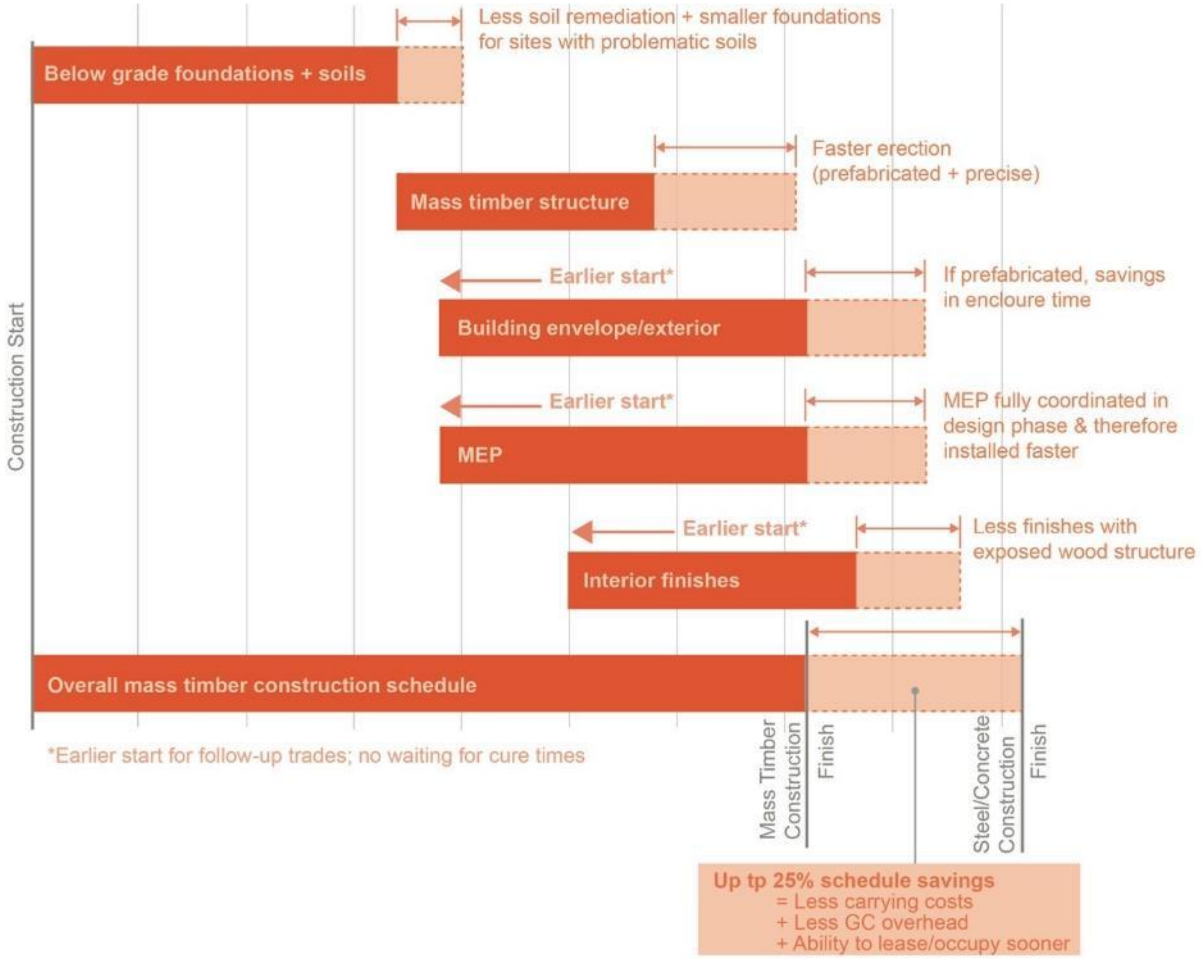


Figure 9: Compressing the Typical Construction Schedule with Mass Timber. Potential cost savings in comparison to steel and concrete.
(WoodWorks 2019)

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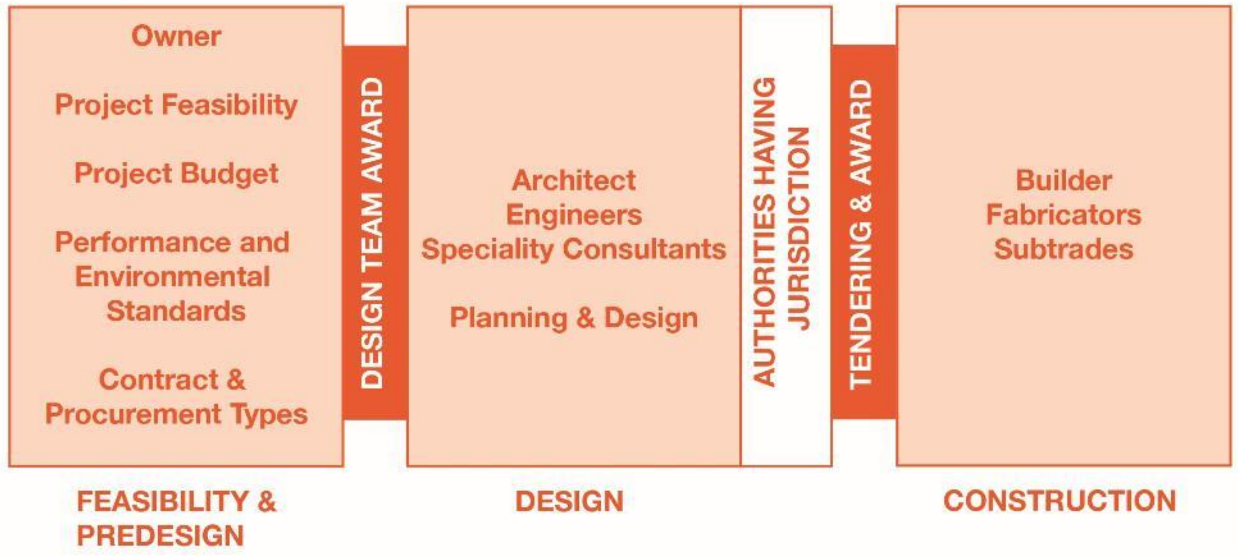
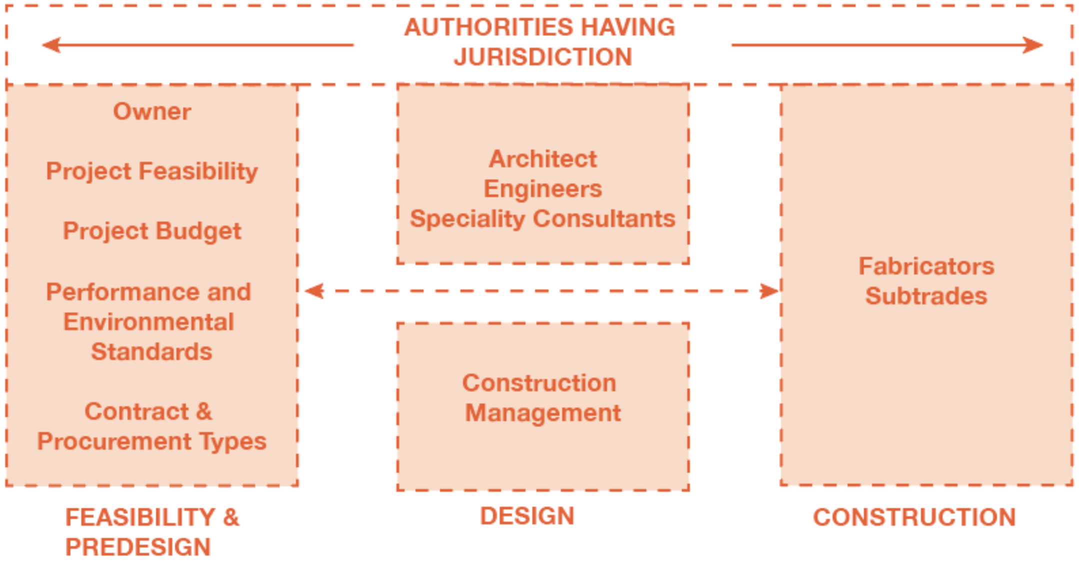
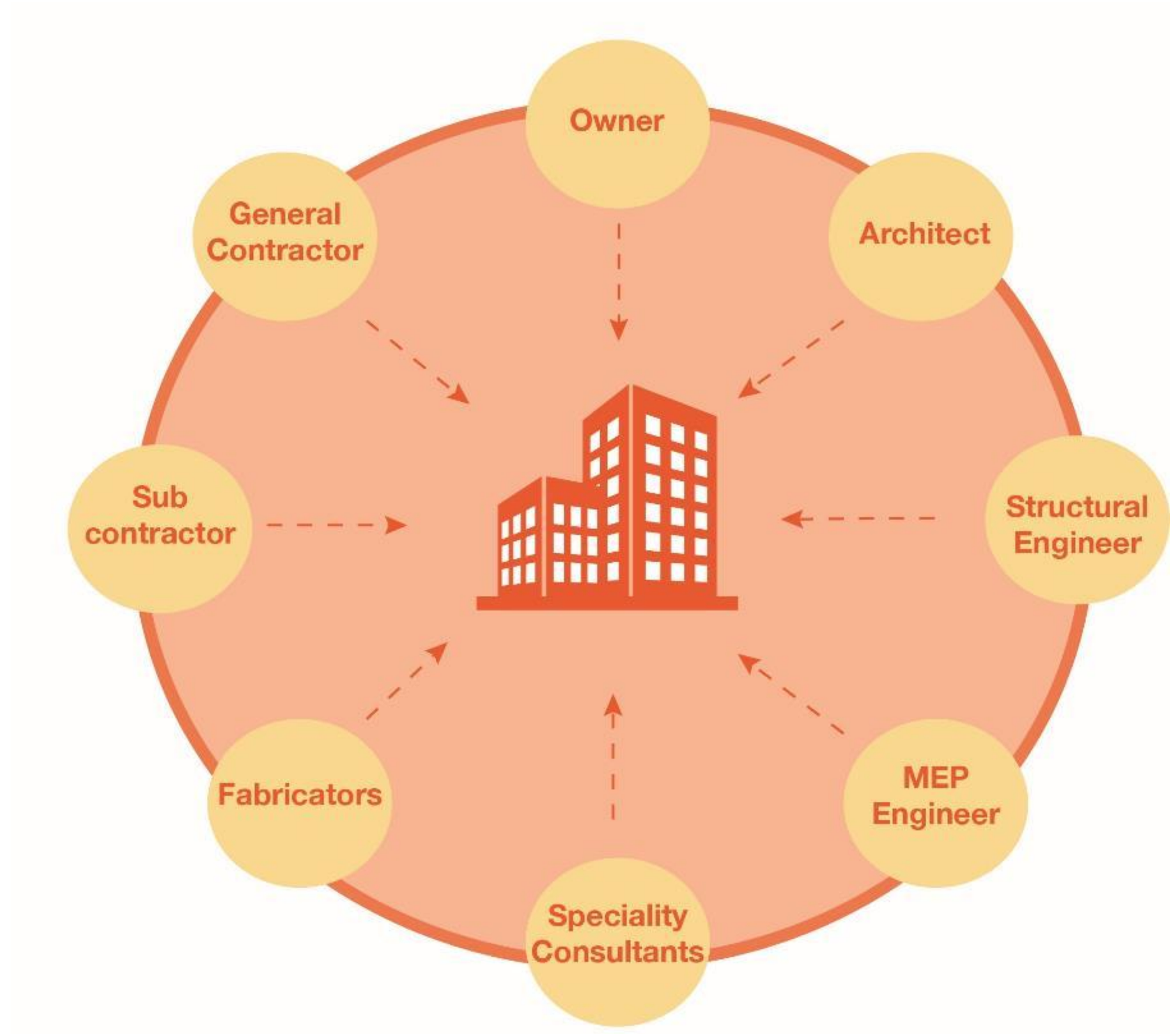
Traditional Project Delivery - Design-bid-build



Cooperative Planning



Integrated Design And Project Delivery



The Integrated Team

Key Planning Considerations

- Integrated design process to ensure careful considerations of building use, site considerations, structure, systems integration and construction sequencing.
- Sufficient time must be budgeted in the planning stages.
- Enhanced coordination of systems during the design process.
- Prefabrication and detail planning are critical to resolve before construction.
- Significantly reduce time during the construction stage and heightened overall quality control.

Manufacturer Input

- Capabilities for product and sizes
- Optimize size
- Reduce waste

Albina Yard in Portland Oregon by LEVER Architecture. Photo by LEVER Architecture.

Kit of Parts

Brock Commons Tall Wood House. Architects: Acton Ostry Architects, Structural Engineer: Fast + Epp, Photo By: Pollux Chung

Know Your Product and Supply Chain March 2021

EUROPEAN SUPPLIERS

- Storaenso
- KLH
- Binderholz
- Hasslacher
- Mayr Melnhof

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Activity – Integrated Design Process

1. *Describe the differences between the design-bid-build and the integrated design process (IDP). Provide a diagram of the relationships. Consider:*

    a. *What are the key advantages to IDP in mass timber buildings?*
    b. *What is the collaboration process critical?*

Module 2: Design Considerations for Optimized Design

Objectives:

Understand key design considerations to optimize design for prefabrication of mass timber design.

- Structural design considerations
- Fire protection design considerations
- Acoustic and vibration design considerations
- Retrofits and adding storeys to existing building design considerations

Design Consideration of Mass Timber Design

Mactan Cebu
International Airport Terminal 2,
Cebu City, Philippines.

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Structural Design Considerations

Selecting a Mass Timber System

Installation of glulam beam during the construction of the First Tech Credit Union headquarters building in Hillsboro, Oregon.
Source: https://www.capitalpress.com

- Strength and stability
- Load capacity
- Program and use
- Long term flexibility

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Common Timber Systems

- Framed Systems
- Panelized Systems
- Hybrid Systems

Structural System and Program Use

Structural System and Program Use

Key Considerations

- Program Use
- Cost
- Fire Protection
- Vibration and Acoustic Control
- Authorities and Code Requirements

Factors in Selecting a Structural System

Cost

- Cost of design
- Cost of materials
- Cost of transportation
- Cost of installation
- Cost of protection and maintenance

Schedule

- Shop drawings and approvals
- Materials acquisition
- Construction productivity

Factors in Selecting a Structural System

Function

- Clear span
- Program requirements and long-term flexibility
- Depth of members and clear height
- Location of bearing walls and other supports
- Incorporation of mechanical and electrical systems
- Thermal insulation

Code Requirements

- Fire protection
- Sound transmission
- Structural capacity
- Durability

Factors in Selecting a Structural System

Aesthetics

- Appearance of material
- Appearance of finished system
- Architectural blend of form and function

Environmental

- Environmental impact of harvesting, mining, quarrying, and manufacture
- Energy required to manufacture, transport, and install materials
- Thermal efficiency of building systems
- Disposal, recycle or reuse at end-of-life cycle

Framed Structural System

Framed System - 9x9m GRID

Economical
Deep structure
5-stories, perhaps 6-stories depending on floor-to-floor height requirements

Girders and Purlins
Target Occupancy Type: Office
Grid Spacing: 9m x 9m

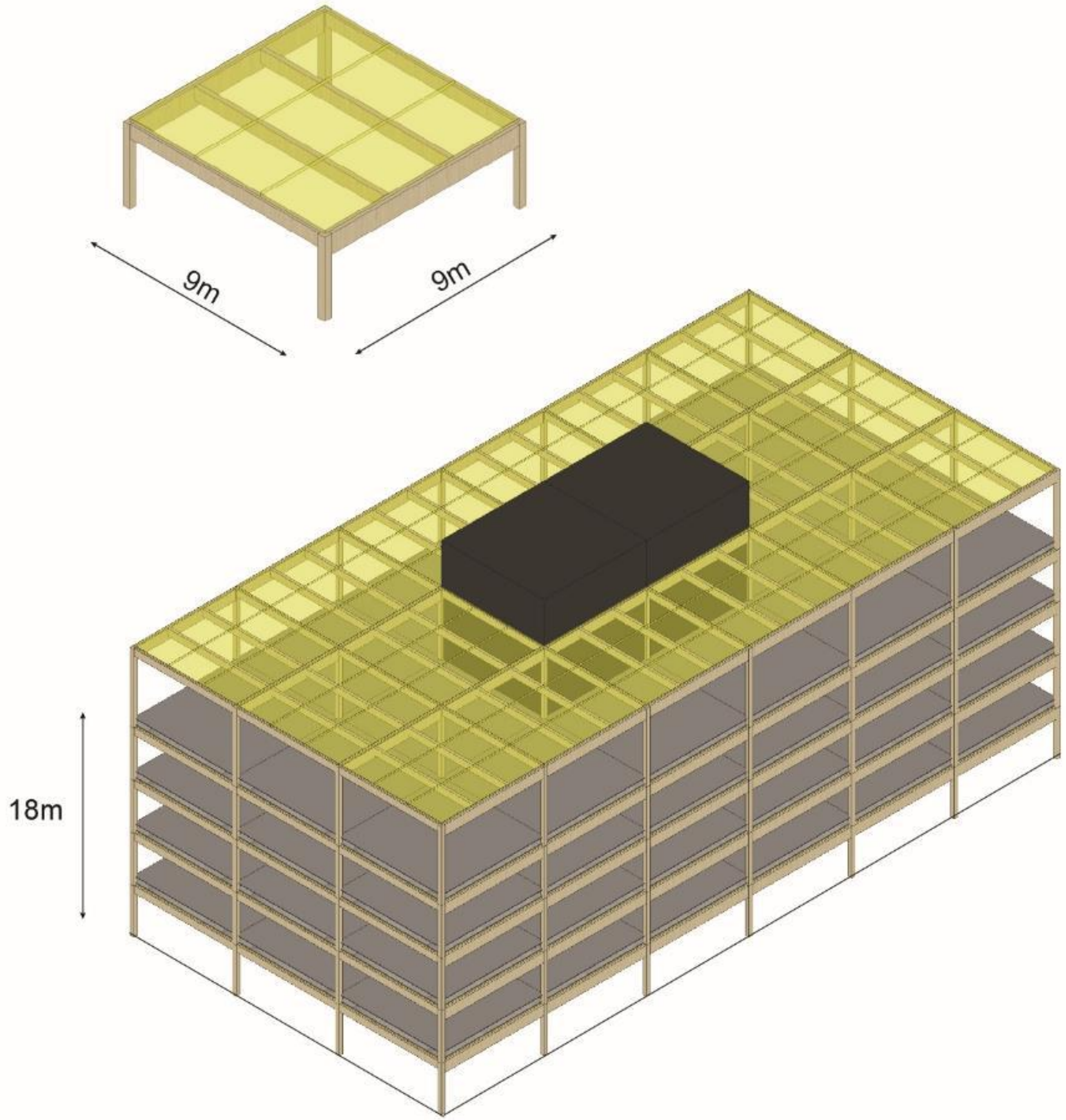
Column Size: 456 x 390 mm
Girder Size: 265 x 874 mm
Purlin Size: 215 x 570 mm

Deck:
Fire Rating = 60 minute min.
TYP. 3-ply CLT Encapsulated
TYP. 5-ply CLT Exposed

Total Structural Depth: 1013mm

Alternative Deck:
NLT / DLT / GLT

Mechanical Considerations
Underfloor air distribution
Radiant ceiling panels or chilled beams



Ontario Secondary School Teachers’ Federation

Moriyama & Teshima Architects, www.mtarch.com

Framed System - 6x9m Grid

Economical
Open span between girders for overhead system distribution (no purlins)
Deep structure

Long Beam, Short Deck
Target Occupancy Type: Office
Grid Spacing: 9m x 6m

Column Size: 418 x 365 mm
Girder Size: 265 1178 mm

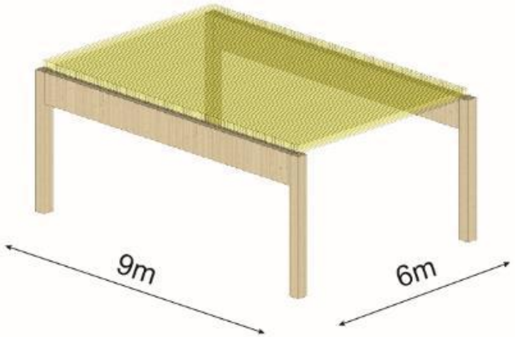
Deck:
Fire Rating = 60minute min.
235mm NLT / DLT with 5/8” plywood

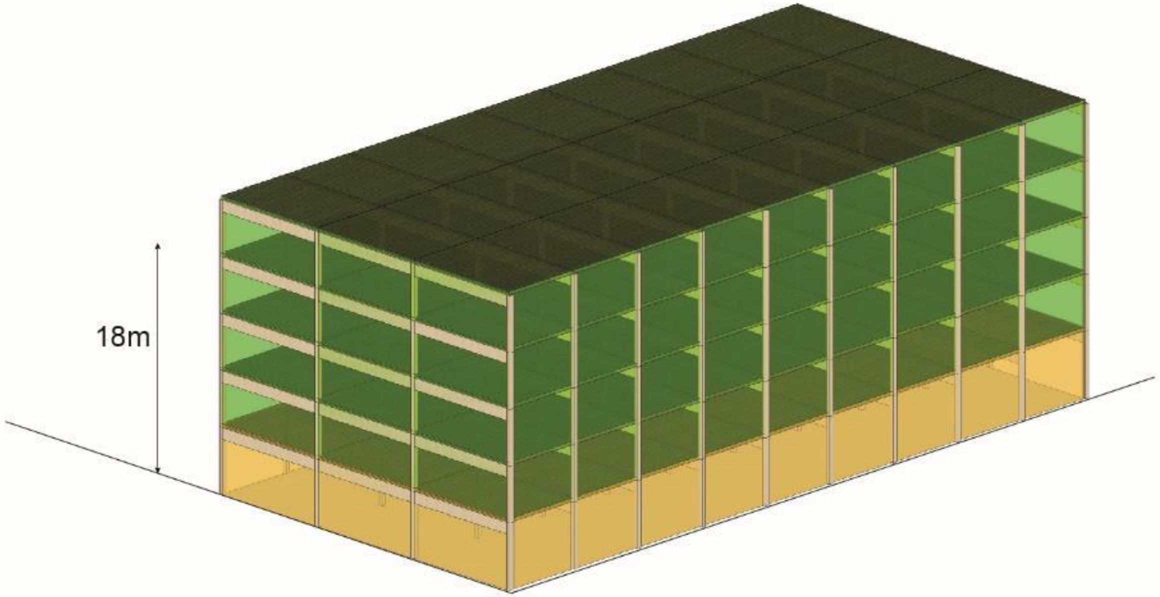
Total Structural Depth: 1413 mm

Alternative Deck:
9-ply CLT or GLT

Total Structural Depth:
1531 mm

Mechanical Considerations
Overhead system distribution, distribution between girders





80 Atlantic Avenue – Toronto Ontario

Quadrangle Architects
https://www.archpaper.com/2020/01/80-atlantic-toronto-timber-office-building/

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Framed System - 3x4m Grid

Economical
Shallow structure
Short bay

Short Span
Target Occupancy Type: Residential
Grid Spacing: 9 m x 9 m

Column Size: 266 x 265mm
Girder: 265 x 228 mm

Deck:
Fire Rating = 60 minute min.
5-plyCLT partially exposed

Total Structural Depth: 367 mm

Point Loaded CLT
Short Span
Occupancy Type: Residential

Grid Spacing: 4 m x 2.45 m

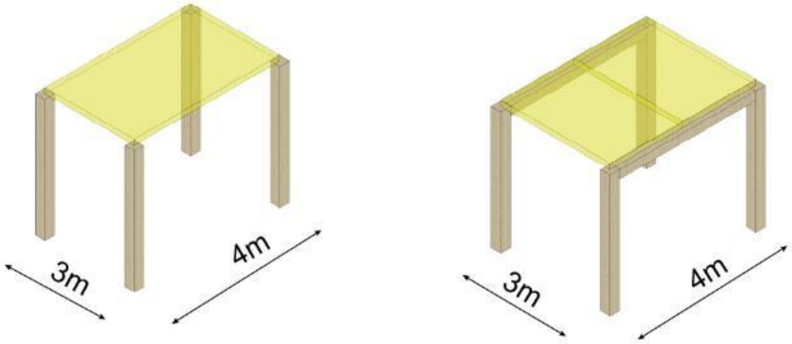
Deck:
Fire Rating = 60 minute min.
5-plyCLT partially exposed *

