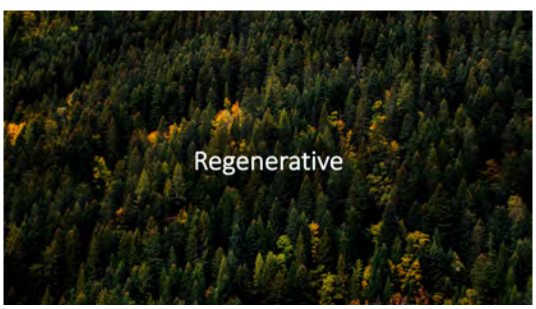
# 1. Introduction and Project Planning for Optimized Design

## 1.1 Title slide


## 1.2 Module 1: Objectives


## 1.3 Introduction – Regenerative Design




We live in a time that is quickly changing. The effects of climate change are becoming increasingly evident with real consequences – extreme weather events, droughts, floods, to name a few. These effects cause areas of the world to be dangerous and even uninhabitable, in addition to experiencing the loss of our ecological systems and even face the extinction of many animals on earth.

Impacts of Climate Instability:

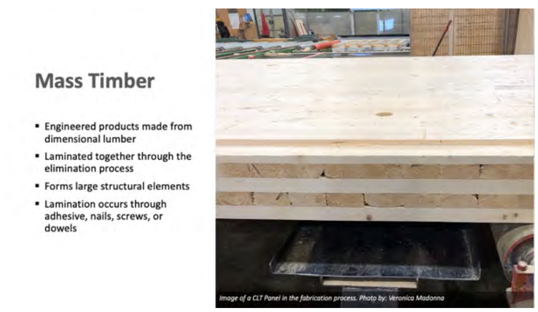
- increase of extreme weather events such as heatwaves, droughts or flooding,

- threaten human health and well-being, both directly and indirectly,
- Significant impact on ecosystems and how they function

The time to make change is now, and we must take responsibility to provide a healthy world for future generations.

As architects, engineers, buildings, contractors - anyone must recognize that the construction industry constitutes nearly 50% of the greenhouse gas emissions globally. We need to look towards passive design and innovation in construction to reduce carbon, energy use and gain buildings that promote health and wellness.

## 1.4 Mass Timber Defined




Mass timber is an advancement of an old tradition that can have many benefits. This series of education modules will explore mass timber and key design considerations to optimize the design of a system that uses new technologies and techniques of prefabrication. Prefabrication requires a paradigm shift in thinking and design and that the following modules will explore.

Mass timber is a grouping of engineered products made from dimensional lumber, veneer, or wooden strands bonded together through a lamination process to create larger structural elements. These elements can include columns, panels and beams. The lamination of the products can come through in a number of methods. The most common procedures include adhesives, nails, screws and dowels.

## 1.5 Mass Timber Products

There are several mass timber assemblies and products available. Each has a different characteristic, both structurally and aesthetically. Knowing your product offering and the features of each will give you an advantage of exploring innovation in design.

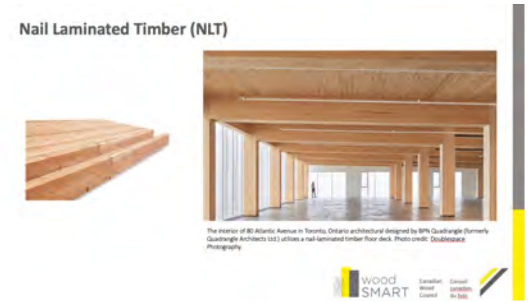
## 1.6 Glulam


**Glulam** consists of dimensional lumber pieces bonded together with adhesive. The grain of the laminations run parallel to each other, **allowing for long spans and strength.** Glulam is available in standard and custom sizes with depths ranging from 6 inches to 72 inches and widths from 2.5 inches to 10.75 inches.
Common Use: Columns and Beams

## 1.7 Cross Laminated Timber (CLT)


**Cross Laminated Timber (CLT)** panels consist of layers of dimensional lumber, usually 3, 5 or 7 lams thick, stacked crosswise at 90-degree angles and bonded with adhesive. The panel widths are typically restricted by manufacturer capability; however, the length can range and is often dictated by transportation restrictions. **CLT is becoming widely used due to its strength, dimensional stability and rigidity**. Although available in custom sizes, efficiency and cost-effectiveness can be achieved by designing standard and modular sizes.
Common Use: Wall and Floor Panels

## 1.8 Nail Laminated Timber




**Nail Laminated Timber (NLT)** is a traditional method of decking that can be seen in many turn-of-the-century post-and-beam heavy timber buildings. NLT consists of dimensional lumber placed on edge with individual pieces mechanically fastened together by nails or screws. Boards are nominally 2x, 3x and 4x thick, and widths range from 4 to 12 inches. NLT does not require a dedicated manufacturing facility and can be fabricated with readily available dimensional lumber.