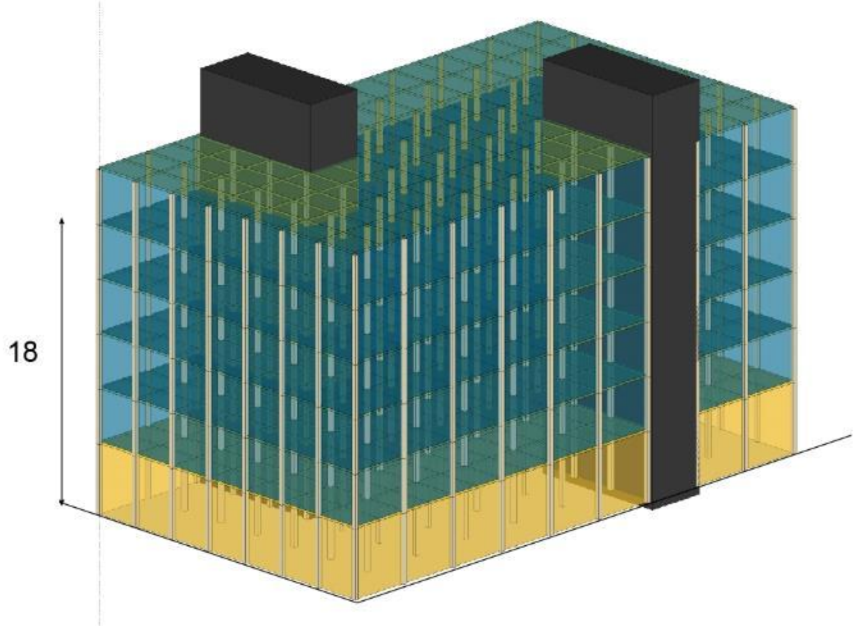
* Encapsulation may be required dependent on fire loads

Alternative Deck:
89 mm NLT / DLT or GLT

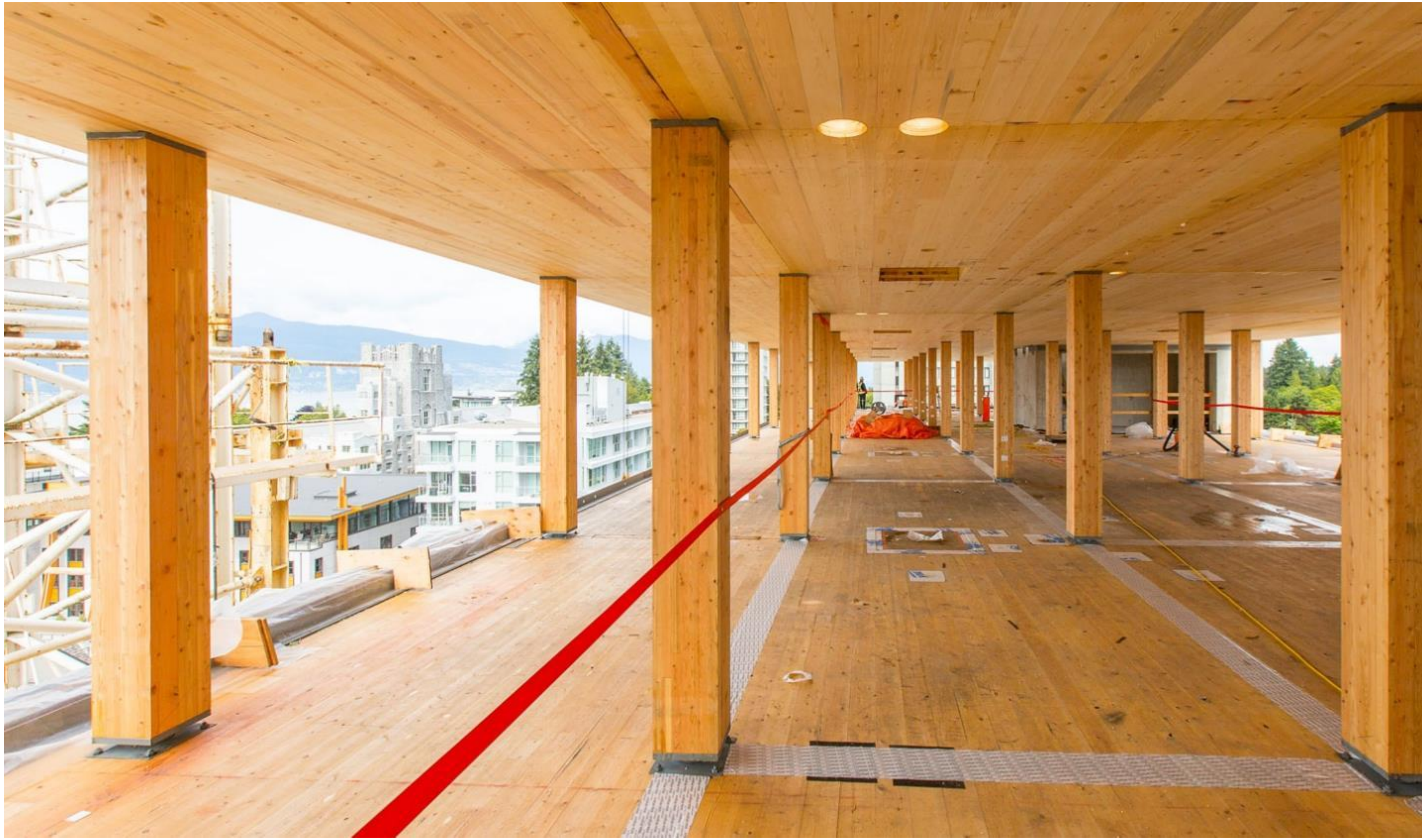
Total Structural Depth:
317 mm

Mechanical Considerations
Unit mechanical
Overhead distribution
Partial dropped ceiling or reduced head





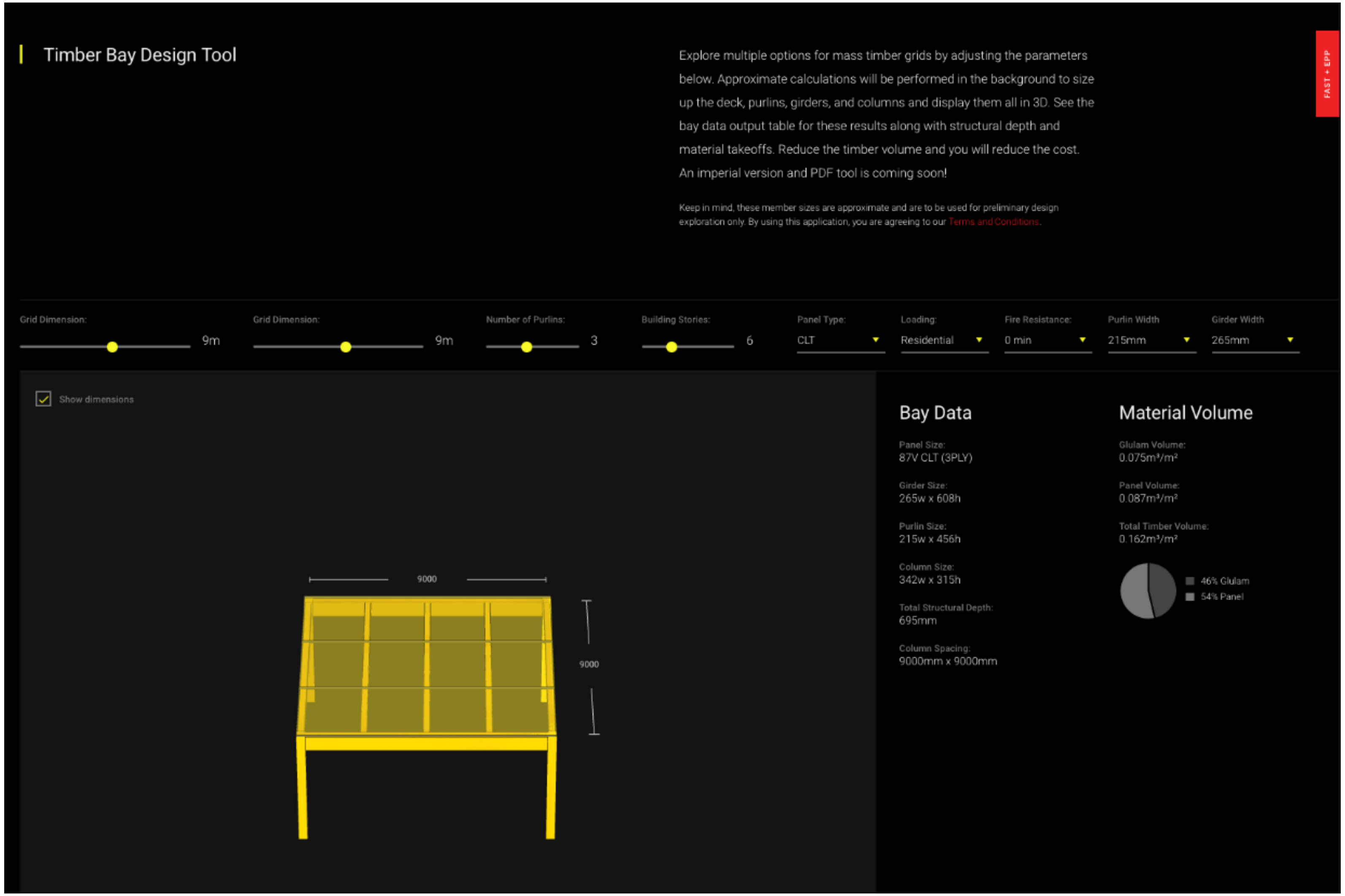
Brock Commons Tall Wood House



Acton Ostry Architects

Timber Bay Design Tool – Fast + Epp Concept Lab

https://www.fastepp.com/concept-lab/timber-bay-design-tool/



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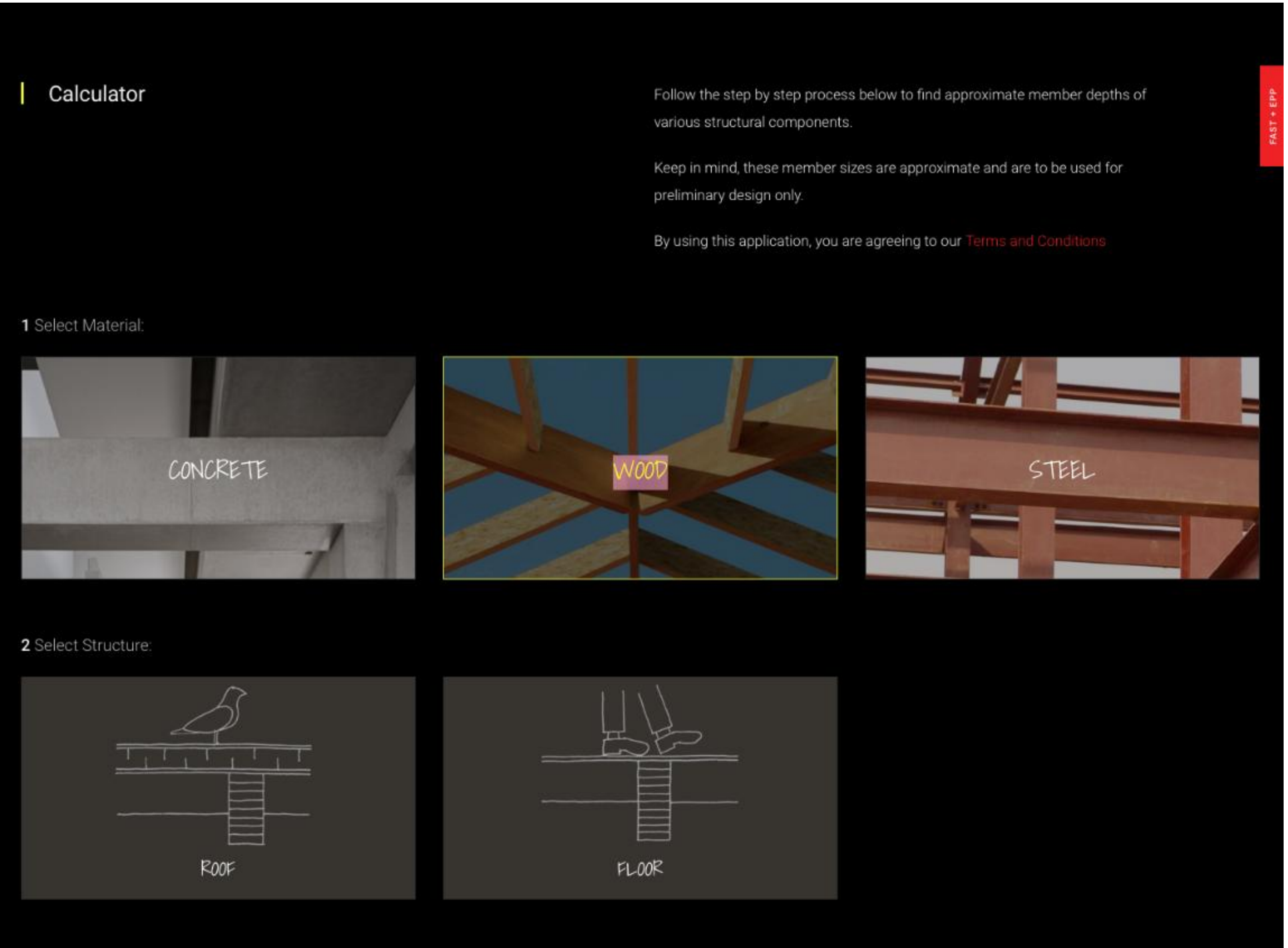
Member Calculator Tool – Fast + Epp Concept Lab

https://www.fastepp.com/concept-lab/calculator/



Activity – Factors in Selecting a Structural System

1. *Name the six factors described in selecting a structural system.*
2. *Utilizing the Fast + Epp Concept Lab Timber Bay sizing tool, calculated the size of the structural members of the following structural grid spans.*

   a) *8x6m Office Building, 6 stories with a 60 min fire resistance rating.*

   Describe the advantages and challenges in design choices available for the scenario.

Hybrid System

Hybrid System - Concrete and Wood Composite Slab
9x7m Grid

Shallow Structure
Flat slab, shallow structure
Cost Premium
6 stories possible

Flat Slab
Target Occupancy Type: Office

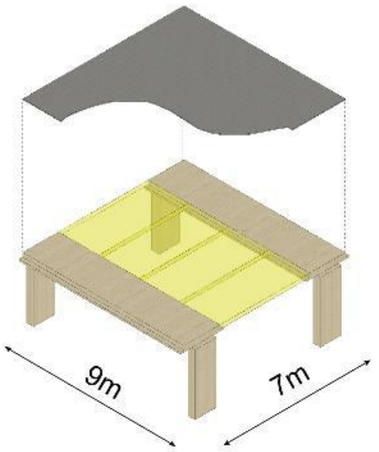
Grid Spacing: 7m x 9m

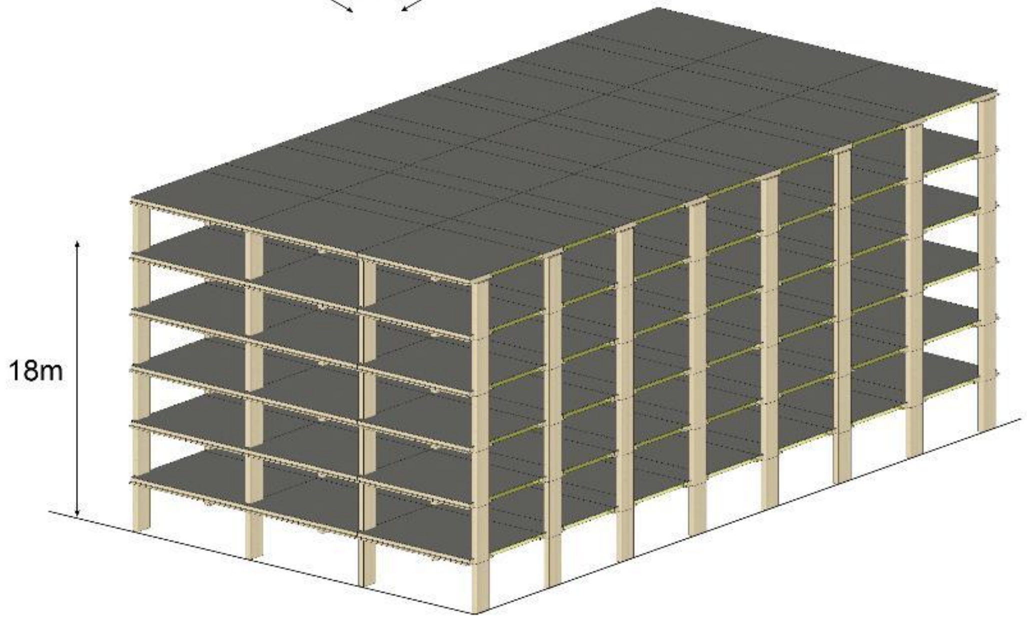
Column Size: 400 x 1200 mm
Flat Slab Beam: 9-ply CLT

Composite slab:
5-ply CLT
50mm concrete

Total Structural Depth: 365 mm

Mechanical Considerations
Underfloor air distribution or
overhead system distribution





The Arbour at George Brown College

Moriyama & Teshima Architects and Acton Ostry Architects

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Hybrid System - Steel Delta Beam with Wood and Concrete Composite Slab

Shallow Structure
Flat slab to minimize floor-to-floor heights
Cost Premium,
Delta Beam Propriety

Flat Slab
Target Occupancy Type: Office
Grid Spacing: 8m x 8m

Column Size: 400 x 1200 mm
Flat Slab Beam: 9-ply CLT

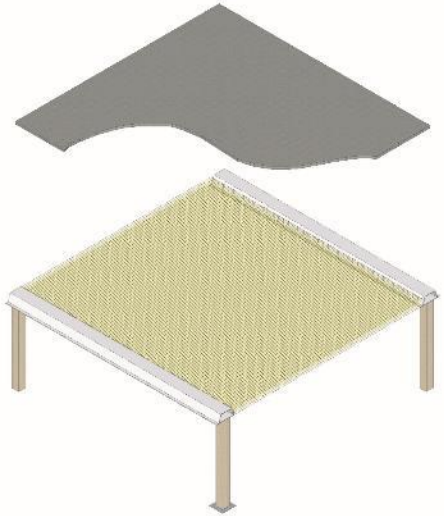
Composite slab:
150mm concrete on 175mm CLT

Alternative:
315mm CLT

Alternative Deck:
9-ply CLT

Total Structural Depth:
1531 mm

Mechanical Considerations
Underfloor air distribution or overhead system distribution



77 Wade Avenue, Toronto Ontario

BNKC Architects

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80 M Street, Washington D.C.

Figure 44: 80 M Street in Washington D.C. is a vertical expansion of an existing building. Source: Think Wood.

Panelized System

Cross Laminated Timber Panelized System

Vertical and horizonal loads
Cross Laminated Timber Panels
Load Bearing
Modular, potential cost savings
Compartmentalized planning

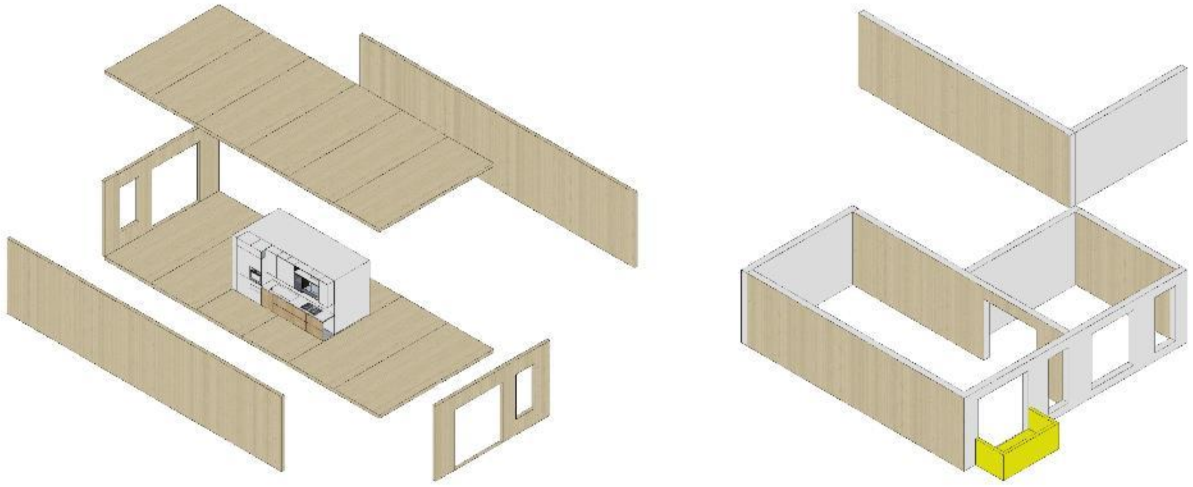
Cross Laminated Timber
Target Occupancy Type: Residential
Grid Spacing: 6m x 12m

Panel Width – 3.0m / 2.4m / 1.6m
Max Panel Length – 12m – 19.5*
Max panel Thickness: 89mm – 267 mm

Panel Tolerance –
+/- 3mm width
+/- 6mm panel length*

* CLT panel dimensions vary between

Mechanical Considerations
Coordination through panels



The Cube – Hamburg, Germany

The Cube in Hamburg, Germany, is constructed using CLT panels for floor and wall structure.

Photo credit IBA Hamburg, Martin Kunze.

Case Study:
R-Hauz R-Town, Toronto Ontario

Panelized Cross-Laminated Timber (CLT)

Concept rendering of the front elevation along Queen Street East in Toronto, Ontario. Image Source: www.r-hauz.ca.

Case Study
R-Hauz, R-Town

Developer: R-Hauz

Architect: CMV Architects

Structural Engineer: Moses Engineering

Cross-Laminated Timber Panels

Case Study: R-Hauz, R-Town

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Case Study:
YWCA Supportive Housing
Kitchener-Waterloo, Ontario

Panelized Cross-Laminated Timber (CLT)

Case Study: YWCA Supportive Housing

Concept rendering of the proposed exterior of the YWCA Supportive Housing. Image Source: Edge Architects and Element5.

Architect: Edge Architects

Owners: YWKW

Developer: Melloul Blamey Construction

Mass Timber Fabricator: Element5

Cross-Laminated Timber Panels

Case Study: YWCA Supportive Housing

Concept rendering of the interior of the ground floor amenity space. The structural grid in this location shifts from a panelized system to a post and panel system. Image Source: Edge Architects and Element5.

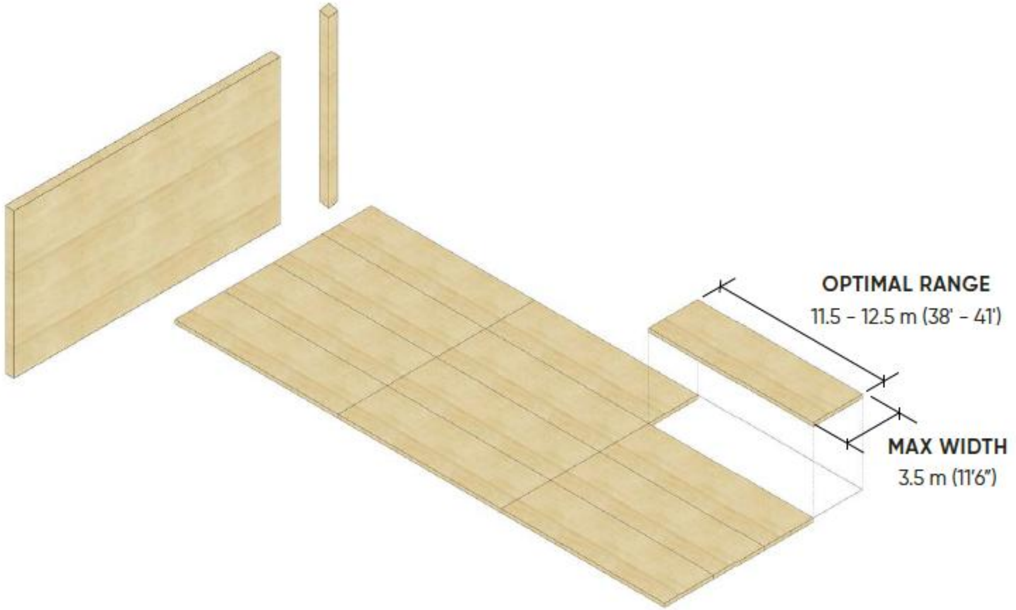
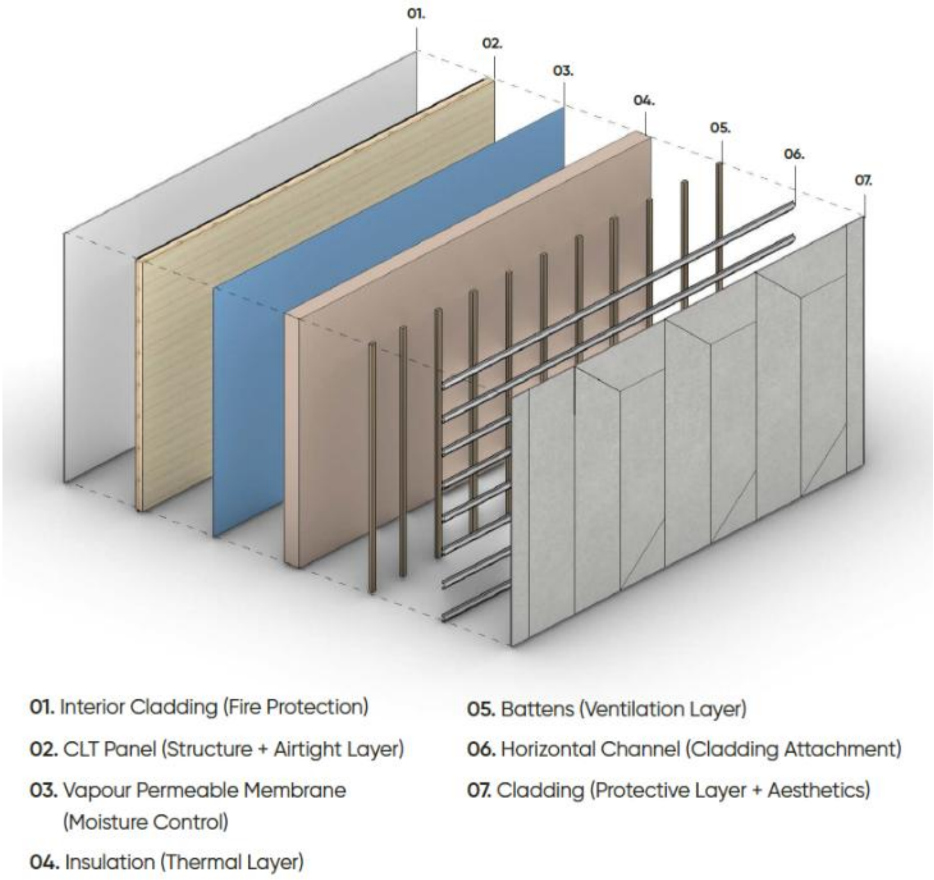
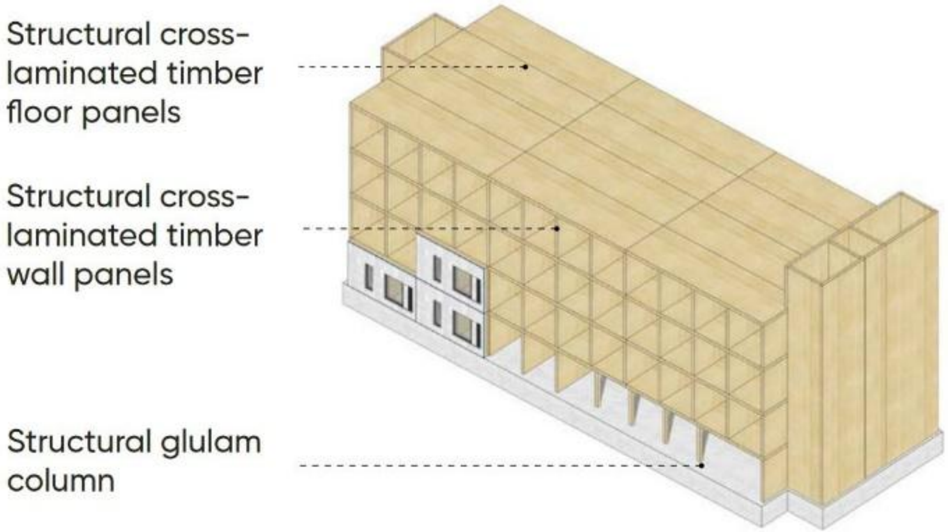


Diagram of cross-laminated timber panel distribution. Image source: Edge Architects and Element5.

Case Study: YWCA Supportive Housing





Left: Diagram of Element5's CLIP system. Right: Building Diagram illustrating the prefabricated mass timber structural system and exterior envelop components. Image Source: Edge Architects and Element5.

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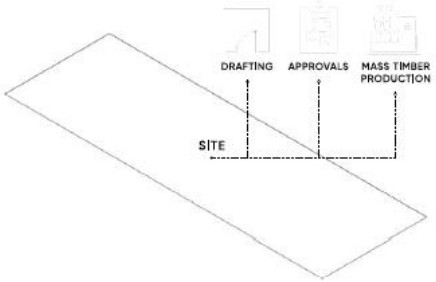
Case Study: YWCA Supportive Housing

01

Planning and Approvals

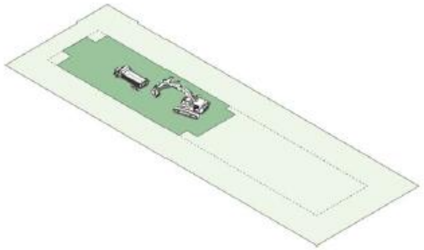
Architectural plans are adapted to the chosen site and submitted for any municipal approvals and permits. Element5 develops shop drawings and begins manufacturing the structural components in their factory.



02

Site Work Begins

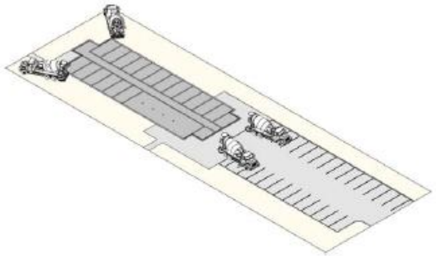
Once plans are approved, site work and grading can commence. Meanwhile, production continues on the structural components off-site at the Element5 factory.



03

Foundation

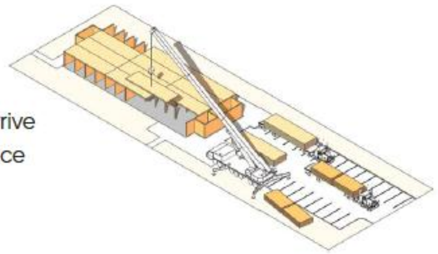
Foundations are poured on-site.



04

Super Structure

Modular wall, floor, and roof panels arrive on-site. They are then craned into place to create the super structure.



05

Envelope Panels

Modular, prefabricated exterior wall panels arrive on-site. They are then craned into place to quickly enclose the building.

06

Completion

Once the envelope has been installed, the interior can be completed. Final landscaping and other site work is completed simultaneously.

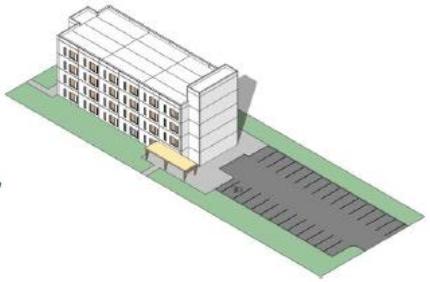


Diagram and description of the process and sequencing of construction.
Image Source: Edge Architects and Element5.

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Designing for Fire Protection

Fire Protection – Key Considerations

Low-rise, Mid-rise, High-rise Code Requirements

Passive Fire Protection Strategies

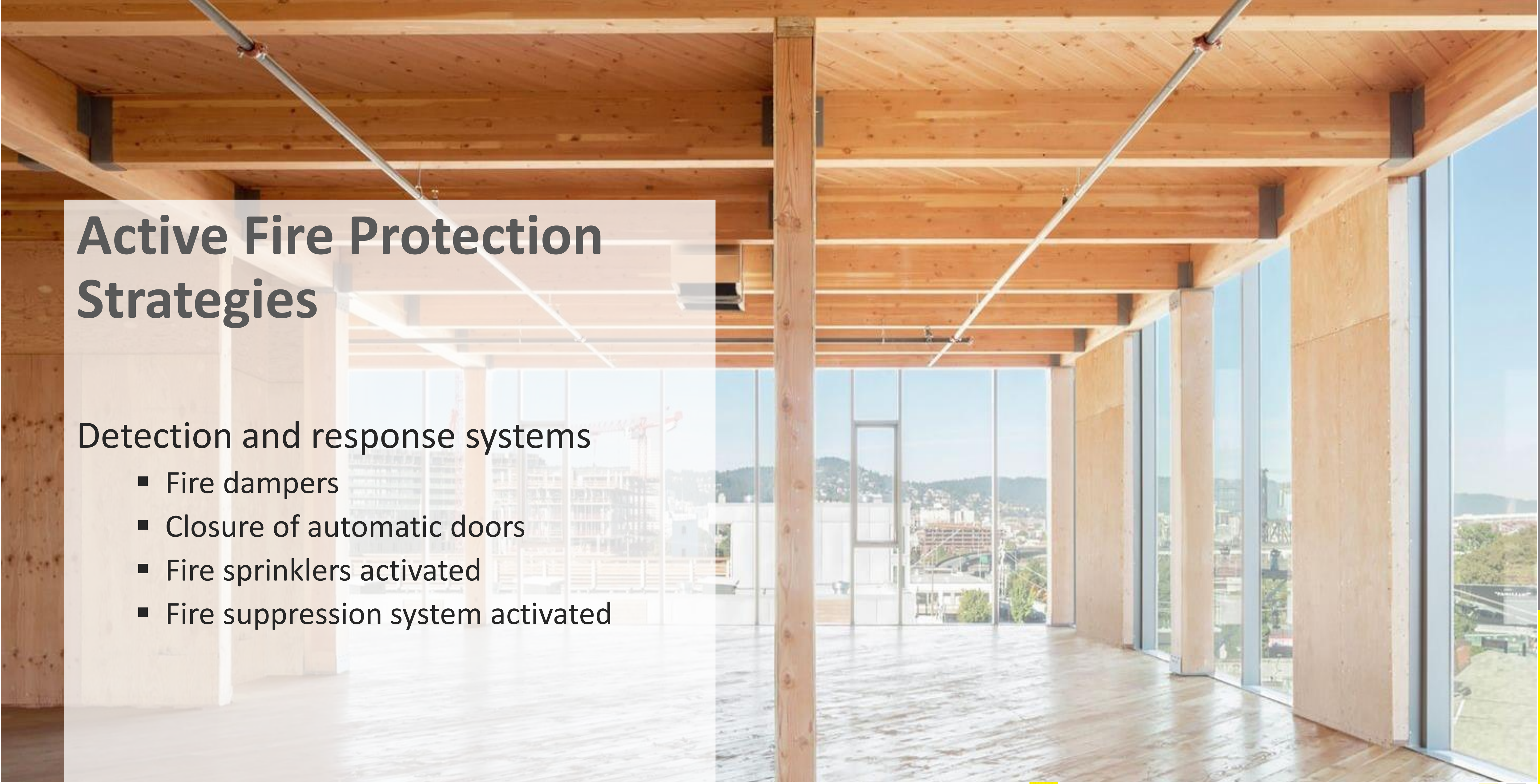
Active Fire Protection Strategies

Fire Protection During Construction

Passive Fire Protection Strategies

- Fire resistant rating of structure in floors
- Level of encapsulated material or char consideration
- Fire rating of egress routes
- Fire separation requirements

Components and systems are intended to contain fire or slow the spread of fires through the use of fire-resistant building elements



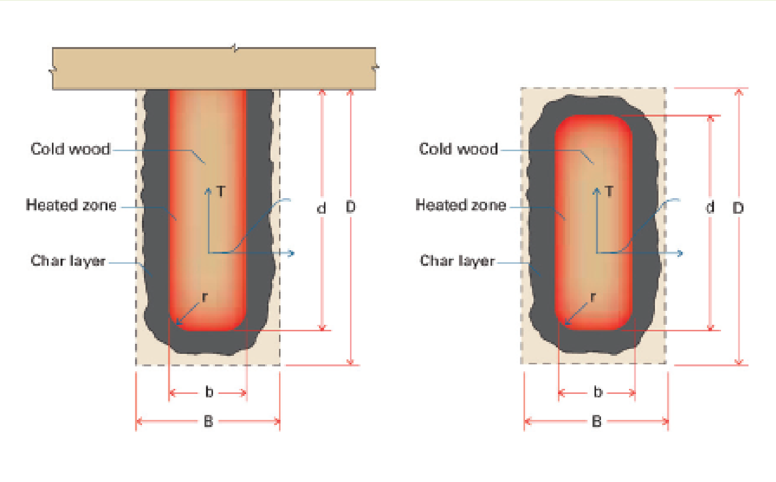
Active Fire Protection Strategies

Detection and response systems

- Fire dampers
- Closure of automatic doors
- Fire sprinklers activated
- Fire suppression system activated

Fire Protection – Char Theory

FIGURE 2:
Reduction in Member Width and Depth over Time



Source: TR 10, AWC

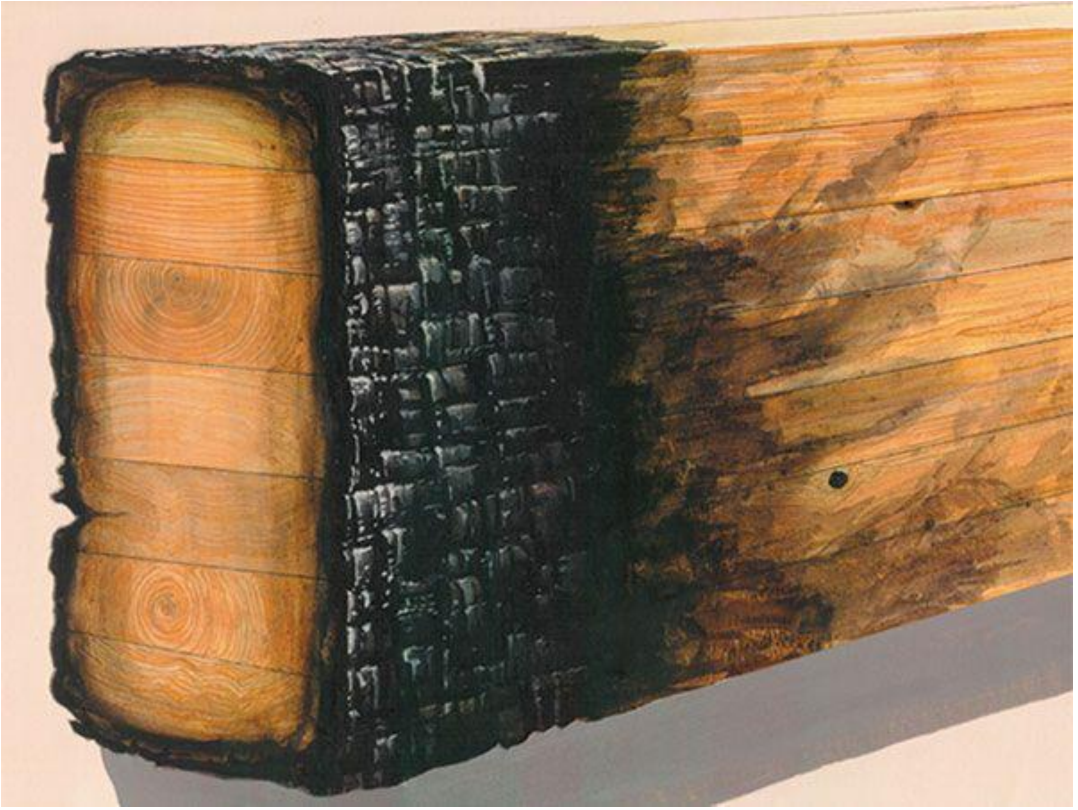
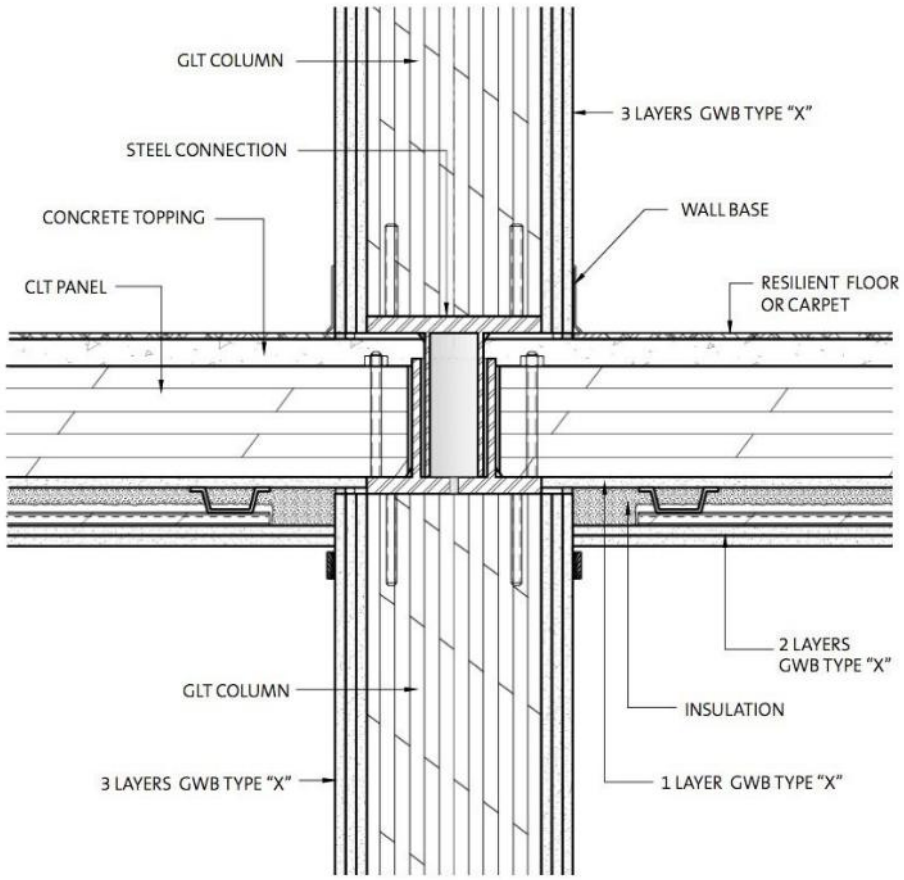


TABLE 6:
Effective Char Rates and Char Depths
(for β_n = 1.5 inches/hour)

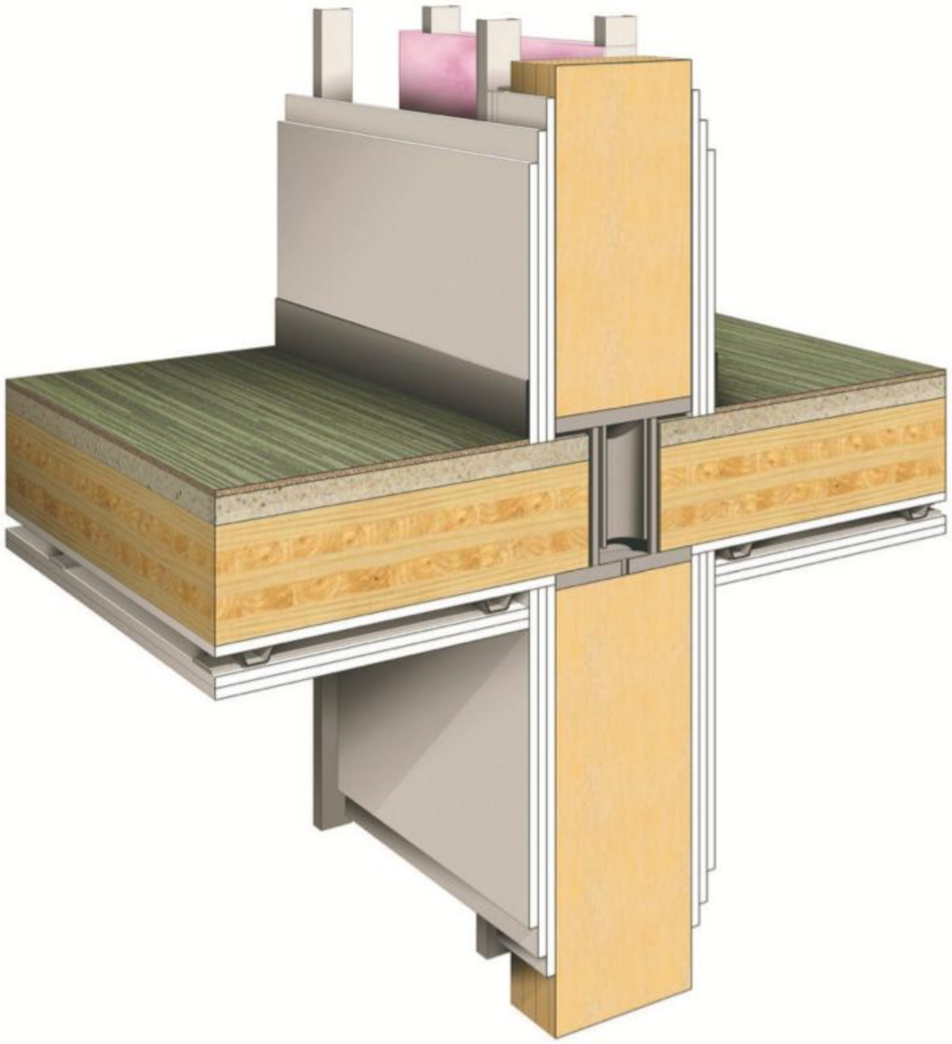
Required Fire Endurance (hours)	Char Depth, a_{char} (inches)	Effective Char Depth a_{eff} (inches)
1	1.5	1.8
1-1/2	2.1	2.5
2	2.6	3.2

Source: NDS Table 16.2.1A, AWC

Fire Protection – Encapsulation



Detail of typical column and floor intersection and encapsulation, by Fast + Epp.