Common Use: Floor Deck

Example: 80 Atlantic Avenue, Toronto

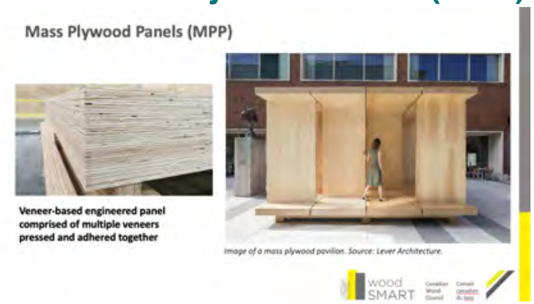
The interior of 80 Atlantic Avenue in Toronto, Ontario architectural designed by BPN Quadrangle (formerly Quadrangle Architects Ltd.) utilizes a nail-laminated timber floor deck.

## 1.9 Dowel Laminated Timber (DLT)


**Dowel Laminated Timber (DLT)** is similar to NLT, except it is fastened together using wood dowels rather than metal screws or nails. DLT consist of dimensional lumber placed on edge and friction-fitted together using hardwood dowels. DLT is an all-wood mass-timber product with no metal or adhesives. With advancements in CNC machinery in wood manufacturing, DLT is becoming increasingly desirable.

Common Use: Floor Deck

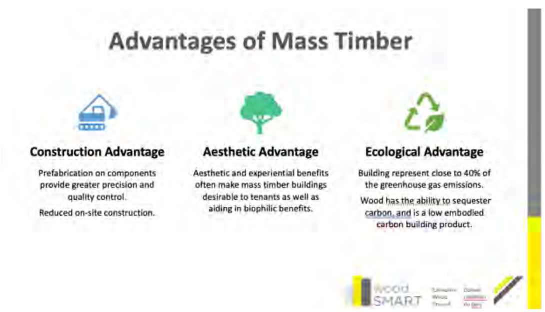
## 1.10 Mass Plywood Panel (MPP)




**Mass Plywood Panel (MPP)** is a veneer-based engineered panel comprised of multiple veneers pressed and adhered together in a staggered alternating grain direction for the most efficient orientations. MPP is an alternative to CLT, concrete and steel. These panels are light-weight and efficient use of material; however, they use a significant amount of glue in the production.

Common Use: Wall and Floor Panels

## 1.11 Advantages of Mass Timber




There are many advantages in building with mass timber and include:

- Construction Advantage
  - Prefabrication on components provides greater precision and quality control.
  - Reduced on-site construction.
- Aesthetic Advantage
  - Aesthetic and experiential benefits often make mass timber buildings desirable to tenants and aiding in biophilic benefits.
- Ecological Advantage
  - Buildings represent close to 40% of the greenhouse gas emissions.
  - Wood can sequester carbon and is a low embodied carbon building product.

## 1.12 Additional Advantages


Proven Performance and Safe

- In recent years, mass timber has undergone many test studies to prove performance and fire safety and seismic performance.

Light-weight and Low Embodied Carbon Material

- Mass timber products have a lighter environmental footprint than energy-intensive materials, contributing to low-and-zero-carbon construction.
- Wood products are 50% carbon by dry weight, meaning mass timber can sequester carbon well into the future, reducing the global warming potential of a building.

Efficient, Cost-Saving Construction

- Mass timber construction is faster than other structural assemblies. This time savings during construction can have significant overall cost savings.

Thermal and Health Benefits

- Mass timber products can contribute to improved occupant comfort. They have lower thermal conductivity compared to concrete, steel-frame, and masonry construction and are well-suited to energy-efficient design.
- Prefabricated factory-built mass timber solutions can improve thermal performance by delivering a precise fit that is tested and airtight. In addition, an increasing number of studies focused on wood's biophilic qualities have linked the use of exposed timber in buildings with improved occupant well-being.[1]

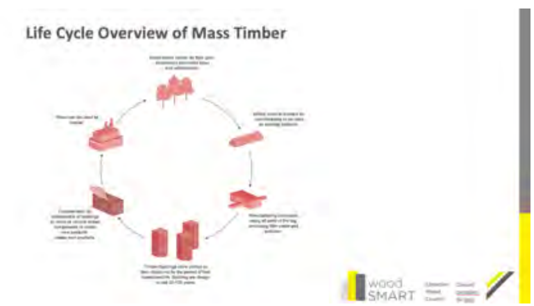
## 1.13 Social, Economic, Environmental and Cultural Benefits


[1] ThinkWood; WoodWorks;, "Mass Timber Design Manual," 2021, https://info.thinkwood.com/masstimberdesignmanual.

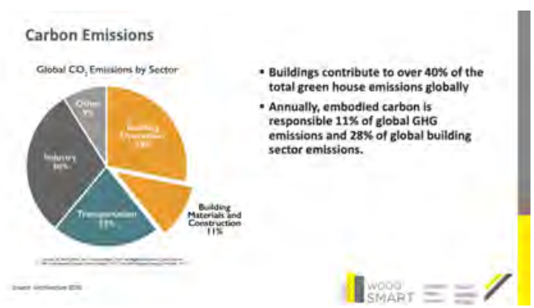
The construction of wood can provide impact on multiple levels economic, social, environmental and cultural aspects.

- It is a valuable consideration in catalyzing new industry creating new jobs.
- It can have a significant impact on climate stability.
- It can offer new industrialized opportunities for engineering and prefabricated wood products.
- The industrialized and prefabricated process can provide rapid, durable, and quality affordable housing creating equitable communities.
- It can positively impact rural communities by strengthening industry, reducing depopulation, unemployment and poverty.
- As well, its physical and mental well-being through its biophilic qualities.