Source: Denis Blount, ARUP – *"Knock on Wood: Acoustical Design in Mass Timber Structures".*

Fire Protection Case Study – Brock Commons Tall House
Fire Safety During Construction

High-Rise

- Less than four levels of unprotected wood during construction.
- Protection of wood structural elements by installing a layer of Type X gypsum board and concrete topping as structure is built.
- Functional standpipe in concrete cores.
- On-site security and fire watch

Image: Source: Think Wood, https://www.thinkwood.com/projects/brock-commons-tallwood-house

Image: Source: Think Wood, https://www.thinkwood.com/projects/brock-commons-tallwood-house

Carbon 12 – Portland Oregon

Image Source:
https://www.kaiserpath.com/carbon12
Images: Andrew Pogue, Marcus Kauffman

Fully Exposed Mass Timber

Maximum height: 9 stories; 85 feet

Maximum area: 405,000 SF total building; 45,000 SF average per floor

Fire-rating requirements: 2-hour primary frame; 2-hour floors

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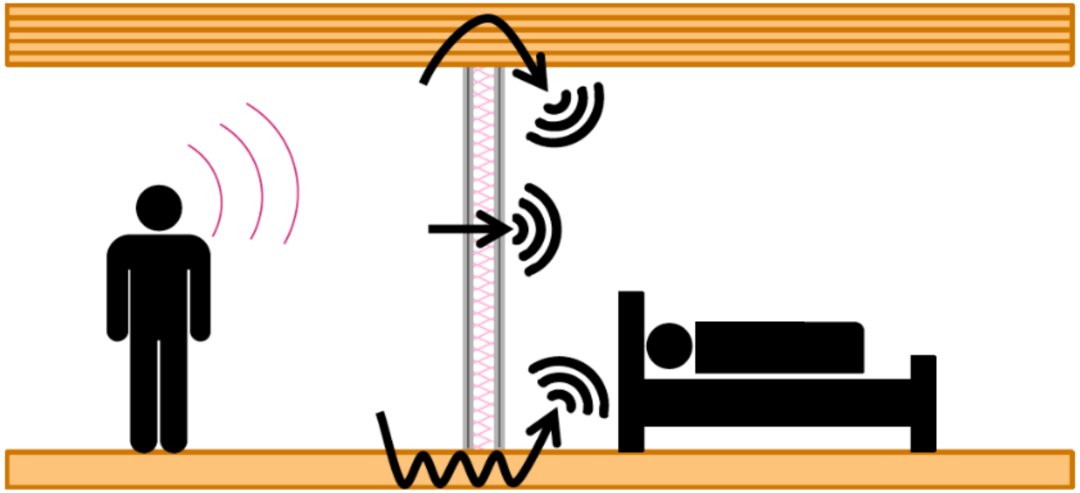
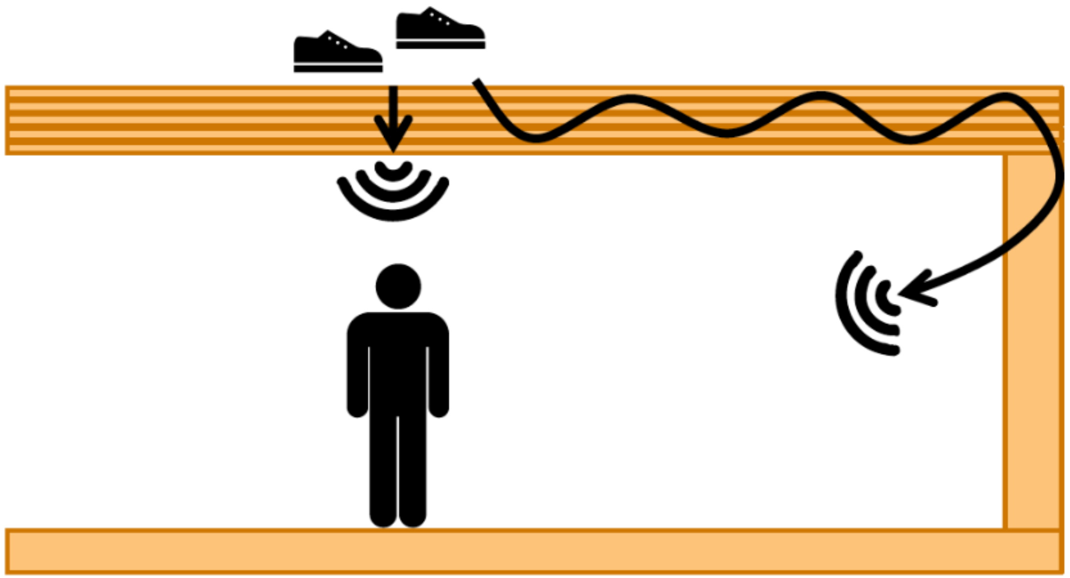
Designing for Acoustics and Vibration

Acoustics – STC vs IIC





Sound Transmission Class (STC) – Airborne

- “Through” partitions
- Around partitions (flanking)
- Through structural coupling

Impact Sound Isolation (IIC) – Impact

- Through floor assemblies
- Through structural coupling

Source: Denis Blount, ARUP – *“Knock on Wood: Acoustical Design in Mass Timber Structures”.*

Improving Acoustics

Add Mass

Mass provides weight to mitigate transfer of low frequency sounds. For example, impact noise.

Add Noise Barriers

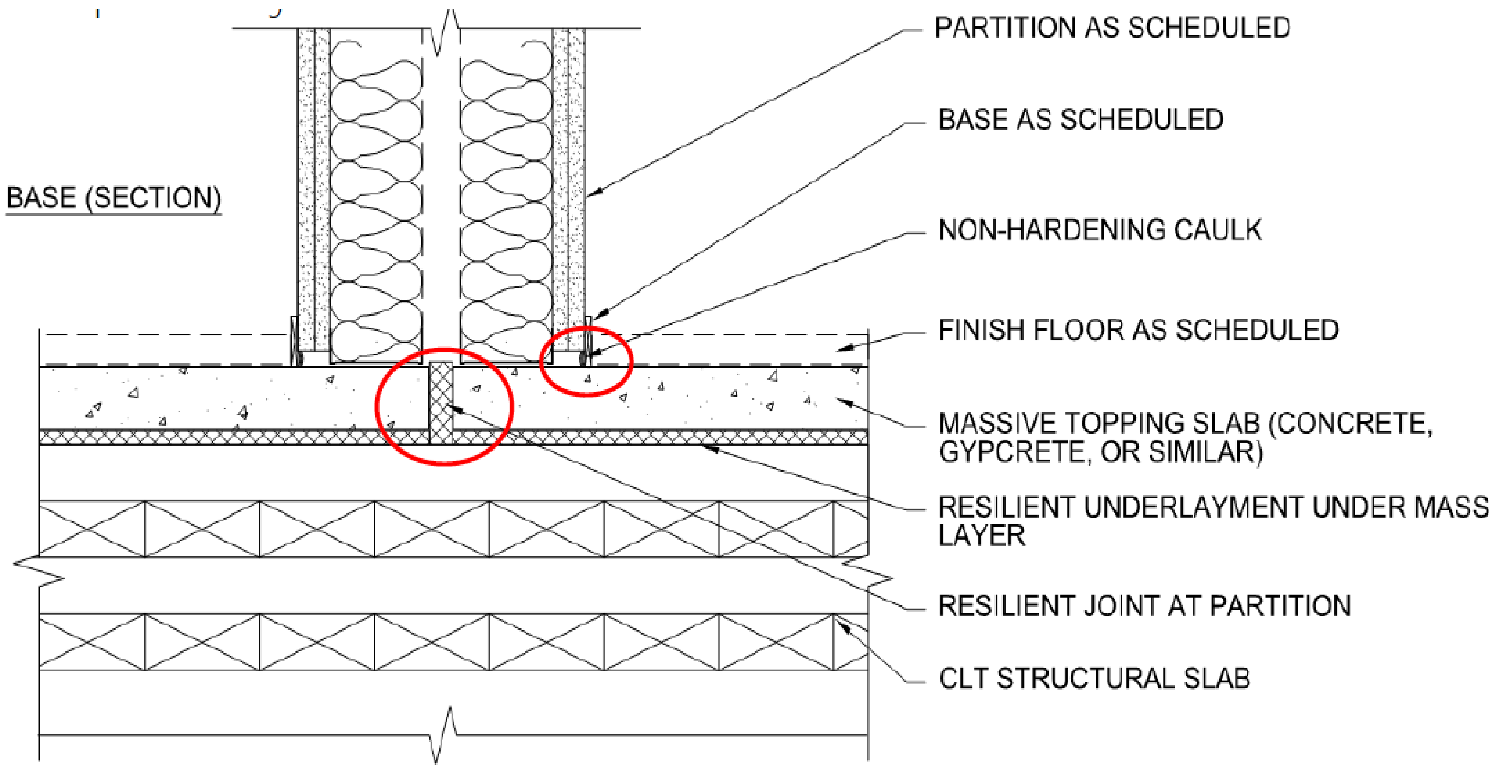
Add insulation and other acoustic absorptive material

Add Decouplers

Resilient layers to “separate” materials provides decoupling to reduce the transfer of vibration.

Acoustics – Flanking Control

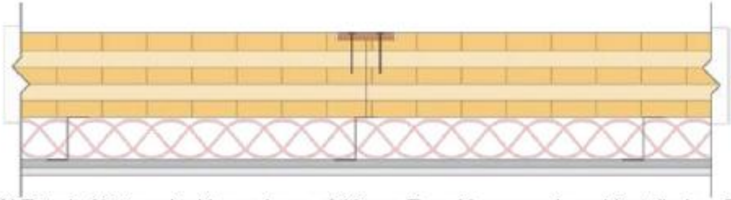
- Decoupling of floor topping at CLT
- Decoupling walls from space below
- Acoustic sealant at partition joints

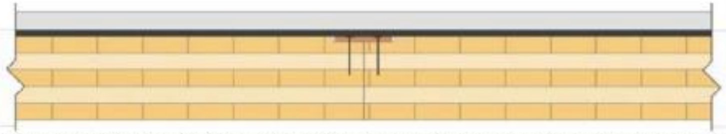


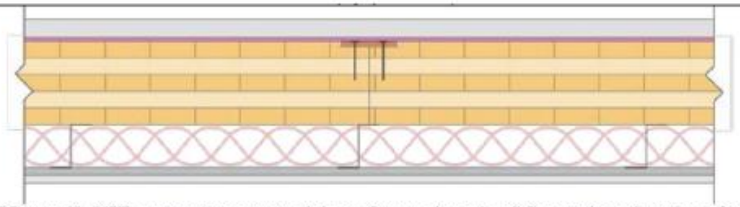
Source: Denis Blount, ARUP – *"Knock on Wood: Acoustical Design in Mass Timber Structures".*

Acoustic Treatments on CLT Floor Assembly

Sketch and Short Description	STC Rating	IIC Rating
 Bare CLT 5 ply (175 mm)	42	26

Sketch and Short Description	STC Rating	IIC Rating
 CLT 5 ply (175 mm) with one layer of 16 mm Type X gypsum board installed on Z channels	62	48

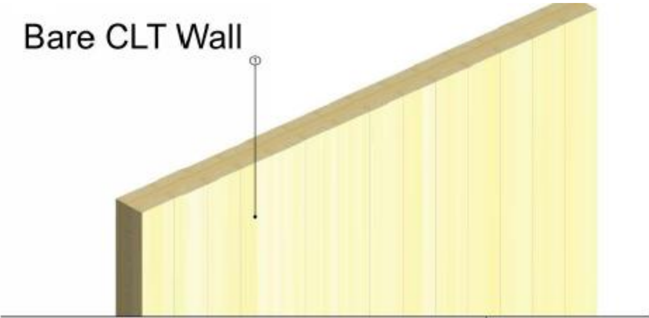
Sketch and Short Description	STC Rating	IIC Rating
 38 mm (1-1/2") precast concrete slab on 13 mm (1/2") rubber membrane placed on top of a CLT 5 ply (175 mm).	56	48

Sketch and Short Description	STC Rating	IIC Rating
 38 mm (1-1/2") precast concrete slab on 9 mm closed cell foam placed on top of a CLT 5 ply (175 mm) with one layer of 16 mm Type X gypsum board installed on Z channels.	70	56

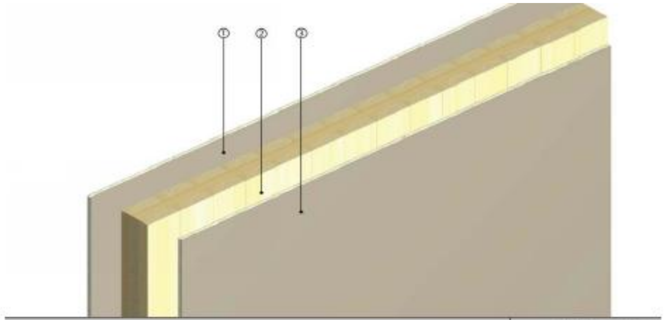
Reference: Canadian CLT Handbook – 19th Edition, FP Innovations

Source: Denis Blount, ARUP – *"Knock on Wood: Acoustical Design in Mass Timber Structures".*

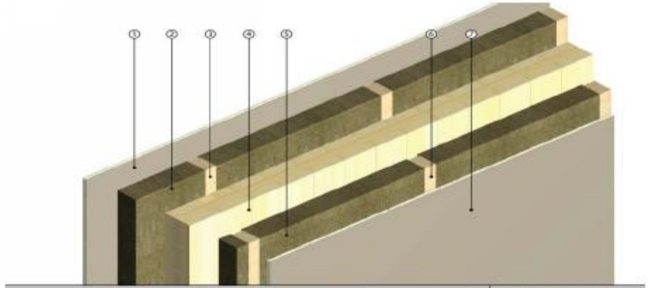
Acoustic Treatments on CLT Wall Assembly



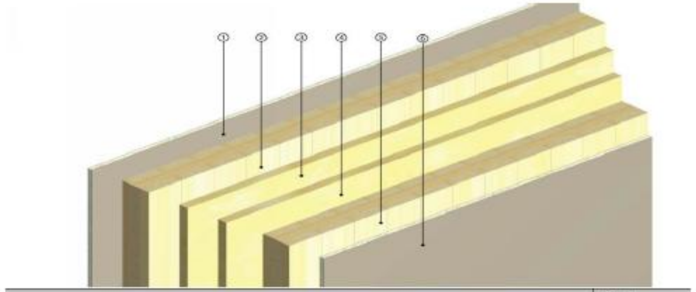
	Wall Composition	Airborne (STC) dB
1	3-layer CLT panel (95 mm ~ 115 mm)	≤ 32~34



	Wall Composition	Airborne (STC) dB
1	Gypsum board 15 mm	≤ 36~38
2	3-layer CLT panel (95 mm ~ 115 mm)	
3	Gypsum board 15 mm	



	Wall Composition	Airborne (STC) dB
1	Gypsum board 15 mm	≤ 58
2	Mineral wool (~ 60 mm)	
3	Lumber studs (38 mm x 63 mm)	
4	3-layer CLT panel (95 mm ~ 115 mm)	
5	Mineral wool (~ 60 mm)	
6	Lumber studs (38 mm x 63 mm)	
7	Gypsum board 15 mm	



	Wall Composition	Airborne (STC) dB
1	Gypsum board 15 mm	≤ 60
2	3-layer CLT panel (95 mm ~ 115 mm)	
3	Sound insulation material (rock wool) (~ 30 mm)	
4	Sound insulation material (rock wool) (~ 30 mm)	
5	3-layer CLT panel (95 mm ~ 115 mm)	
6	Gypsum board 15 mm	

Reference: Canadian CLT Handbook – 19th Edition, FP Innovations

Source: Denis Blount, ARUP – *"Knock on Wood: Acoustical Design in Mass Timber Structures"*.

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Other Design Considerations

- Full scale mockups
- Fire proofing of connectors
- Vibration and Acoustics
- Approval Process and AHJ
- Insurance Requirements
- Temporary fire protection during construction
- Onsite Security and Protection
- Supply Chain

CLT floor slab is lowered into place and fastened to the glulam columns. Photo: KK Law, Courtesy of Naturally: Wood.

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Activity – Understanding Fire Protection and Acoustics

1. *Name the various passive and active strategies involved in designing for fire protection of mass timber buildings.*

2. *What are the two main acoustic concerns when it comes to mass timber buildings?*

3. *What are the three main ways to improve acoustical performance and what are some of the key considerations of each?*

Retrofits and Adding Storeys to Existing Buildings

Adding Stories to Existing Buildings and Mass Timber

Illustration representing design opportunities with adding storeys to an existing building. Concept rendering by Studio Veronica Madonna Architect.

Consideration of Mass Timber and Adding Stories

South Boston Rivet Factory

Adding storeys to South Boston Rivet Factory, by Margulies Perruzzi Architects.

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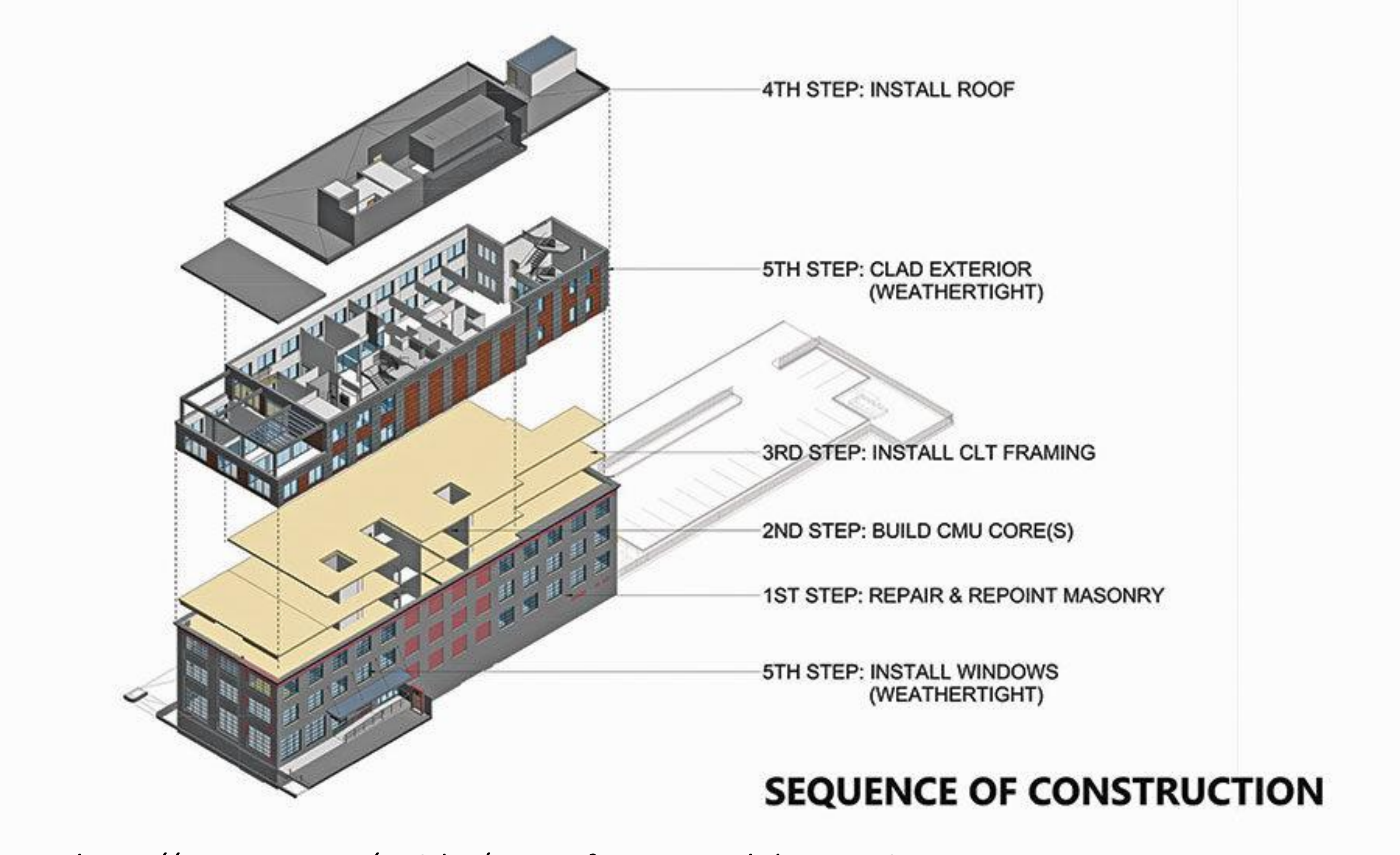
South Boston Rivet Factory



Source: https://www.enr.com/articles/51022-former-south-boston-rivet-factory-gets-heavy-timber-upgrade

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Resources

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Module 3: Early Construction Consideration

Objectives:

Understand the key early construction consideration involved with prefabrication and mass timber design.

- Building Information Modelling (BIM) and Design for Manufacturing and Assembly (DfMA)
- System Integration
- Envelop and Moisture Consideratioins
- XXXX

Assignment: Embodied Carbon Comparison

Automation and Industrialization of Mass Timber

Image of an automated fabrication process of mass timber, Katerra.

Source: www.kateria.com.

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Benefits of Prefabrication

Less noise, dust and site disruption

Improved health and safety

Continuity of employment

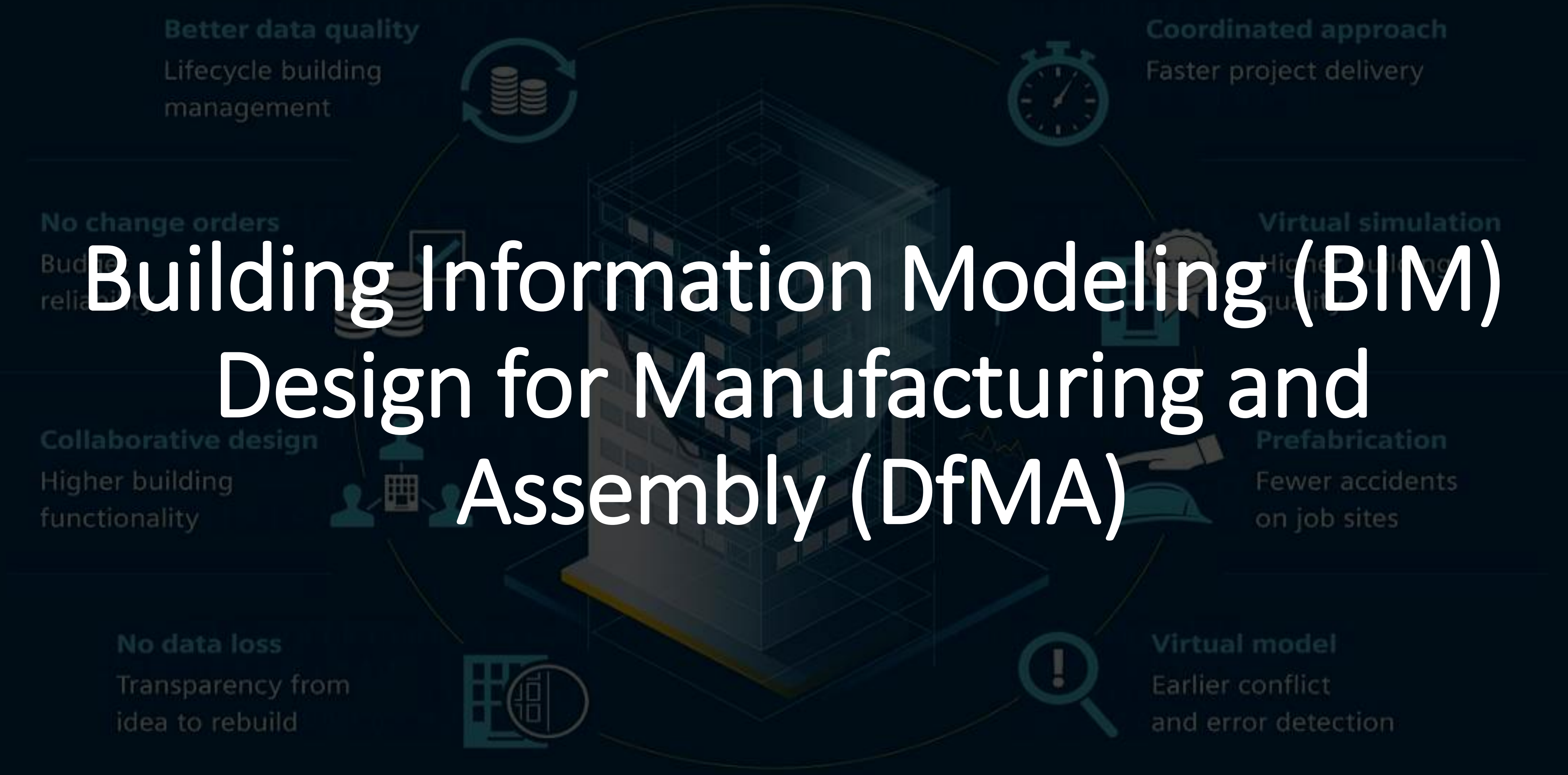
Workforce upskilling

Predictable product performance

Lower product operational costs

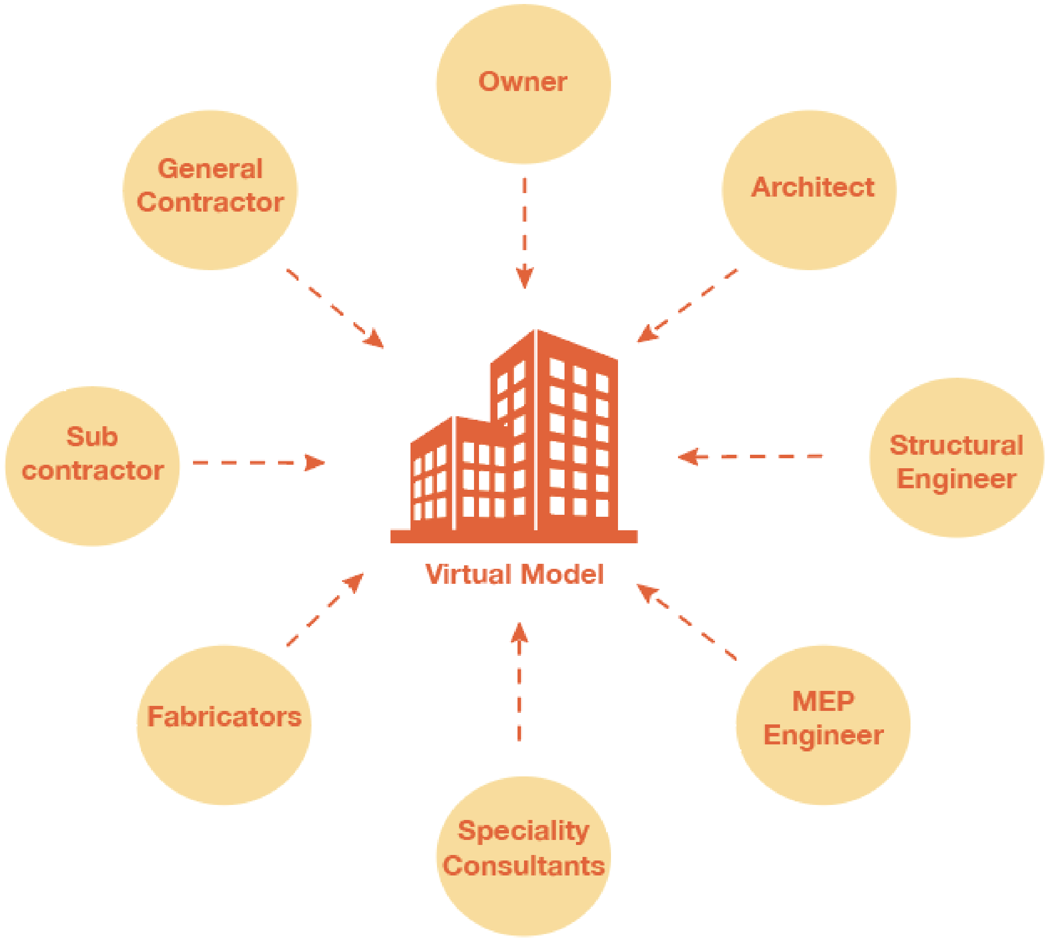
Image of Element5's new factory in Ontario. Source: Element5

Building Information Modeling (BIM) Design for Manufacturing and Assembly (DfMA)




Better data quality
Lifecycle building management
Coordinated approach
Faster project delivery
No change orders
Budget reliability
Virtual simulation
Higher building quality
Collaborative design
Higher building functionality
Prefabrication
Fewer accidents on job sites
No data loss
Transparency from idea to rebuild
Virtual model
Earlier conflict and error detection

Importance of BIM and DfMA Integration

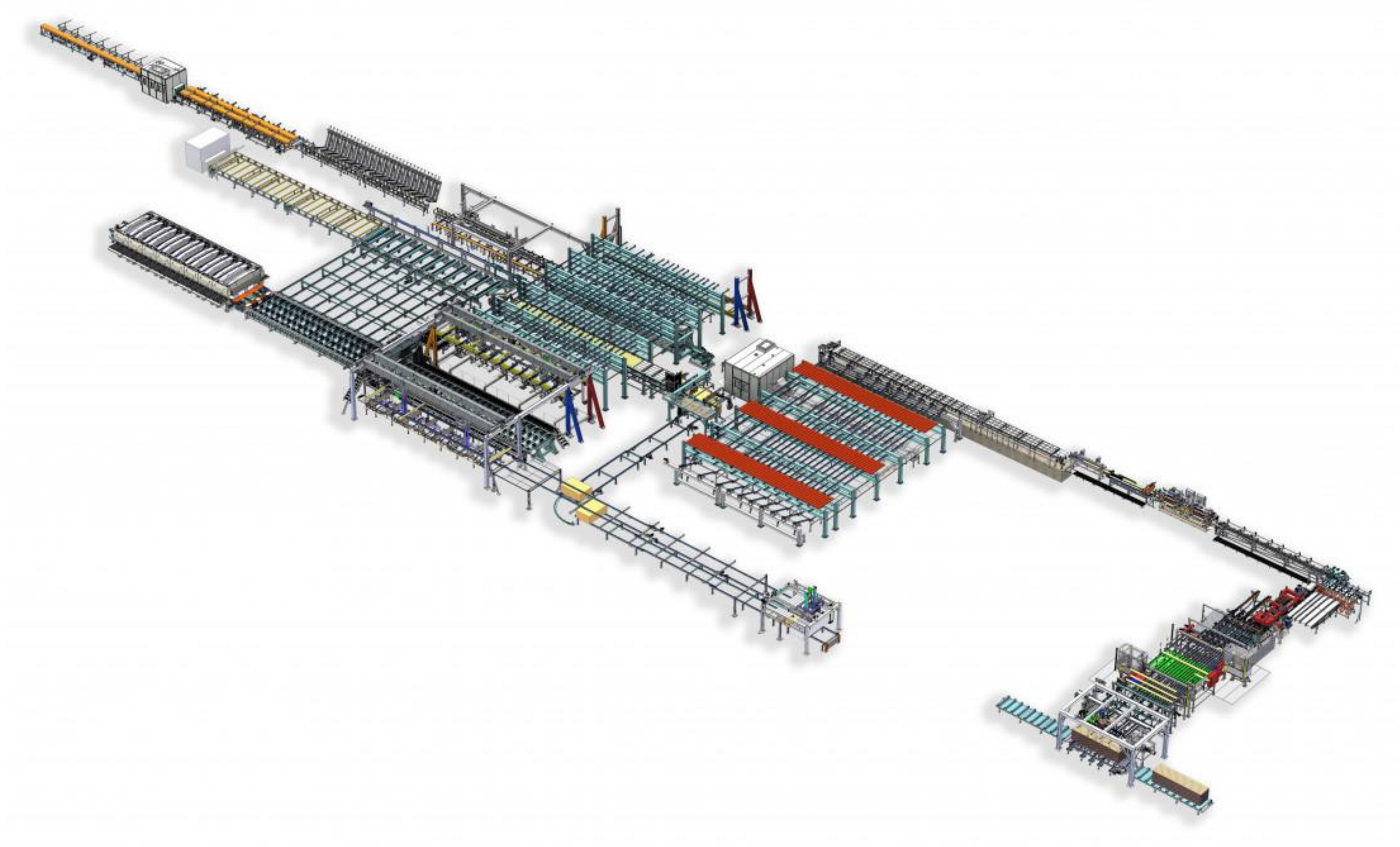


Integration of BIM amongst the owner, design and construction team.

Virtual Design and Construction Modelling

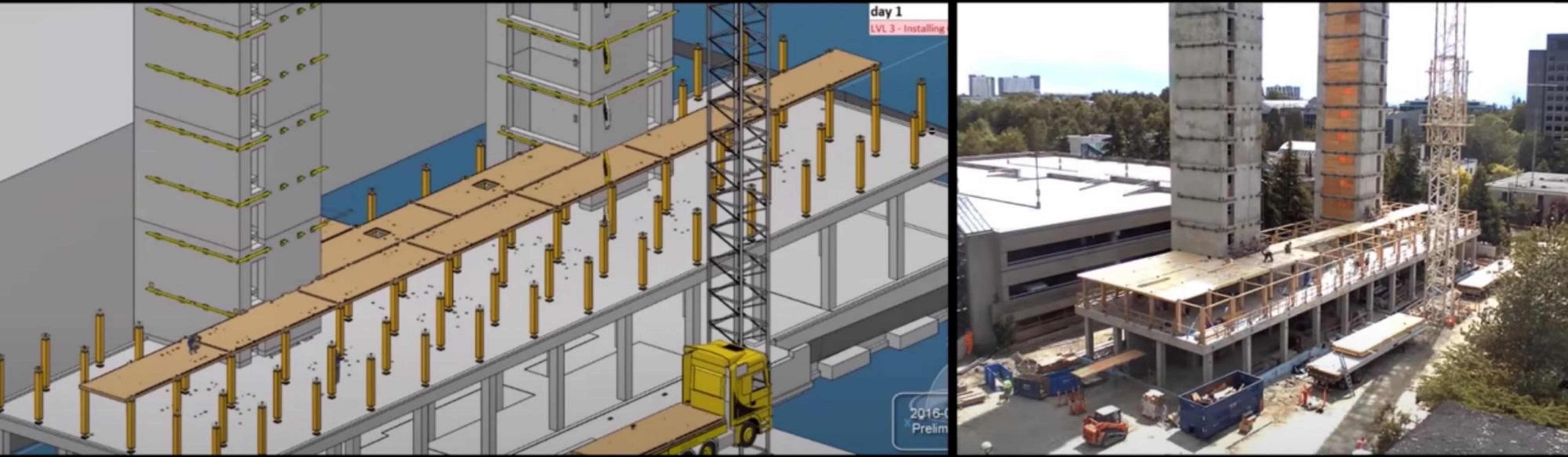
Brock Commons Tallwood House utilized various levels of Virtual Design and Construction Modelling throughout the design and construction process. Source: Wood-Works, Brock Commons Tallwood House: Construction Modelling.

Mass Timber Factory



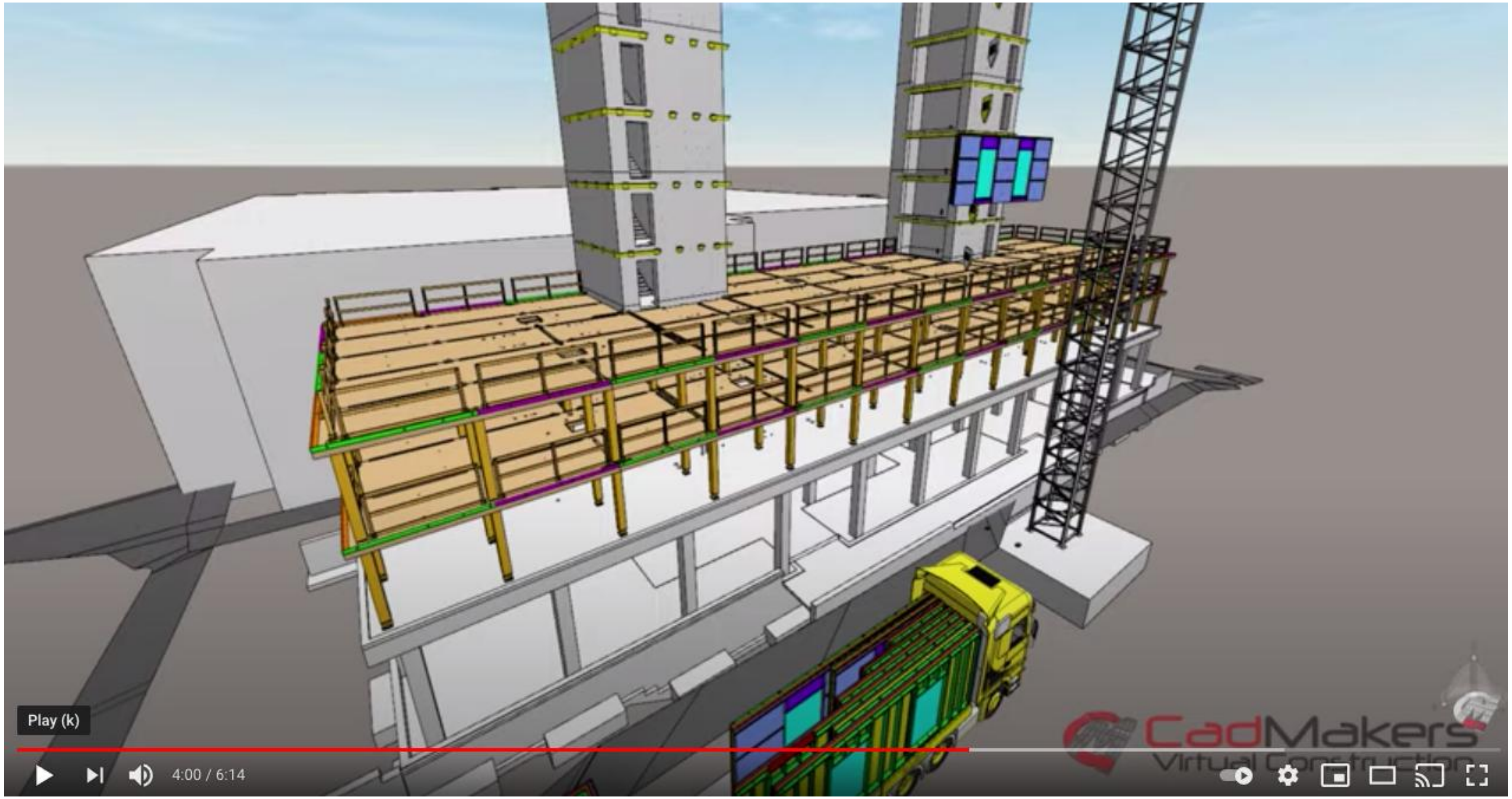
Layout of the new CLT line for Element5's new state-of-the-art mass timber facility in St. Thomas, Ontario. Source: www.ledinek.com

Digital Twin / Virtual Design and Construction Model



Video – Digital Twin, Virtual Design and Construction Modeling

https://www.youtube.com/watch?v=ATKpFtzCVFU



Next Generation

Mass Timber research at ETH Zurich.
Robot – dimROB

Source: “Mobile Robotic Fabrication on Construction Sites: DimRob”

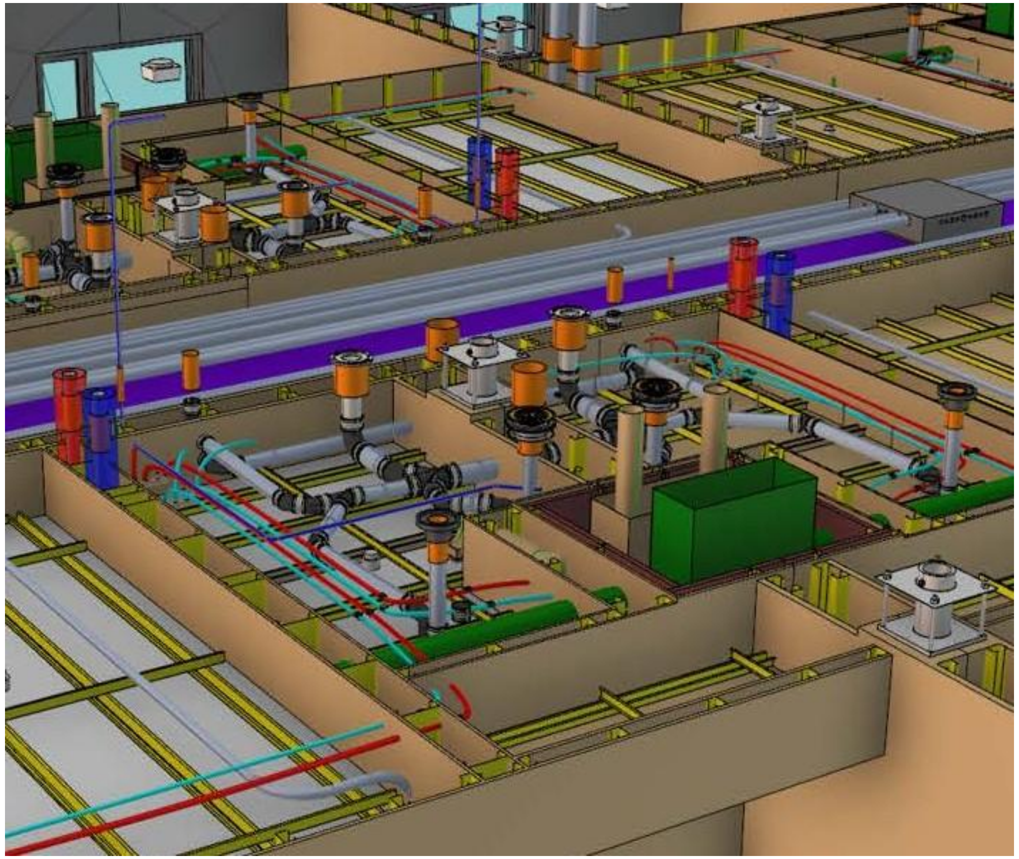
Activity – Benefits of Prefabrication

1. Which of the following is a benefit of wood prefabrication?
   a. Process efficiency
   b. Controlled environment
   c. Material efficiency
   d. Sustainability
   e. All of the above

2. Name all six identified benefits of prefabrication.

System Integration

Prefabrication and System Integration



Right: Image by Cadmakers illustrating the level of detail involved in coordinating MEPF systems for fabrication. Left: Image of plumbing shelving and penetrations through CLT slab (Photo source Structurlam).

Wood Innovation Centre, University of Northern British Columbia
Source: Michael Green Architecture

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80 Atlantic Avenue, Toronto
Source: Quadrangle Architects

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Case Study:
Brock Commons Tallwood House

University of British Columbia

Brock Commons Tallwood House

18 storeys
53 metres high

PROJECT CREDITS

OWNER
University of British Columbia, Student Housing and Hospitality Services

OWNER'S REPRESENTATIVE
University of British Columbia, Infrastructure Development

PROJECT MANAGER
UBC Properties Trust

ARCHITECT OF RECORD
Acton Ostry Architects Inc.

TALL WOOD ADVISOR
Architekten Hermann Kaufmann ZT GmbH

STRUCTURAL ENGINEER
Fast + Epp

MECHANICAL, ELECTRICAL, FIRE PROTECTION ENGINEER / LEED CONSULTANT
Stantec

BUILDING CODE & FIRE ENGINEERING
GHL Consultants Ltd.

BUILDING ENVELOPE & BUILDING SCIENCES
RDH Building Science Inc.

ACOUSTICAL ENGINEER
RWDI AIR Inc.

CIVIL ENGINEER
Kamps Engineering Ltd.

LANDSCAPE ARCHITECT
Hapa Collaborative

BUILDING ENERGY MODELLING
EnerSys Analytics Inc.

VIRTUAL DESIGN & CONSTRUCTION MODELLERS
CadMakers Inc.

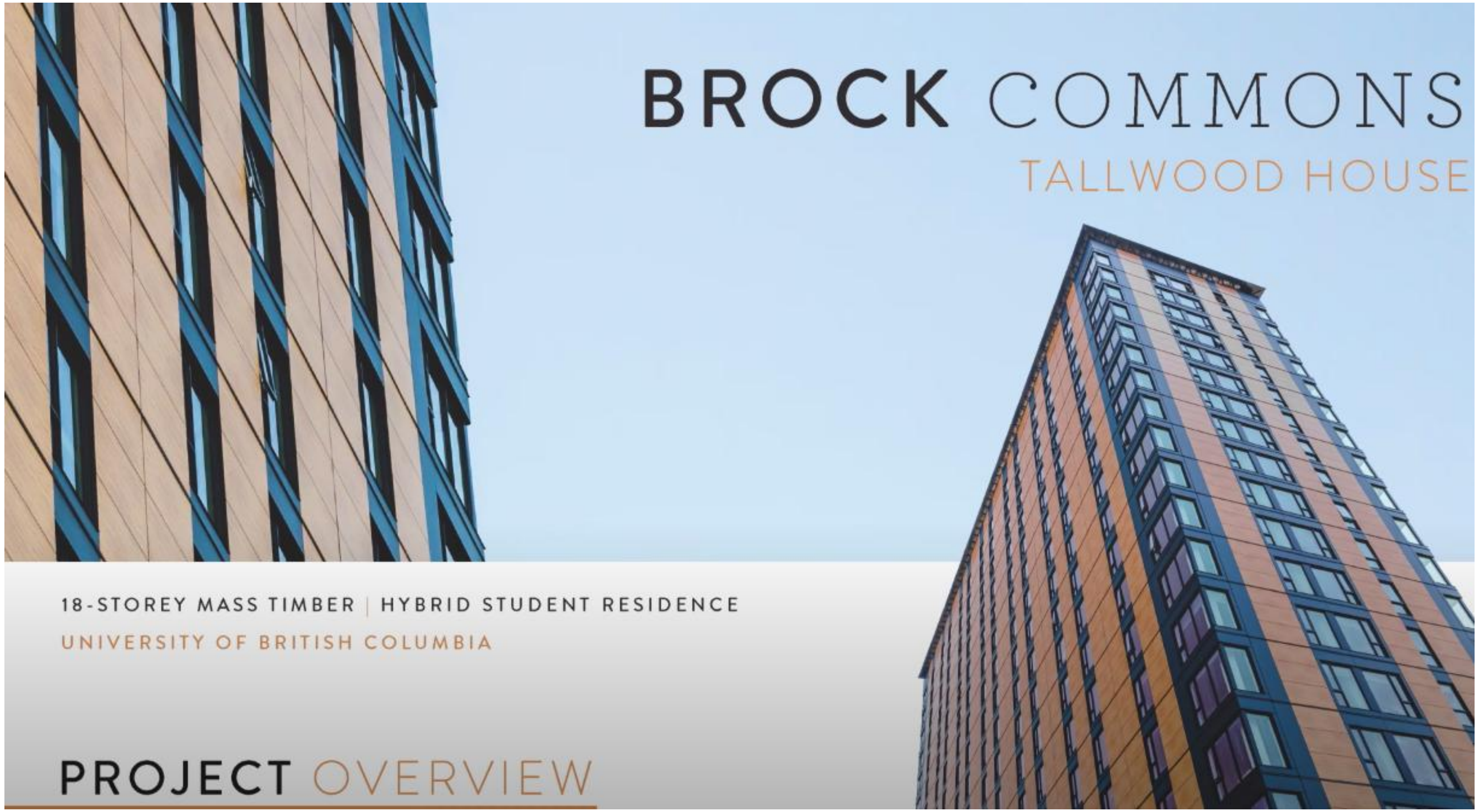
CONSTRUCTION MANAGER
Urban One Builders

DESIGN-ASSIST TRADES
Structurlam Products LP
Seagate Structures
Whitewater Concrete Ltd.