## 1.14 Life Cycle Overview of Mass Timber




## 1.15 Carbon Emissions

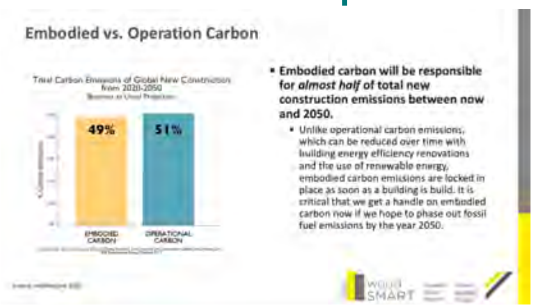



The construction sector can offer considerable opportunities for reducing greenhouse gas emissions both in embodied and operational carbon. It is estimated that approximately 40% of the greenhouse gas emissions are due to the building industry alone.[2] On a global scale, embodied carbon constitutes 211% of the annual greenhouse gas emissions and equals 28% of the building sector emissions. Building with wood can temporarily sequester carbon from the earth's atmosphere and replace non-renewable resources.

[2] Architecture 2030, "New Buildings: Embodied Carbon – Architecture 2030," accessed May 21, 2021, https://architecture2030.org/new-buildings-embodied/.

The manufacturing of wood products for construction produces low carbon emissions from fossil sources than other building materials, offering a low embodied carbon solution. Prefabricated processes, such as mass timber and light frame, can reduce waste and have greater efficiencies. Also, the potential for reducing construction time through prefabricated methods can reduce time and resources that may benefit the environment. Considerations for embodied and operational carbon must be integrated into the design parameters at an early stage. To avoid negative impacts, sustainable forestry management must be practiced, and considerations for end-of-life use of the material.

## 1.16 Embodied vs. Operational Carbon




From Architecture 2030[3]

- Annually, embodied carbon is responsible for 11% of global GHG emissions and 28% of global building sector emissions.
    - The embodied carbon emissions of building products and construction represent a significant portion of global emissions: concrete, iron, and steel alone produce ~9% of annual global GHG emissions; embodied carbon emissions from the building sector make 11% of annual global GHG emissions

- When we look at all the new construction projected to occur between now and 2050, we see the critical role embodied carbon plays.
    - Every year, 6.13 billion square meters of buildings are constructed. The embodied carbon emissions of that construction are approximately 3729 million metric tons $CO_2$per year. By the year 2050, accounting for all the new construction in those 30 years, embodied carbon emissions and operational carbon emissions will be roughly equivalent.

- 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 built. We

[3] Architecture 2030.

must handle embodied carbon now if we hope to phase out fossil fuel emissions by the year 2050.

## 1.17 Activity – Understanding Mass Timber

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

*See section 1.7 -1.11.*

2. ***What are the three advantages of mass timber?***
   - *Construction Advantage*
     - *Prefabrication on components provides greater precision and quality control.*
     - *Reduced on-site construction.*
   - *Aesthetic Advantage*
     - *Aesthetic and experiential benefits often make mass timber buildings desirable to tenants and aiding in biophilic benefits.*
   - *Ecological Advantage*
     - *The building represents close to 40% of the greenhouse gas emissions.*
     - *Wood can sequester carbon and is a low embodied carbon building product.*

3. ***Describe the four benefits of utilizing mass timber.***
   *The construction of wood can provide impact on multiple levels economic, social, environmental and cultural aspects.*

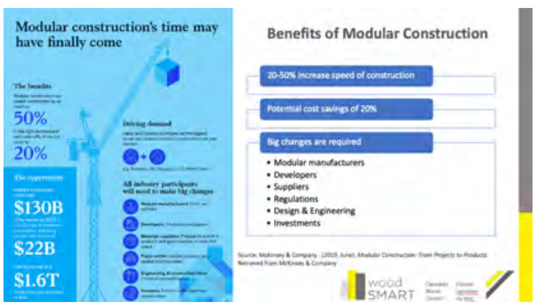
## 1.18 Advantages of Prefabrication


## 1.19 Prefabrication Process

Increased industrialization and automation of the construction process have led to the increased productivity of modular construction. This increase in industrialization is shifting building activity away from traditional on-site building to off-site manufacturing. This is moving processes toward prefabricated and modular building components where it is then assembled on-site.

There are varying degrees of modular construction, from kit-of-parts to three-dimensional volumetric units. The degree of modularity will depend on program requirements, site conditions, skills knowledge and manufacturer capabilities, to name a few. Developing a design that includes modular components requires a different framework for project development. Early adoption and commitment to modularity can lead to cost and schedule efficiencies and greater quality control.

## 1.20 Construction Advantage




As more knowledge and experience are gained in modular building products, it has been reported by McKinsey & Company that modular projects have consistently been completed 20-50 percent faster than traditional on-site builds.[4]

In addition, modular construction can:

- Reduce overall build costs
- Accelerate build schedules
- Greater certainty on build times and costs
- Improve the quality of the building, including better energy and seismic performance

## 1.21 Construction Advantage

[4] Nick Bertram et al., "Modular Construction: From Projects to Products," 2019.