COMMISSIONING CONSULTANT
Zenith Commissioning Consulting

Brock Commons Overview – Video 1

https://www.youtube.com/watch?v=G22kYhaT-h4



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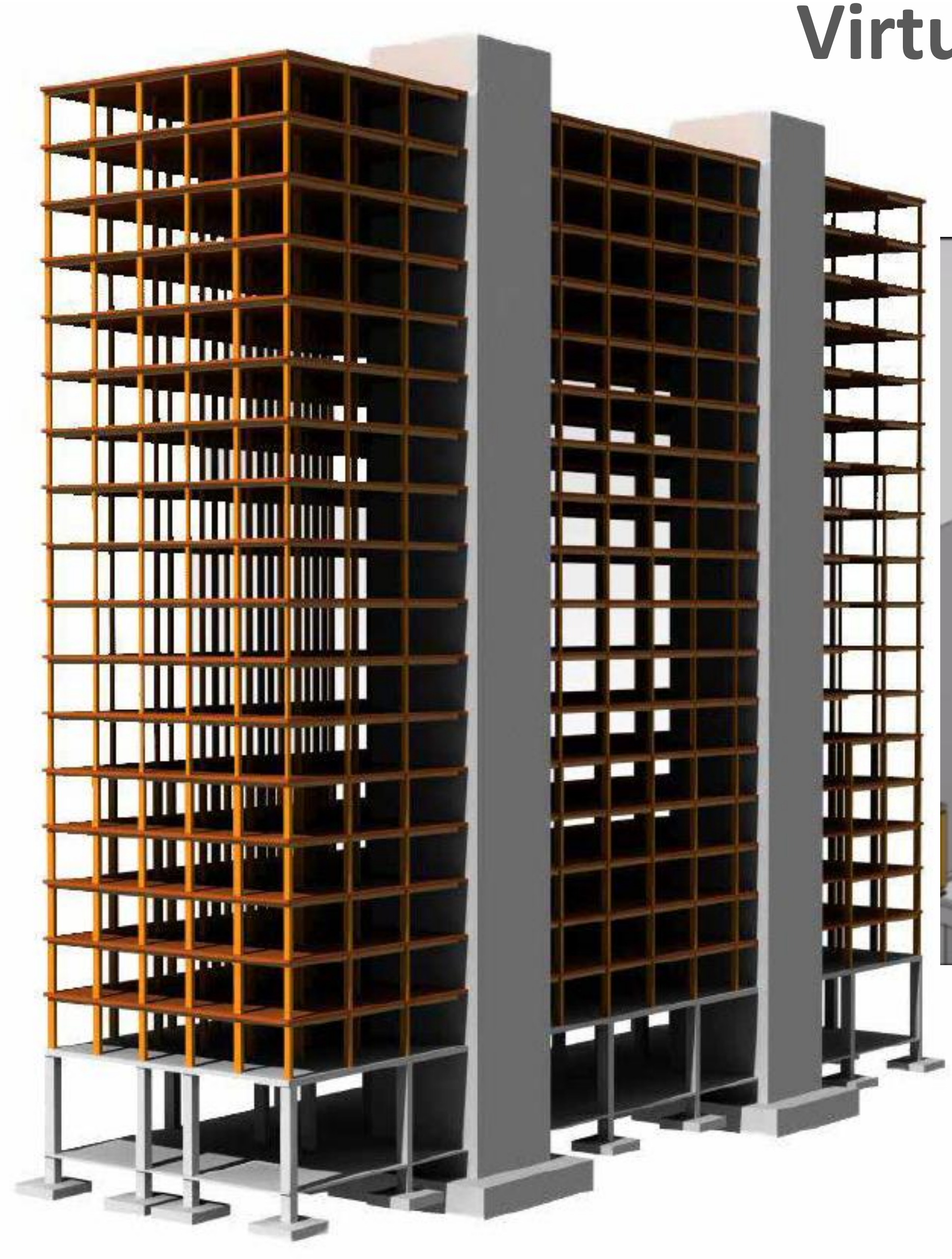
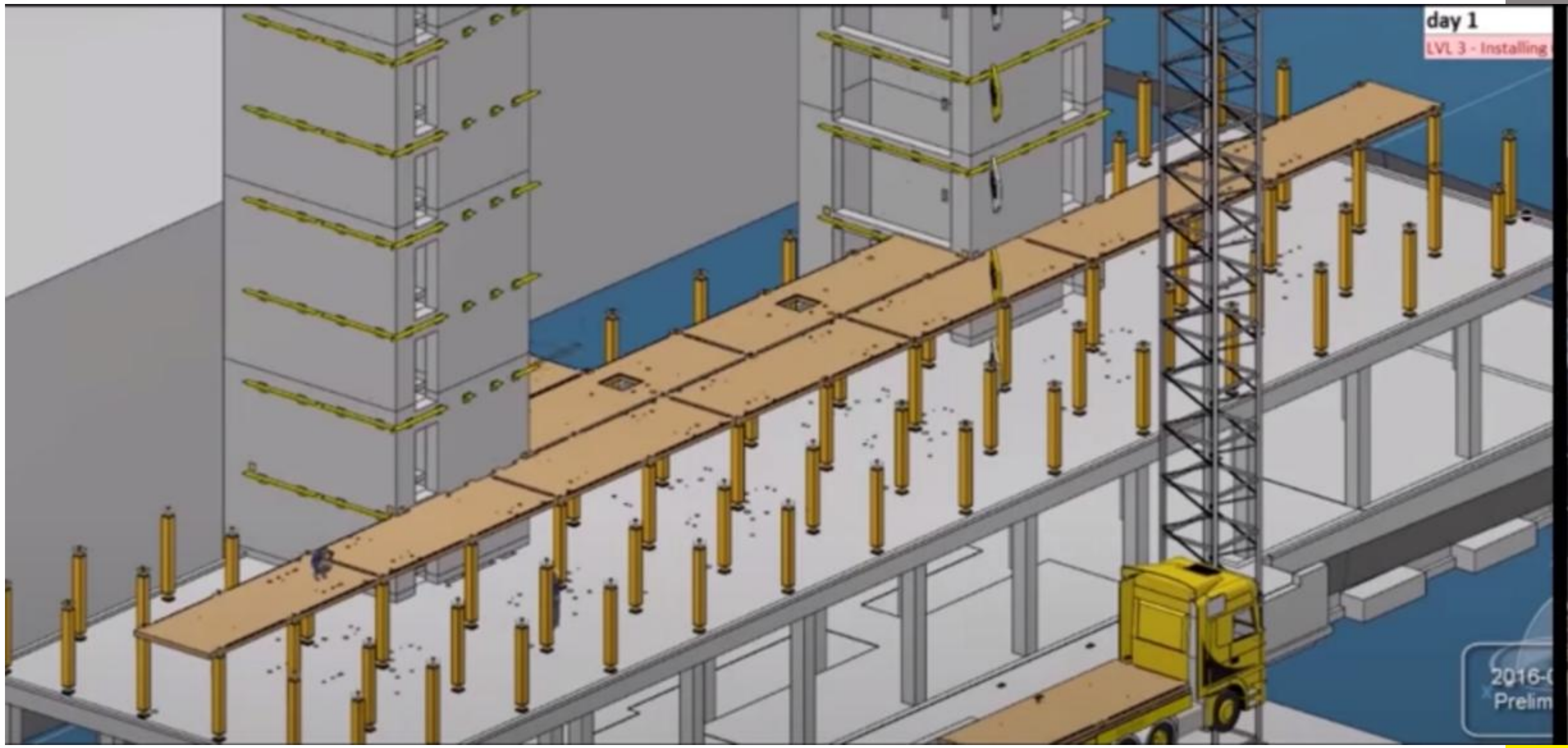
Brock Commons

Virtual Design and Construction Modelling



Render of hybrid mass timber and concrete structure, by CadMakers Inc.



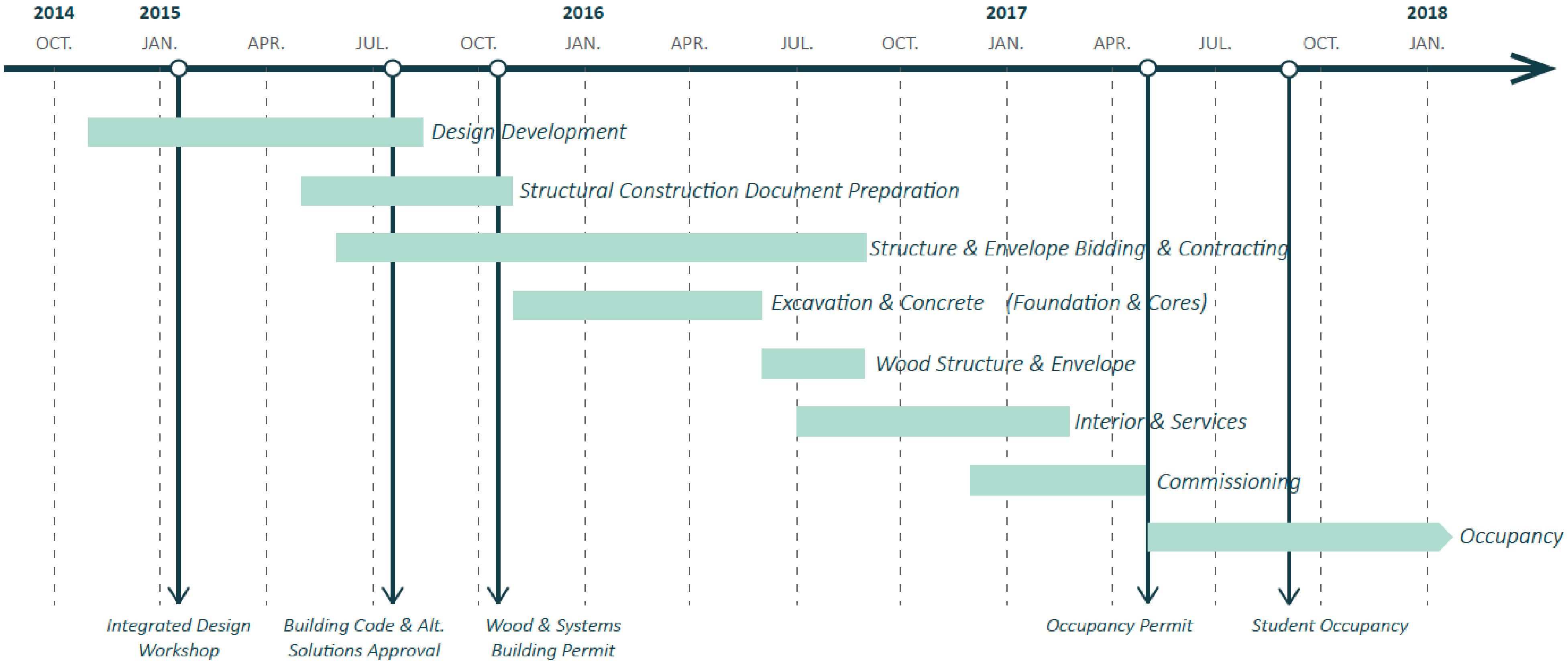
Brock Commons

BROCK COMMONS TALLWOOD HOUSE: CONSTRUCTION OVERVIEW

Brock Commons Design Process – Video 2

https://www.youtube.com/watch?v=ABQHbNwvU_s

Brock Commons Project Schedule Overview



A overview of the project schedule.

Laura Gilmore

Full-Scale Mock-Up

Brock Commons

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Construction Planning

Photography by KK Law

Kit of Parts

Brock Commons

Brock Commons Construction Process – Video 3

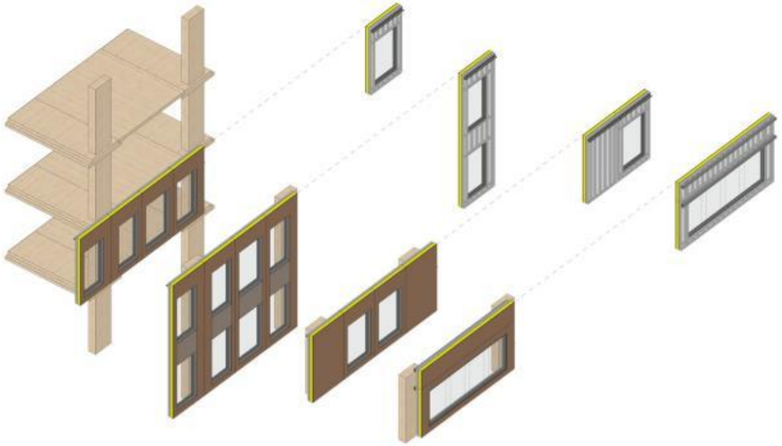
https://www.youtube.com/watch?v=Fmuj4XeHsbo

Activity – Benefits of VDC Modelling

Describe the benefits of VDC modelling. What advantages did it offer on the Brock Common's Tallwood House and why was it an important aspect of the success of the project?

Envelop & Moisture

Envelop and Enclosure

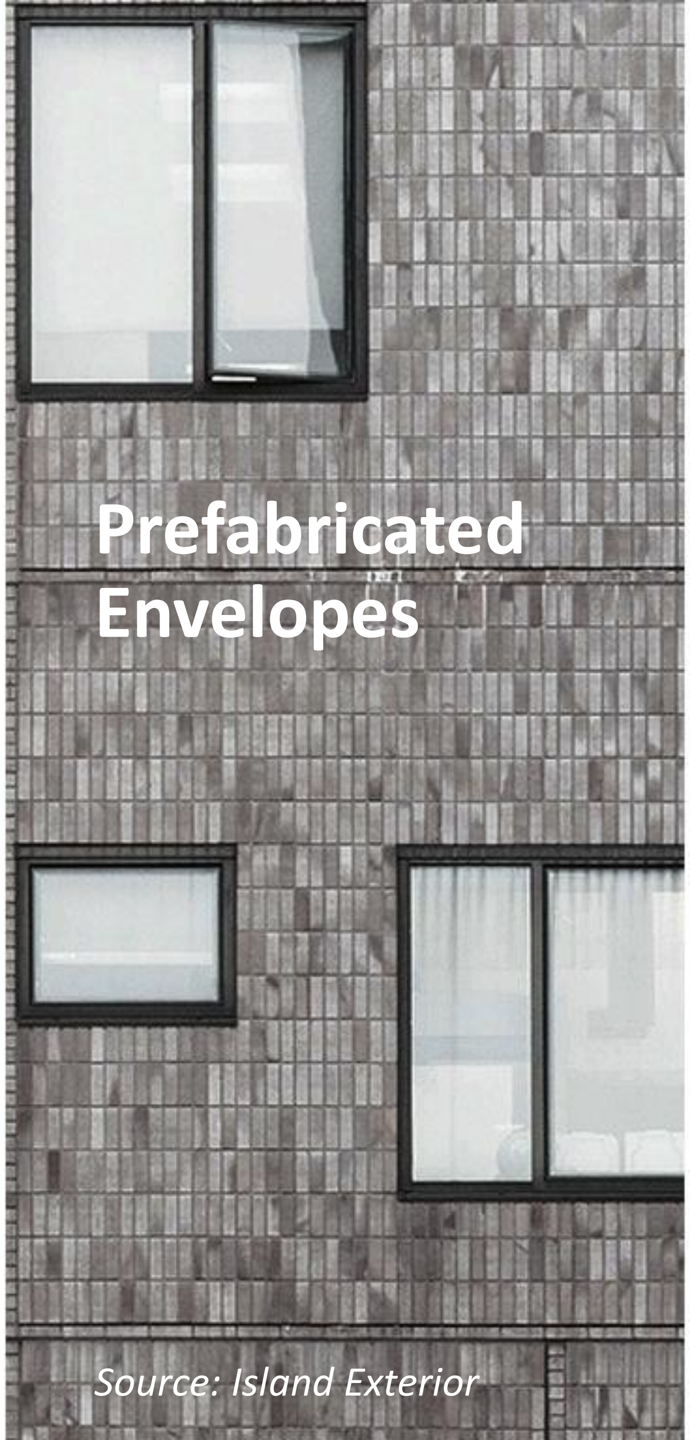


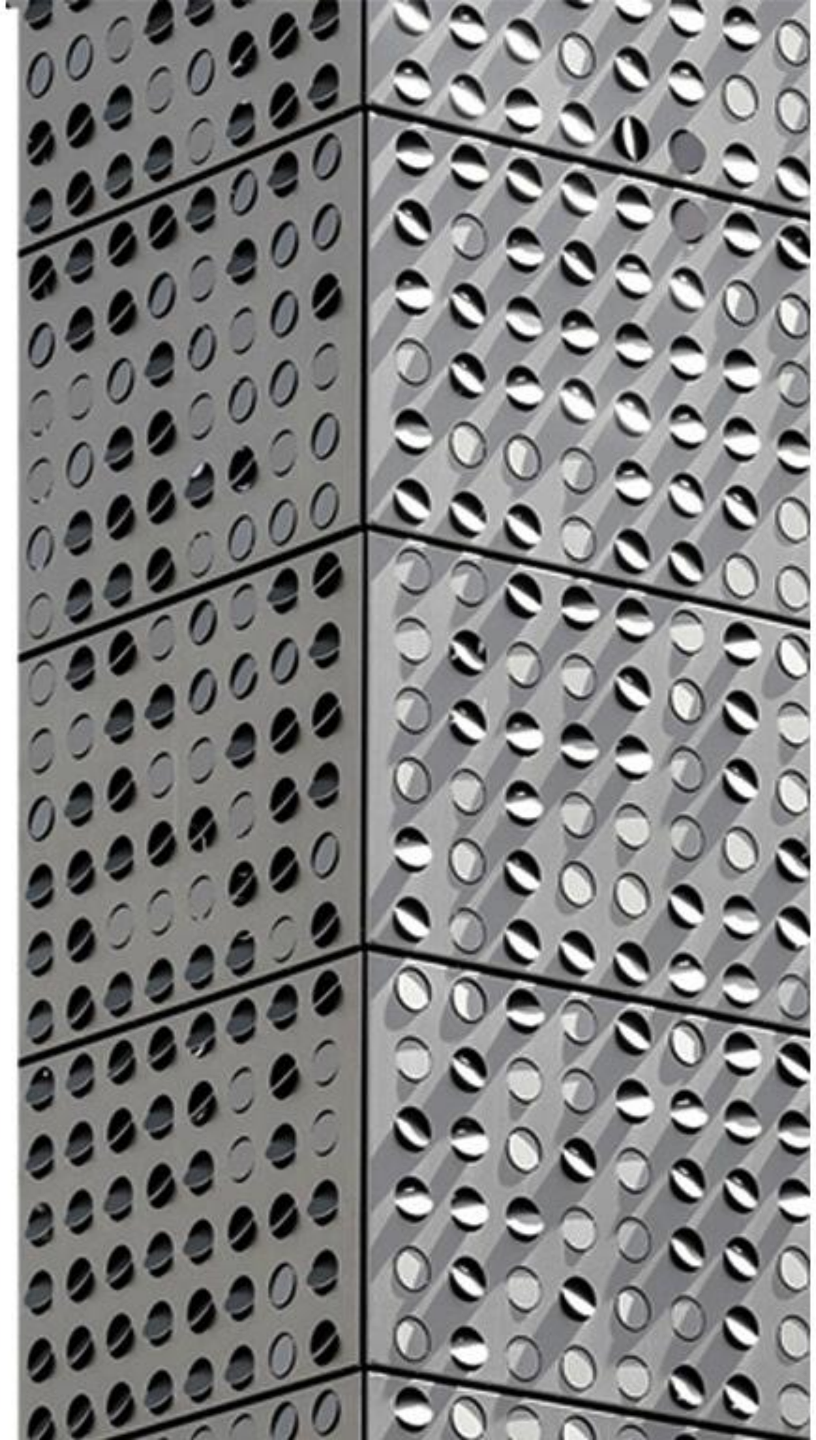
The Arbour, Moriyama & Teshima Architects / Acton Ostry Architects

Temporary Protective Roofing

Temporary protective roofing at the Limnologen Vaxjio construction site, Sweden.

Prefabricated Envelopes





Source: Island Exterior

Managing the Risk of Water Damage During Construction

https://www.surfacesreporter.com/articles/72301/mass-timber-architecture-benefits-and-common-misconceptions

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Managing the Risk of Fire During Construction

- Fire protection system
- Clean site, reduce flammable
- Hot work, such as welding, was done ahead of the mass timber structure installation.
- All trades were required to take fire-prevention and fire response training.
- Temporary fire doors were installed on the two exit stairs and clear exit paths were maintained.

Module 4: Life Cycle Assessment

Objectives:

Describe Life Cycle Assessment and the consideration involved in holistic design.

- Holistic considerations of carbon
- Why is LCA and Carbon Analysis Important
- Life Cycle Assessment Tools
- Biophilia, Health and Wellness

Holistic Considerations of Carbon

Looking Towards The Future

fidential

Life Cycle Assessment

Life Cycle Assessment (LCA) is a cradle-to-grave analysis technique to assess environmental impacts associated with all the stages of a product's life.

The five key stages of LCA include:

Manufacturing

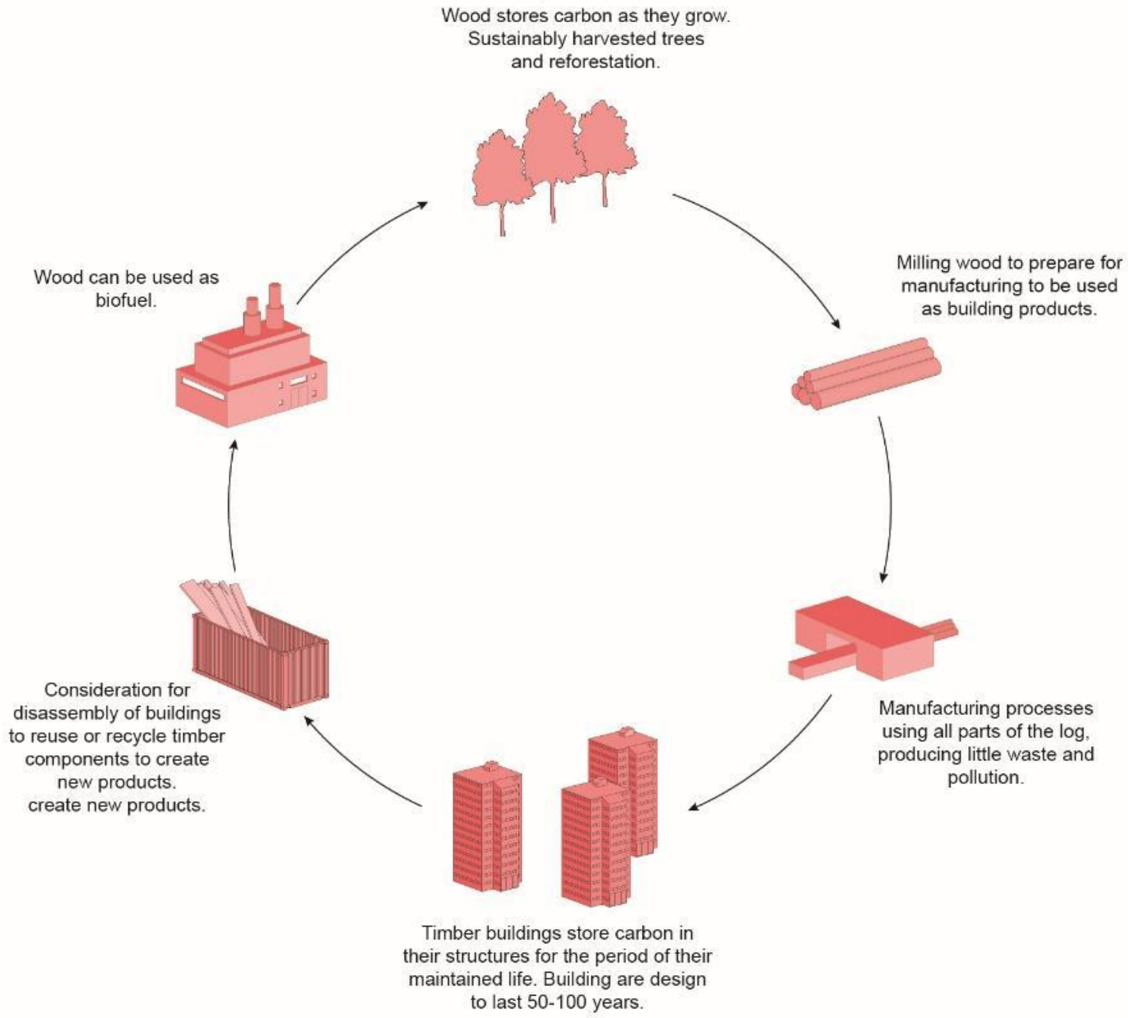
Packaging

Distribution

Use

Disposal

Raw Materials



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The Process of Whole-Building LCA

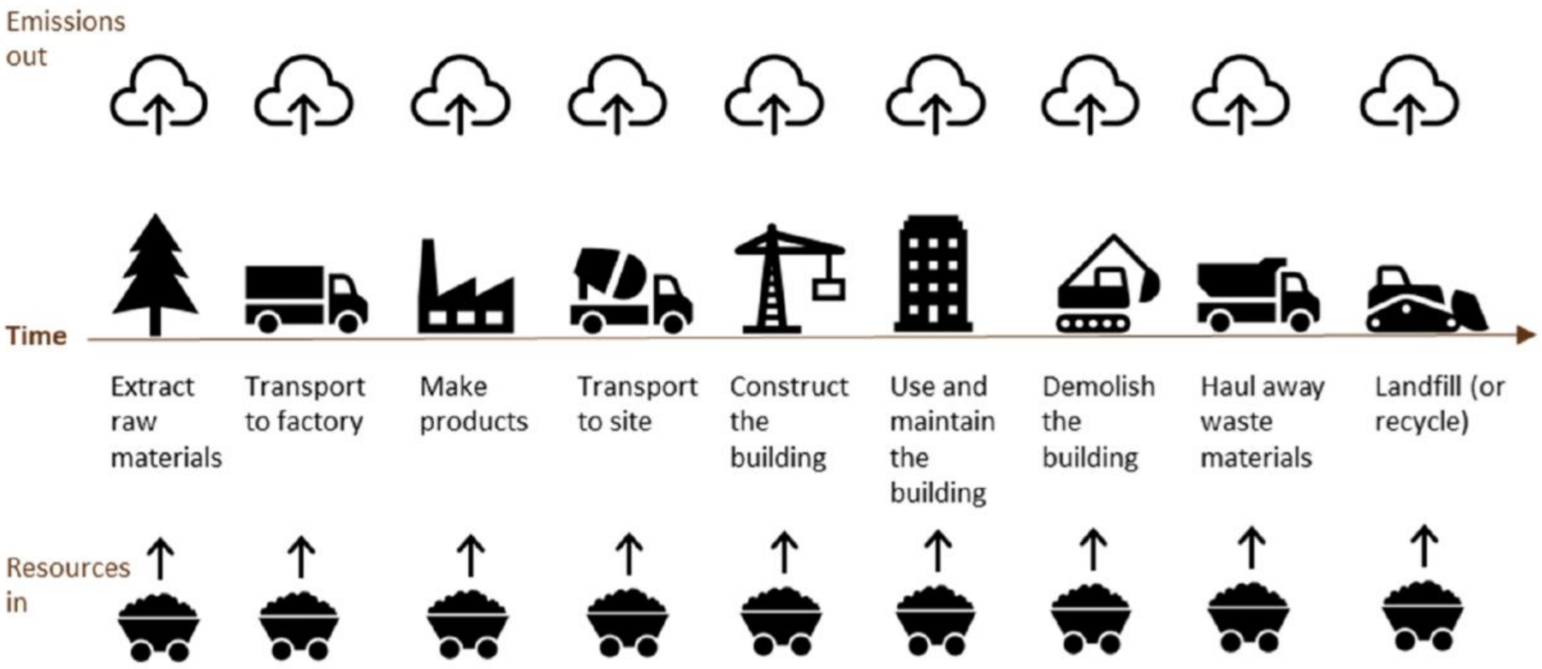

Figure 1: Life cycle phases of a building

Source: Athena Sustainable Materials Institute, "About Whole-Building LCA and Embodied Carbon," 2019.