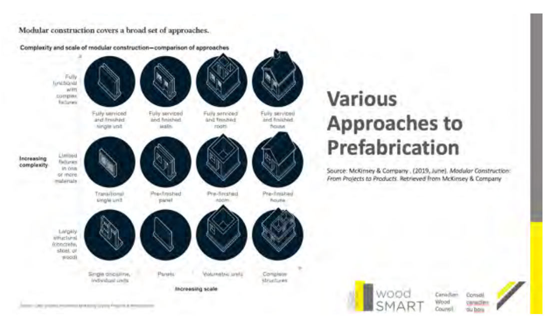

Mass timber construction is fast. According to structural engineering firm Fast + Epp, the firm's experience has been that mass timber projects are completed approximately 25% more quickly than similar projects that use concrete. The advantage is particularly acute for urban infill sites, as mass timber contributes to a 90% reduction in truck deliveries and 75% fewer workers on the active deck, making for a much quieter job site. For developers, less time in the construction phase equates to both lower costs and faster revenue opportunities.[5]

Mass timber weighs 75% less than concrete; they require smaller foundations, which can be a cost-benefit. The lighter frame also allows construction in soil that may not have been suitable previously.[6]

Because mass timber is prefabricated, less waste is involved as the precision of the panels and components is precisely executed. This also leads to greater quality and quality control.

Other advantages include - greater quality control due to in-shop fabrication processes. For the most part, mass timber products are constructed using computerized CNC machines, which provide optimal precision, increased construction speed and enhanced environmental control. This level of prefabrication requires the processes in which architects design buildings to be re-examined.

## 1.22 Various Approaches to Modular

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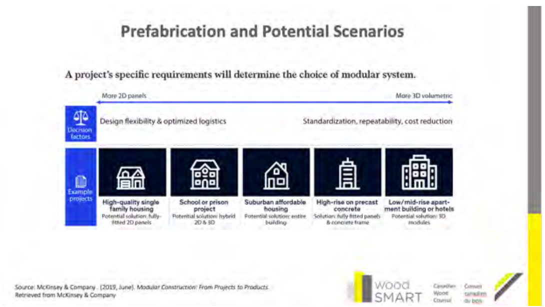
[5] Paul C Quinn and Marcus Campeau, "Imagine 2025: Mass Timber," 2020.
[6] Quinn and Campeau.

Modular construction involves producing standardized components in an off-site factory. The term modular and prefabrication are often used interchangeably yet can cover a range of approaches and systems. This can include a simple approach, such as a single element clipped together using standard connections to a complex, fully functional volume metric unit. Various degrees of prefabrication can exist as well as hybrid models.[7]

## 1.23 Prefabrication and Potential Scenarios




There are many potential degrees and uses of prefabrication and uses to mass timber. From 2D panels to 3D fully complete volumetric units, the varying degrees of prefabrication will be dependent on:

- Building type and program
- Site and location
- Potential for repetition

This slide illustrates some potential uses and varying degrees of prefabrication.

## 1.24 3D Volumetric Prefabrication


Maximize Productivity Benefits

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[7] Bertram et al., "Modular Construction: From Projects to Products."

A 3D volumetric approach is fully assembled and fitted out units that are assembled off-site. This can include a room or an entire small structure. On-site assembly involves lifting the modules into place and connecting this service is such as plumbing and electrical.

This approach can maximize efficiencies and time savings; however, the limitations include transportation costs and sizes. The maximum road transport that does not require police escort is typically 3.5 meters.[8]

This style is more suitable for compartmentalized designs such as hotels, students, or affordable housing because of its limited size.

It is also beneficial for projects that require intricate finishing, such as bathrooms and kitchens.

Modular units do not necessarily mean that every unit will look the same. Using standardized components and modules can be achieved by piercing them together differently to produce a customized result.

## 1.25 2D Panelized


Optimizing Logistics and Flexibility

A 2D modular approach includes prefabricating modular components that can be flat-packed for shipping and then assembled on site. Often used in panelized structural components, integration of mechanical in other service requirements can be prepped off-site.

The on-site assembly is more complicated than 3D volumetric however simpler than a traditional build. An advantage is that the transportation of the panels is more efficient than the 3D volumetric. As well, the shipping costs are significantly less than the 3D volumetric.

The 2D modular approach can also offer greater flexibility and are more appropriate for open plan design, such as for offices.

2D and 3D hybrid combined

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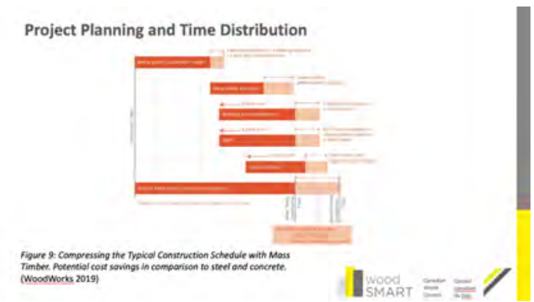
[8] Bertram et al.

It is possible to combine the approach of 2D and 3D modular components. For example, wet rooms and bathroom pods may be beneficial to construct as a 3D volumetric unit and the overall wall and floor assembly in 2D.

The construction sequencing of this approach must be carefully considered when combining the various systems. For example, a bathroom pod's insertion must be sequentially installed as the assembled floor assemblies.

## 1.26 Early Considerations for Optimizing Design
## 1.27 Project Planning and Design Considerations

## 1.28 Project Planning and Time Distribution




Buildings that include prefabricated systems require integrating design upfront in the planning process to ensure careful consideration of building use, site considerations, structure, systems integration, and construction sequencing. Sufficient time must be budgeted to allow extended planning time and enhanced coordination during the design and construction document stages.

Many decisions must be made early on in the process, as prefabrication and detail planning must be resolved before construction. This up-front planning investment can significantly reduce time during the construction phase, reduce on-site time, and heighten overall quality control.

Mass timber components are mostly prefabricated off-site in a factory setting. Increasingly, light-weight wood-framing construction is also prefabricated off-site, lending greater efficiencies on-site and hybrid capabilities.

## 1.29 Traditional Project Delivery – Design Bid Build

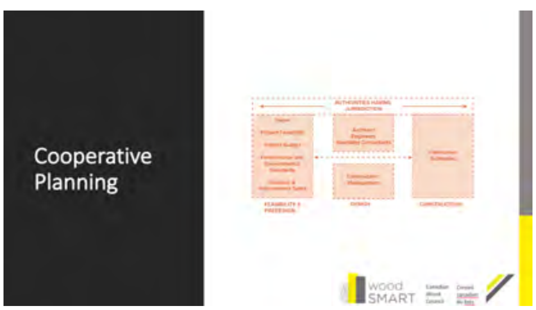

It cannot be overstressed the importance of planning your project carefully. Thorough early planning with a design team and a qualified constructor, experienced and collaborative, will deliver the project on schedule and on time and budget.

Creating an integrated and collaborative team dynamic will enable the group to find creative solutions towards the project's success. This multi-disciplinary team approach typically utilizes each other's strengths in working through the early design phase. Discuss procurement models – engage suppliers and the contractors early. This will enable developers and owners to have a clear understanding of target budgets.

Conversations need to be started as early in the predesign process as possible. It will layout project delivery methods and models, structural systems considered and critical target dates in the construction process.

Standard project delivery, such as design-big-build, does not offer the level of collaboration that can optimize design, cost and schedule opportunities in using prefabricated systems like mass timber.

## 1.30 Cooperative Planning




Integrated Design and Project Delivery methods allow for collaboration throughout critical times of the project. Ideally, the integrated design and construction team engage with the owner at the predesign and feasibility stage to inform overall project aspirations, methodology, schedule and costs.

## 1.31 Integrated Design and Project Delivery


The Integrated Design Process (IDP) is a multidisciplinary approach to building design that prioritizes a whole system approach. Implementing an IDP process is a critical step for achieving high-performance building design. The IDP process seeks to bring all key experts and stakeholders together to facilitate a collaborative design process. The best results are achieved when this process is implemented early on in a project and as early as the predesign stage. Ideally, the IDP process would involve the Owner, Architect, Engineers, Builders and Manufacturers working together from the beginning.[9]

## 1.32 The Integrated Team


Integrated Project Delivery (IPD) integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants. This delivery method can optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.[10] The IPD process involves a multi-party contract where the Owner, Primary Designer and Primary Builder engage. The agreement includes profit at risk to partners of the agreement and shared savings if the project is delivered under budget.[11]

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[9] Busby Perkins + Will and Stantec Consulting, "Roadmap for the Integrated Design Process," 2007, http://www.greenspacencr.org/events/IDProadmap.pdf.

[10] American Institute of Architects, "Integrated Project Delivery: A Guide.," 2007, https://info.aia.org/siteobjects/files/ipd_guide_2007.pdf.

[11] "Integrated Project Delivery for Construction - IPD," accessed June 4, 2021, https://leanipd.com/integrated-project-delivery/.

Conversations need to be started as early in the predesign process as possible to layout project delivery methods and models, structural systems being considered, and key target dates in the construction process.

## 1.33 Key Planning Consideration


Buildings that include prefabricated systems require integrating design upfront in the planning process to ensure careful consideration of building use, site considerations, structure, systems integration, and construction sequencing. Sufficient time must be budgeted to allow extended planning time and enhanced coordination during the design and construction document stages. Many decisions must be made early on in the process, as prefabrication and detail planning must be resolved before construction. This up-front planning investment can significantly reduce time during the construction phase, reduce on-site time, and heighten overall quality control.

## 1.34 Manufacturer Input


Wood is a natural building product, and its material property can vary between species and supplier. Not only can this impact the aesthetic of the material and sizes, but product availability can also range between manufacturers. In the case of mass timber, it is essential to identify the source as early as possible to optimize and inform design opportunities.

When selecting a mass timber structural system, an important consideration is manufacturing capabilities for products and sizing. Manufacturers may have various sizes capable of producing, particularly in cross-laminated timber and light-frame panelized systems. Optimizing panel size and reducing waste are critical for efficiency.