Operational Carbon

OPERATIONAL CARBON is defined as the greenhouse gas emissions associated with the operational energy use of a building. This includes all carbon from energy required to heat and power the building, including but not limited to lighting, plug loads, heating and cooling, and cooking.

Embodied Carbon

EMBODIED CARBON is defined as the greenhouse gas emissions associated with the raw material extraction, manufacturing and processing, transportation, and installation of all building materials.

Net-Zero Carbon

NET-ZERO CARBON is defined as the combined operational and embodied carbon being resolved as zero through material selection, renewable energy and approved appropriate offsets.

LCA / LCI / LCIA and LCC

Life Cycle Assessment (LCA)

- Calculating the lifetime environmental impact of a product or service.

Life Cycle Inventory (LCI)

- Data collection portion of LCA. The accounting of everything involved in the system.

Life Cycle Impact Assessent (LCIA)

- What does it mean? The inventory is analyzed for environmental impact.

Life Cycle Costing

- Direct monetary cost involved with a product or service on the environmental.

Life Cycle Assessment

Whole-Building LCA Explained

LCA looks at cradle-to-grave lifetime of buildings including as resources are consumed and emissions created during each phase of a building's life span.

- Manufacturing and transportation of construction materials
- Process of construction
- Long phase of building occupancy and maintenance
- Demolition
- Removal of waste materials

Activity - Life Cycle Assessment

What is the definition of Life Cycle Assessment and what are the five stages of consideration?

What are five phases of a building?

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Why is LCA and Carbon Analysis Important?

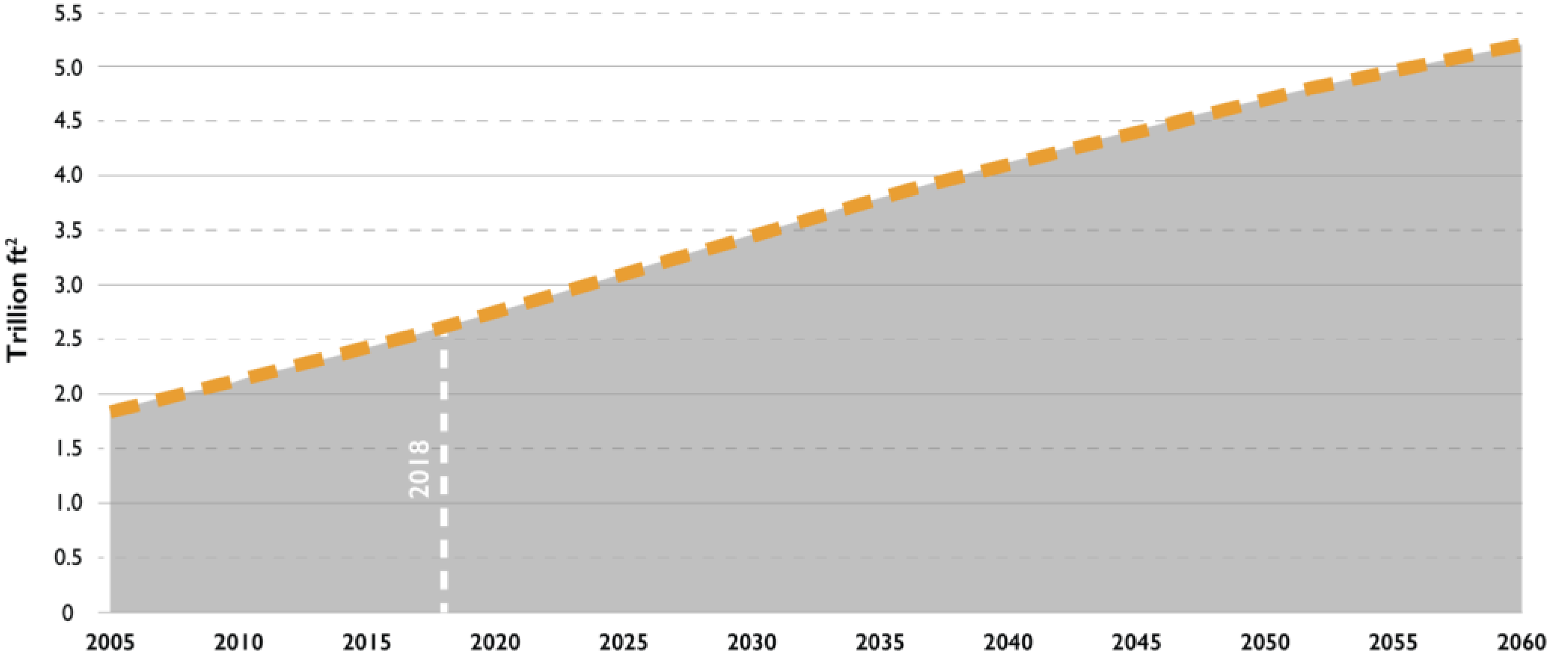
Working Towards Climate Stability

2060 Global Building Stock

Over the next 35 years,

2.5 trillion ft^2

of buildings will be constructed or renovated in cities worldwide



Global Floor Area Growth

Source: UN Environment Global Status Report 2017
Data Source: IEA (2017), World Energy Statistics and Balances

Architecture 2030, "Why The Building Sector?," accessed May 12, 2021, https://architecture2030.org/buildings_problem_why/.

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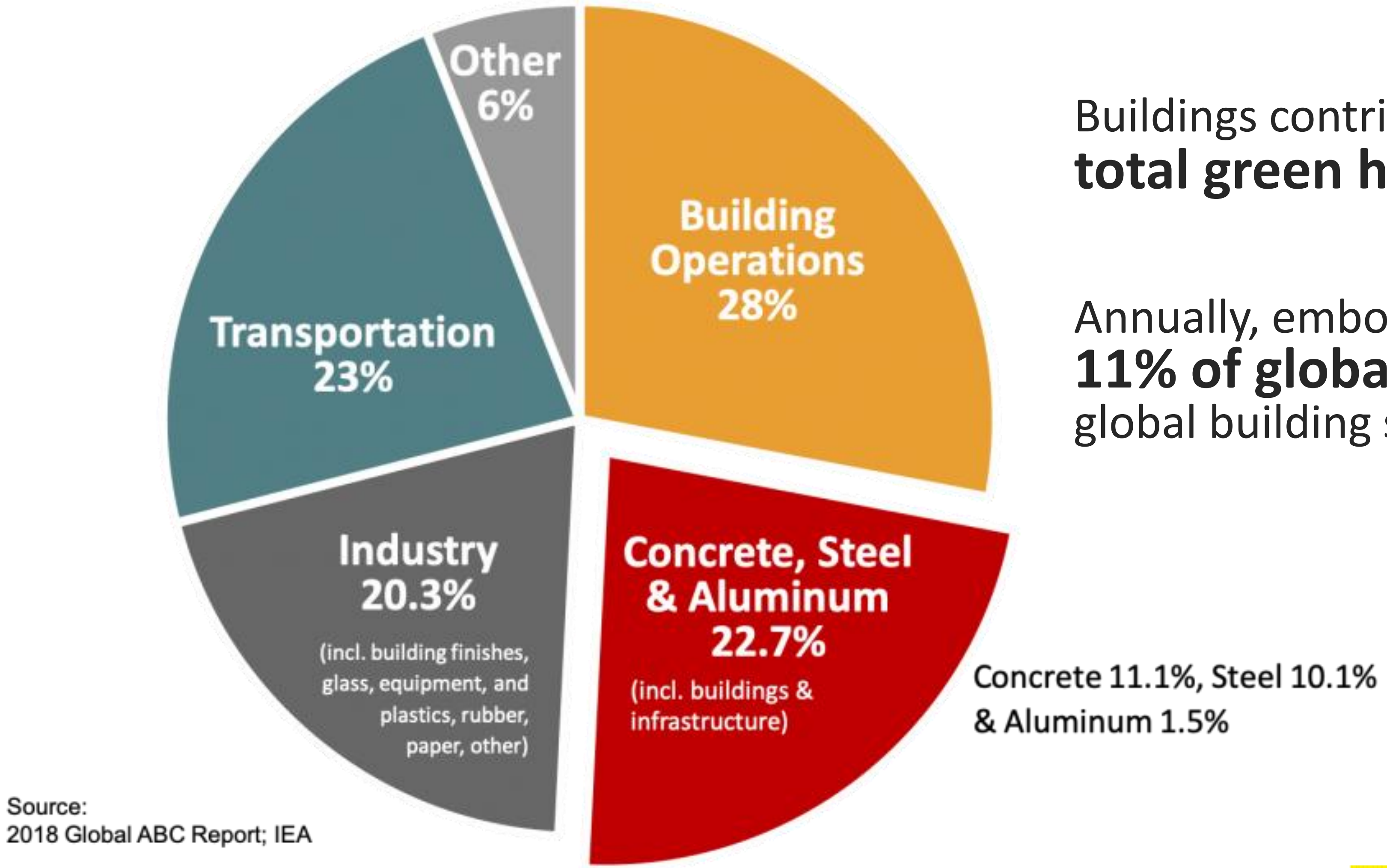
Global CO_2 Emissions by Sector



Buildings contribute to **over 40% of the total green house** emissions globally

Annually, embodied carbon is responsible **11% of global GHG** emissions and 28% of global building sector emissions.

Source: Architecture 2030

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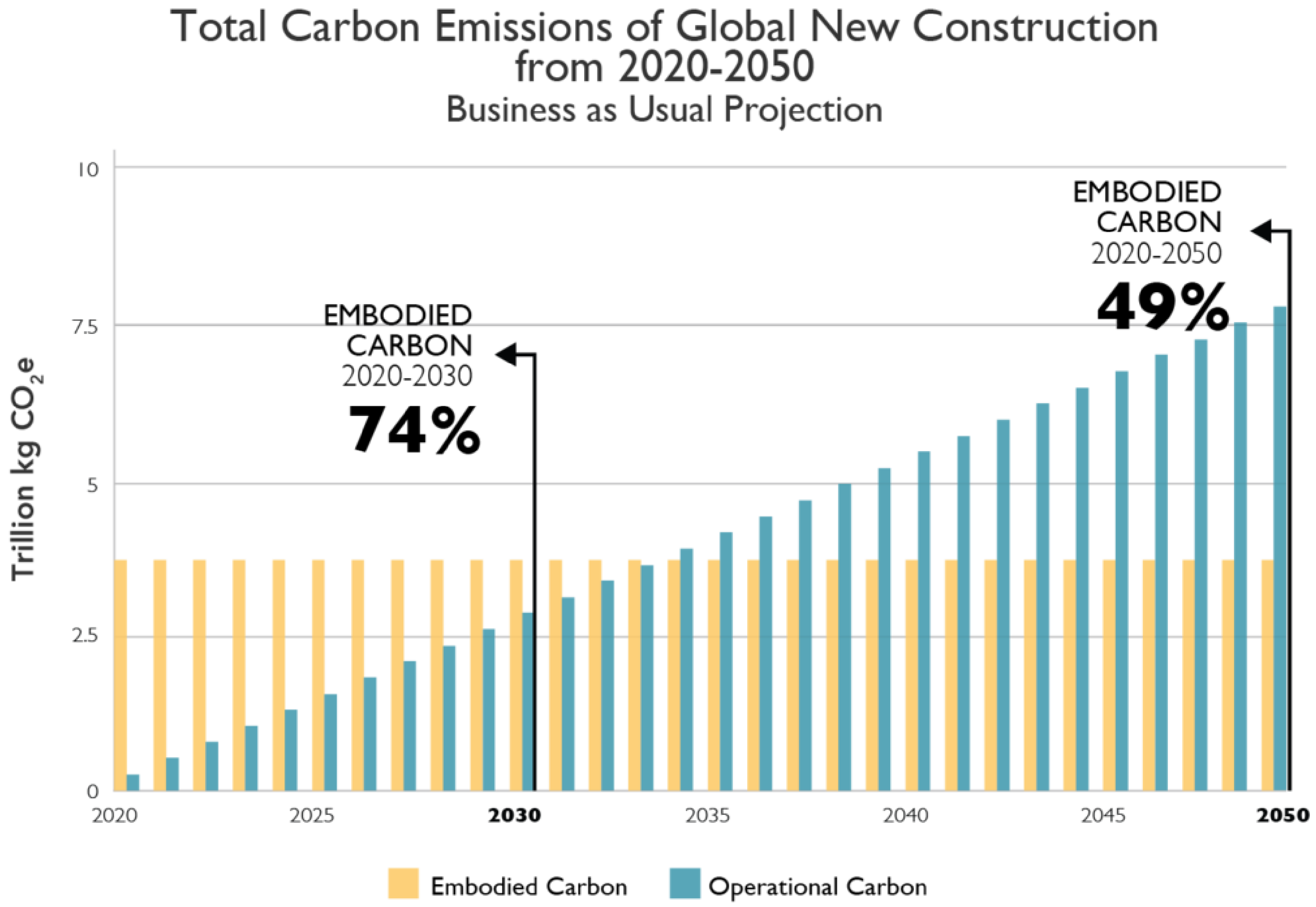
Why is Reducing Embodied Carbon Important?



Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

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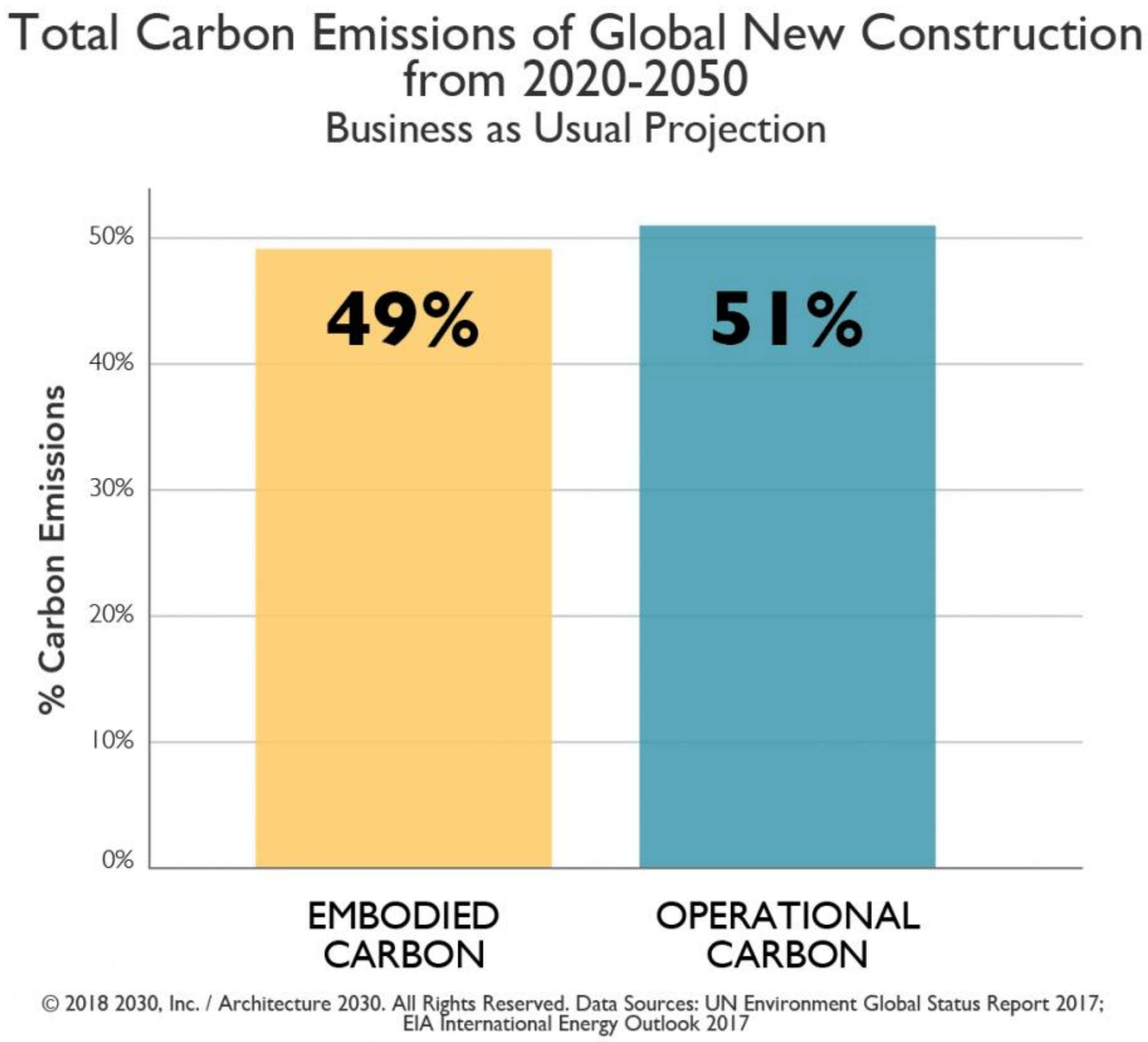
Embodied vs. Operation Carbon



Source: Architecture 2030

Embodied carbon will be responsible for

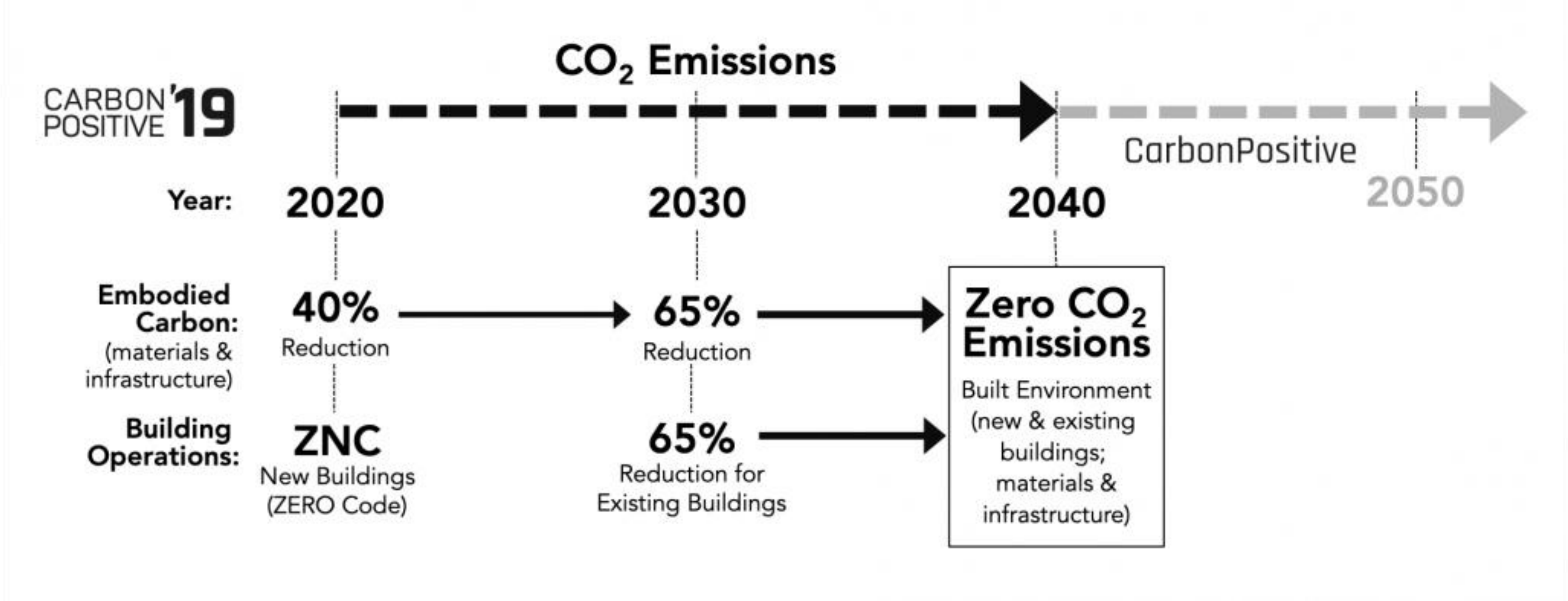
almost half of total new construction

emissions between now and 2050.