## 1.35 Kit of Parts


There are two types of industrialized approaches to prefabricated buildings: building kits (kit-of-parts) and finished modules. Building kits include prefabricated elements or sections that are then delivered and assembled on-site. These may include the roofing package (roof panels, fascia, gutter, etc.), roof structure (ceiling deck and beams), glazing package (windows and entrances) and building structure (wall panels, beam pockets, columns and shear panelling). The kit-of-parts approach, via panelization, is typical for mid-rise wood buildings.[12]

## 1.36 Know Your Products and Supply Chain


Given that wood is a naturally harvested material, the supply chain can impact the product's availability. With increasing interest in wood construction, the supply chain will require adequate time and resources to develop further to meet the demand. Allowing for range and flexibility in the design to accommodate product variation from supplier to supplier can significantly impact a project's viability. The cost of material can also be affected based on the demand of supply.

## 1.37 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?***

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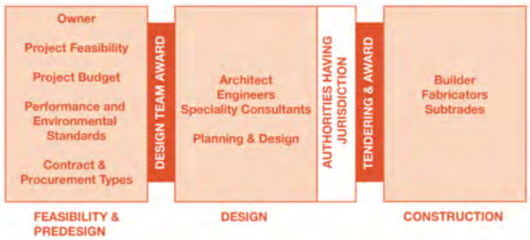
[12] Think Wood, "Designing Sustainable, Prefabricated Wood Buildings," *Architect* 107, no. 7 (2018): 42–45.


Owner
Project Feasibility
Project Budget
Performance and Environmental Standards
Contract & Procurement Types
DESIGN TEAM AWARD
Architect
Engineers
Speciality Consultants
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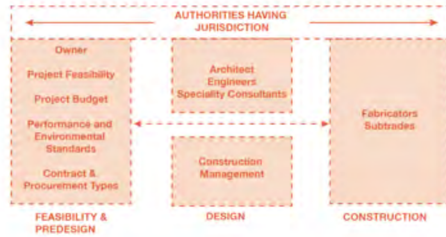
AUTHORITIES HAVING JURISDICTION
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Contract & Procurement Types
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Engineers
Speciality Consultants
Construction Management
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Subtrades
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MEP Engineer
Speciality Consultants
Fabricators
Sub contractor
General Contractor


Insurance
User
Legal
Owner
Facilities Management
Architect
Builder
Structural Engineer
Timber Fabricator
MEP Engineer
Speciality Consultants
Subtrades
MEP Subtrades

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ThinkWood; WoodWorks; "Mass Timber Design Manual," 2021. https://info.thinkwood.com/masstimberdesignmanual.

# 1 Module 1: Project Planning and Optimizing Design

# 2 Module 2: Design Considerations

## 2.1 Module 2: Design and Enhanced Integration (Objectives)


## 2.2 Introduction to Design Considerations


Timber is a complex and variable material. Theory and observation have given us practical design rules, which are continually refined through further research.[1]

- Fire safety design in mass timber buildings requires assessing the safety hazards posed by timber for the building occupants and firefighters. Key considerations include building height, occupancy, and the reaction of mass timber when used in compartments, when used as structure, and when used in internal walls.

- Design for durability involves consideration of the environment, species choice, weather protection, preservation treatments, insect barriers and inspection regimes.

- Design for satisfactory acoustics requires consideration of factors including noise sources, flanking path effects, absorbing underlays and resilient supports and bearings.

- Dynamic modelling and site measurement of timber buildings enable us to predict vibration outcomes relative to preferred comfort criteria for new designs.

[1] ARUP, “Rethinking Timber Buildings,” 2019, 100.

• Modelling and measuring environmental conditions inside timber buildings provide predictions for thermal comfort and energy performance.

## 2.3 Structural Design Considerations

## 2.4 Selecting a Structural System


Multiple factors will influence the choice of the structural system for a building. These include strength and stability, load capacity, program use and long-term flexibility. Also, the availability of material, construction speed, and cost are important considerations for which structural system to use.

## 2.5 Common Timber Systems


There are several systems available in mass timber as well as a number of combinations. Three main systems include:

1. Framed Systems
2. Panelized Systems
3. Hybrid Systems

## 2.6 Structural System and Program Uses


Residential buildings will generally be more compartmentalized and may benefit from panelized or loadbearing shear wall structural systems. On the other hand, commercial and institutional buildings typically require open floor plans and flexible space, which a post and beam system would be highly appropriate.

## 2.7 Structural System and Program Uses


In both instances of residential and office use, lightweight wood-framing construction is a consideration for mid-rise buildings. Lightweight wood-framing construction may be combined with timber posts and beams to achieve these longer spans in-office use.

Considering the requirements of a project, there may be instances where an all-wood structural system may not be appropriate. Combining concrete to create composite floor slabs may allow for longer spans and resolve shear forces. Steel may be utilized to support heavy loads and long spans. The transitioning between wood to steel or concrete may benefit mix occupancies where various grid spans may be desired between the floors. For example, concrete may be considered for podium levels. Also, a more extensive structural bay size may be preferred for assembly occupancy with a tighter grid system of wood for residential use above.

## 2.8 Key Considerations

Many factors are involved in selecting the building's systems. In considering a structural design, the architect and engineer must consider many factors, including program, cost, market conditions, constructability, maintenance and long-term flexibility. In addition, height restrictions, site constraints, and building systems integration may play a significant role in deciding on the proper structural system for the project.