Canada Raising Climate Ambitions

- **Federal Government Announcement - April 21, 2021**
- Go beyond their **30% by 2030**
- Reduce 2005 emission levels by **40-45% by 2030**
- **Net zero by 2050**
- **Price on pollution**
- **Decarbonizing materials**
- concrete, steel and aluminum
- Will make it law

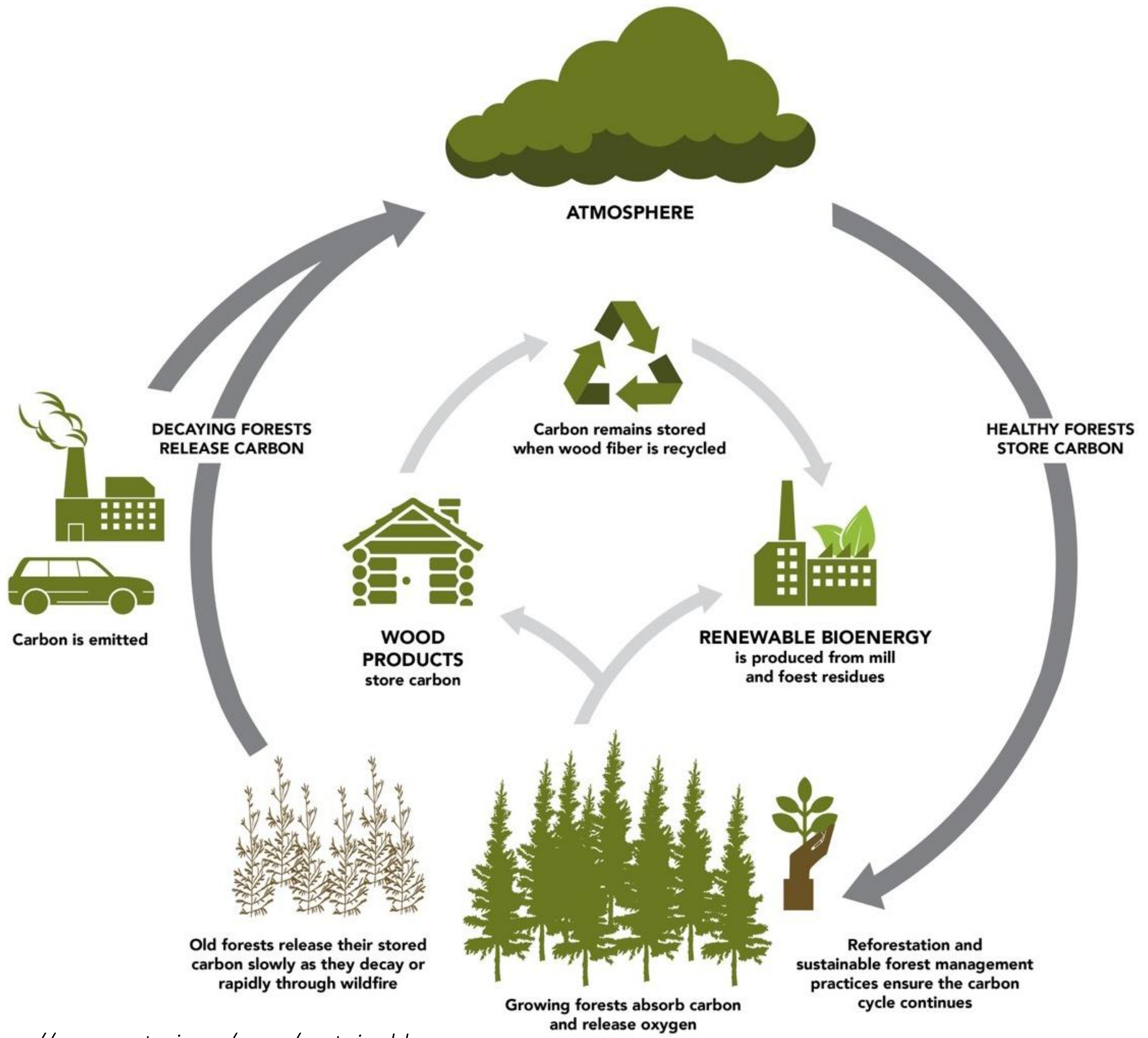
Accelerating to Zero by 2040



Source: Architecture 2030

50% of wood is carbon

Sustainable Forests Strategy



https://www.ontario.ca/page/sustainable-growth-ontarios-forest-sector-strategy

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Activity – Building and Impact on Climate

- Define the following terms:
  - Operational Carbon
  - Embodied Carbon
  - Net-Zero Carbon

Why are each important consideration?

Why is the consideration of embodied carbon critical in achieving climate stability?

Life Cycle Assessment Tools

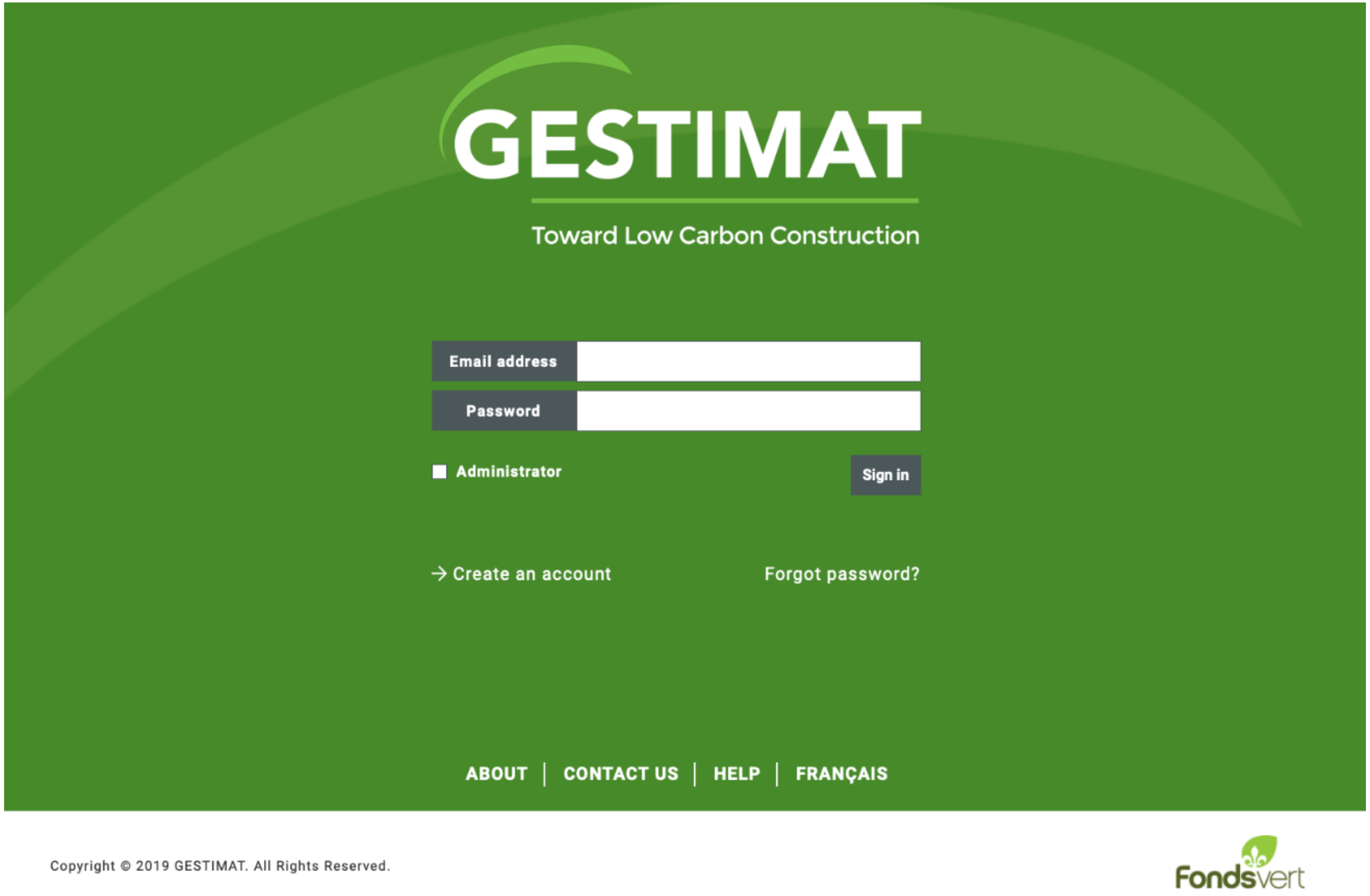
Gestimat, Athena and Other Tools

Life Cycle Assessment Workflow

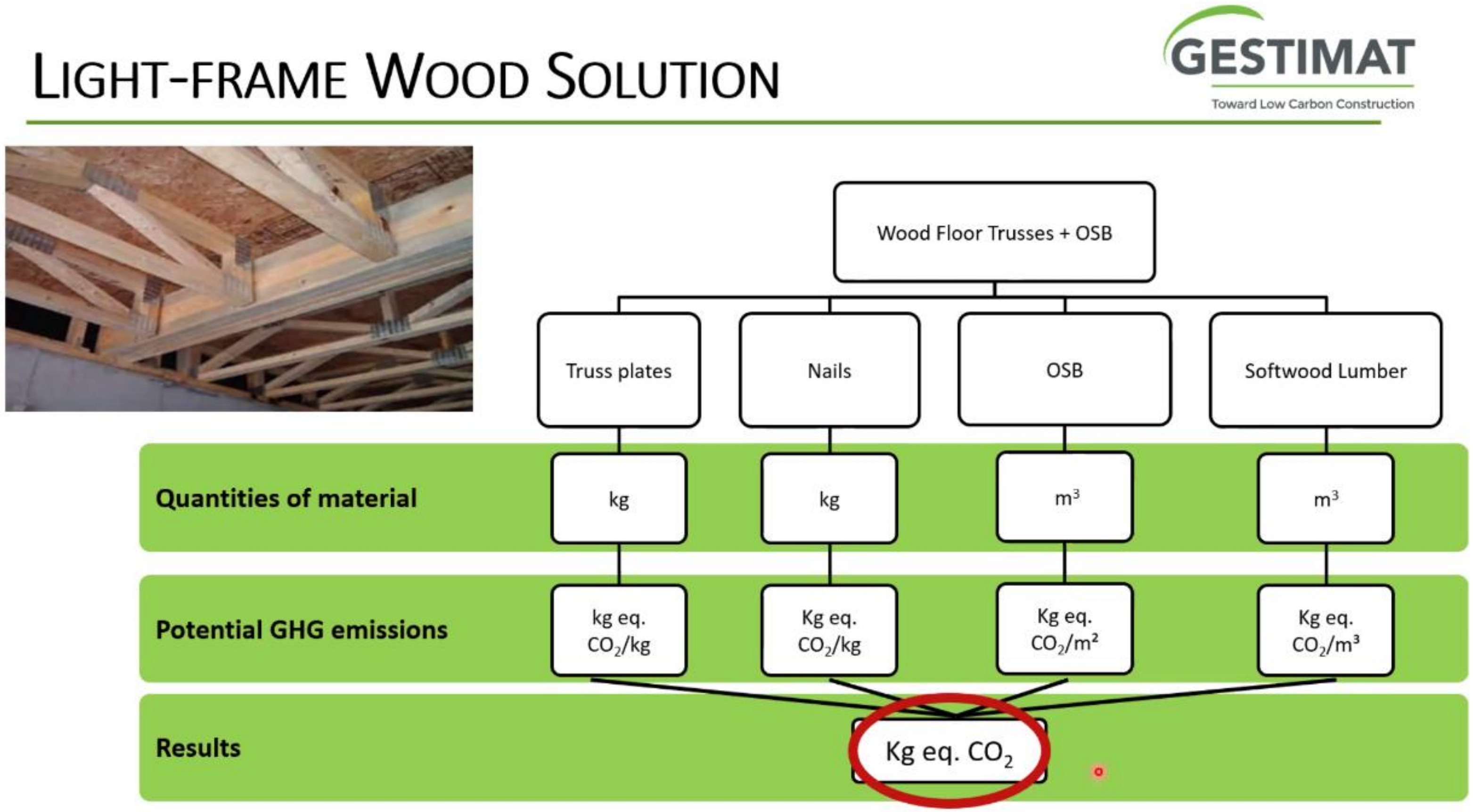
- **Data Gaps:** Some important products and processes are missing or incomplete in the Life Cycle Inventory (LCI) databases. Materials and Energy data is fundamental to whole-building LCA.
- **Data Inconsistency and Lack of Detail:** Currently, there could exist variation in the method and quality of the data. Data on materials may be out of date, and may not adequately resemble regional circumstances.
- **Method and Standards Inconsistency:** There may be variation in approach to LCA, which means results may not be comparable across studies.

Gestimat

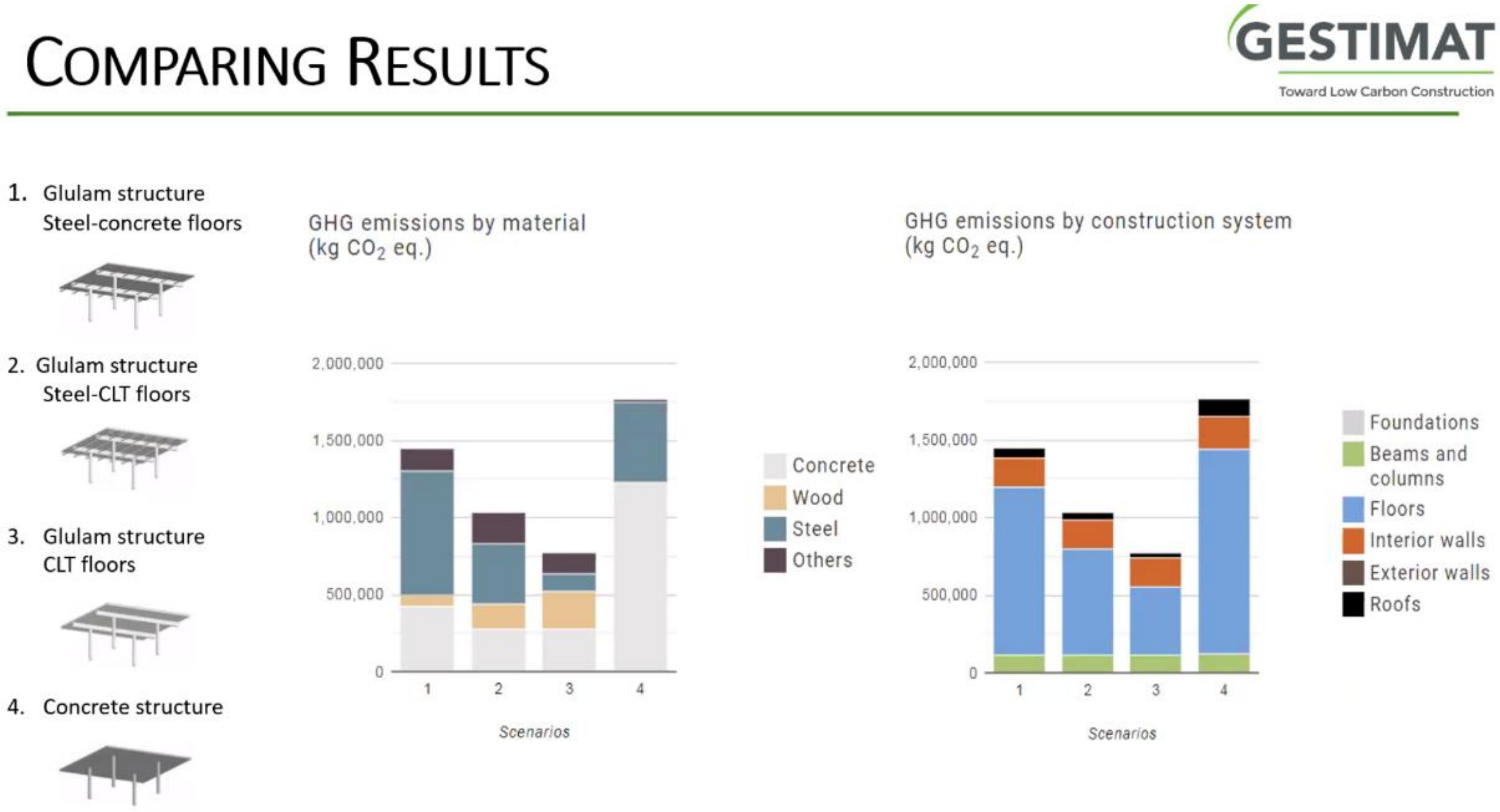
https://gestimat.ca



Comparative Analysis - Gestimat



Gestimat – Comparing Results



Gestimat – Precalculated Typical Buildings

PRECALCULATED TYPICAL BUILDING

GESTIMAT
Toward Low Carbon Construction

✓ Facilitating modeling at predesign phase

Photo: Groupe Robin

Multi-storey Structures
1 to 6 storeys
Grid: 6m x 6m to 9m x 9m

Photo: Stephane Brugger

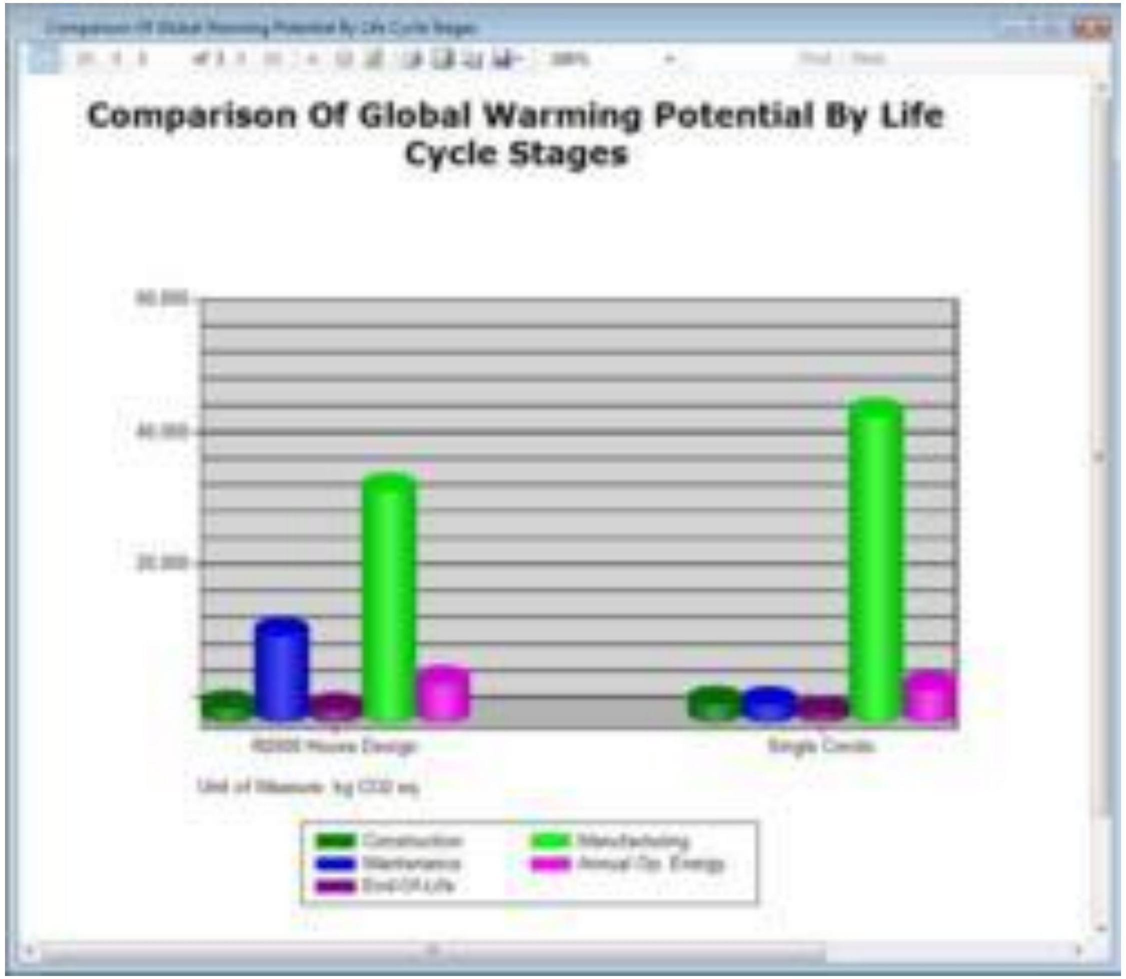
Free-span Structures
10, 15 and 20 m

Fondsvert Québec

cecobois

Tool – Athena Impact Estimator

Athena Sustainable Materials Institute



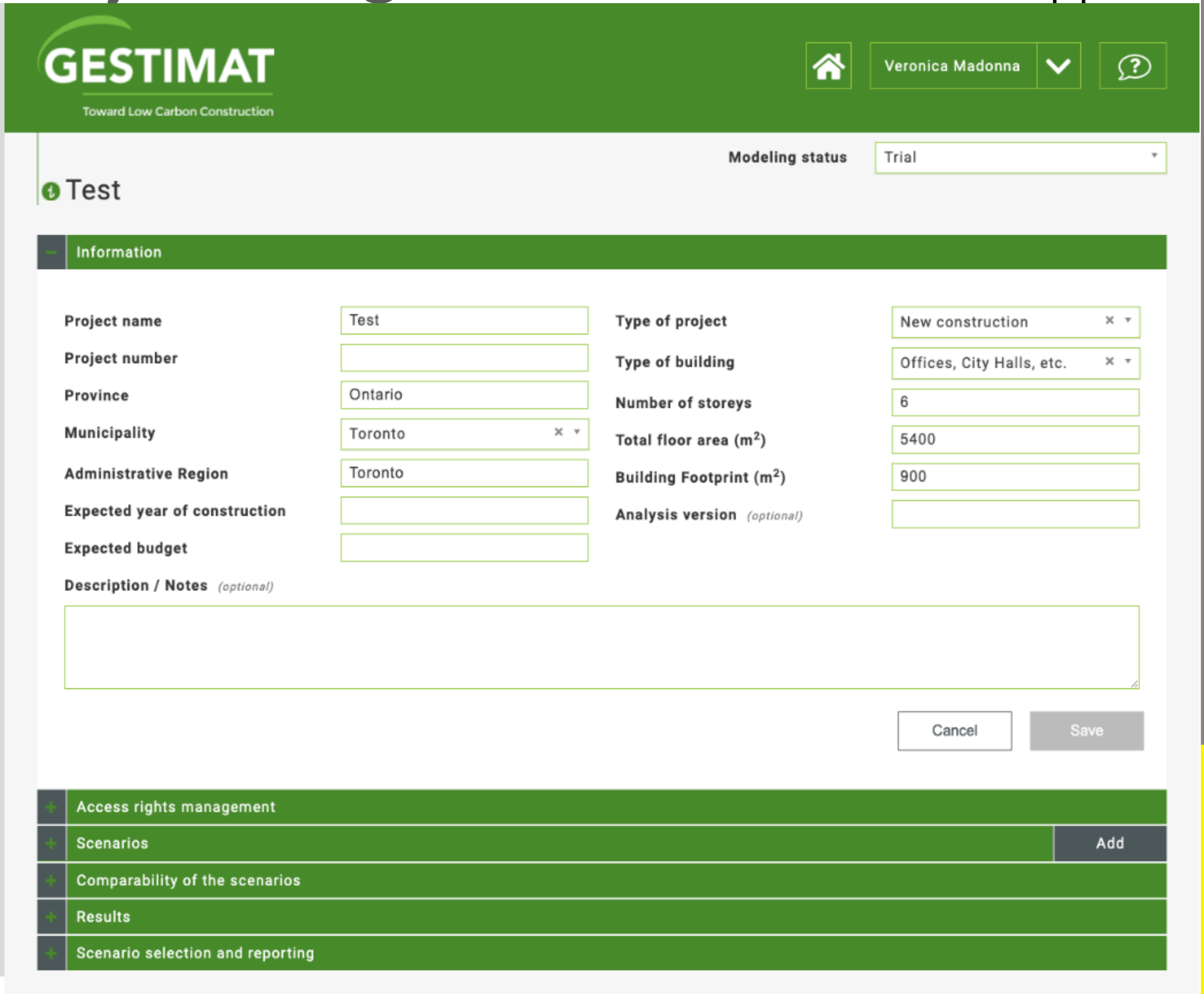
Activity - Embodied Carbon Analysis using Gestimat

Using the Gestimat program, perform a carbon comparison analysis of the following building using the following systems:

- *Steel*
- *Hybrid – Steel structure and CLT deck*
- *Mass timber*

Building Specifications:

- *Begin with the typical commercial building (start with the predefined building in the system)*
- *6 stories*
- *Total Floor Area: 5400 m2*
- *Building Footprint: 900 m2*
- *Location: Toronto, Ontario*
- *Include Foundations:*
  - *15mPA Concrete, 1000m3 Volume*
  - *0.5 metric tons of rebar*



Tools

- Building Information Label: Embodied & Operational Carbon

EC3

tally ENVIRONMENTAL IMPACT TOOL

Athena Sustainable Materials Institute

RETScreen Expert

IES

Thornton Tomasetti Beacon

One Click LCA

CanBIM

GESTIMAT Toward Low Carbon Construction

Associated Engineering