Cost is a driving force in almost any building project. The cost of mass timber is significantly dependent on the price of lumber, supply chain, and wood volume. Optimizing the structural grid to reduce the volume of material will be the cost-effective route when it comes to mass timber.

Fire and acoustic requirements must be carefully considered. The use of concrete may be used in the floor construction to reduce impact noise from transferring from floor to floor. Also, concrete may be used to achieve fire separation ratings in combination or apart from the wood structure.

Code requirements may also dictate the type of mass timber structural system that is selected. For example, some provincial regulations require egress stairs to be constructed out of non-combustible materials; therefore, the use of concrete and steel must be considered in these areas.

All those involved in the decision-making process of each type of structural system's opportunities and constraints must come together early on in the project. Consideration of design, structure, systems integration, construction sequencing, manufacturing, and cost must be carefully weighed at the project's onset.

## 2.9 Factors in Selecting a Structural Form


An architect or engineer should not make this decision alone. Early collaboration with engineers, contractors, owners, and cost consultants can ensure that the project's long-term objectives will be met.

Factors in selecting of structural form. Source: Canadian Wood Council Introduction to Wood Design, 2018.

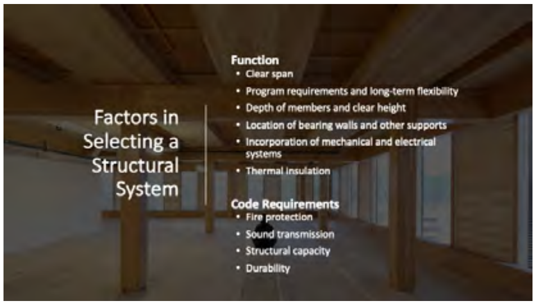
**Cost**

- 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

## 2.10 Factors in Selecting a Structural Form




**Function**

- Clearspan
- 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

## 2.11 Factors in Selecting a Structural Form


**Aesthetics**

- Appearance of material
- The appearance of the finished system
- An architectural blend of form and function

**Environmental**

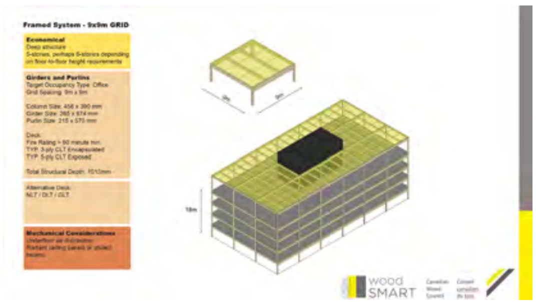
- Environmental impact of harvesting, mining, quarrying, and manufacture
- The energy required to manufacture, transport, and install materials

- Thermal efficiency of building systems
- Disposal, recycle or reuse at end-of-life cycle

## 2.12 Framed Structural System

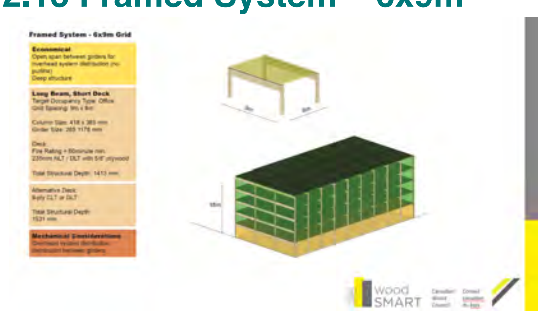
## 2.13 Framed System - 9x9m

Frame systems, which typically consist of posts and beams to carry the vertical and horizontal loads, lend themselves well to building programs that require larger spans between structural columns and flexible interior spaces. This system is ideal for office and commercial use as well as institutional assembly occupancies.

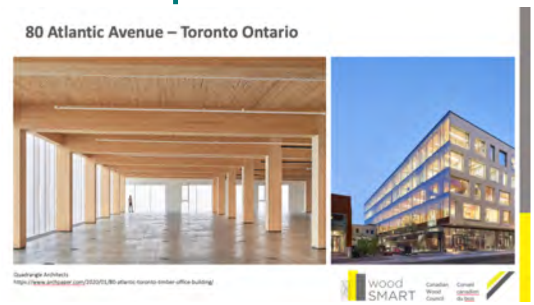



## 2.14 Example

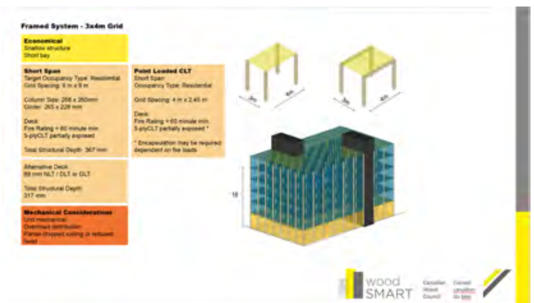

## 2.15 Framed System – 6x9m



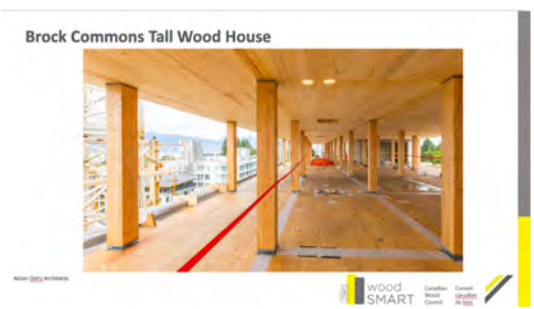
## 2.16 Example



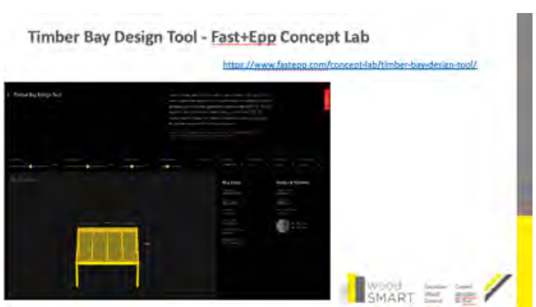

## 2.17 Framed System – 3x4m




## 2.18 Example



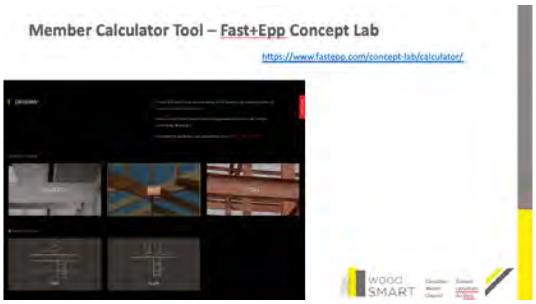

## 2.19 Timber Bay Design Tool – Fast + Epp Concept Lab



This tool, by Fast+Epp Structural Engineers, allows you to explore multiple options for mass timber grids by adjusting the parameters in the interactive web tool. Approximate calculations will be performed in the background to size up the deck, purlins, girders, and columns and display them all in 3D.

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

## 2.20 Member Calculator Tool – Fast + Epp Concept Lab




The member calculator tool, by Fast+Epp Structural Engineers, is a step-by-step selection process to find approximate member depths of various structural components. The sizes are approximate for the preliminary design.

## 2.21 Activity – Factors in Selecting a Structural System

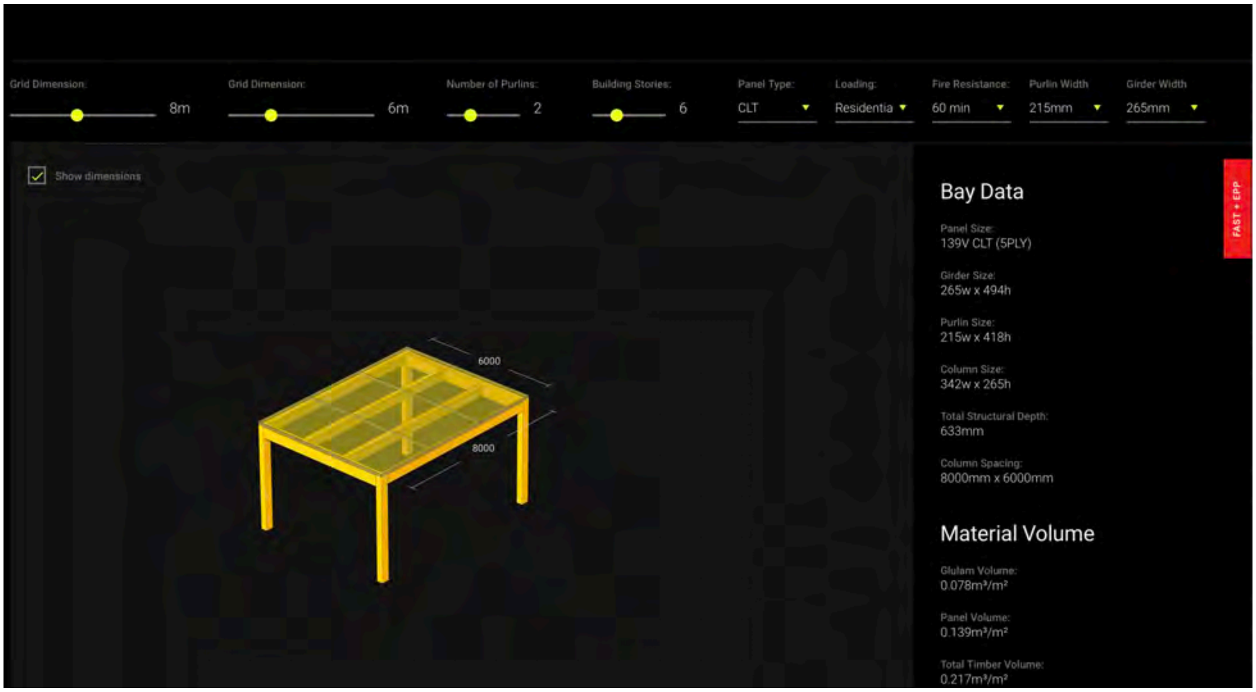
1. ***Name the six factors described in selecting a structural system.***

    *Cost*
    *Schedule*
    *Function*
    *Code Requirements*
    *Aesthetics*
    *Environmental*

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 with a 60 min fire-resistance rating.***

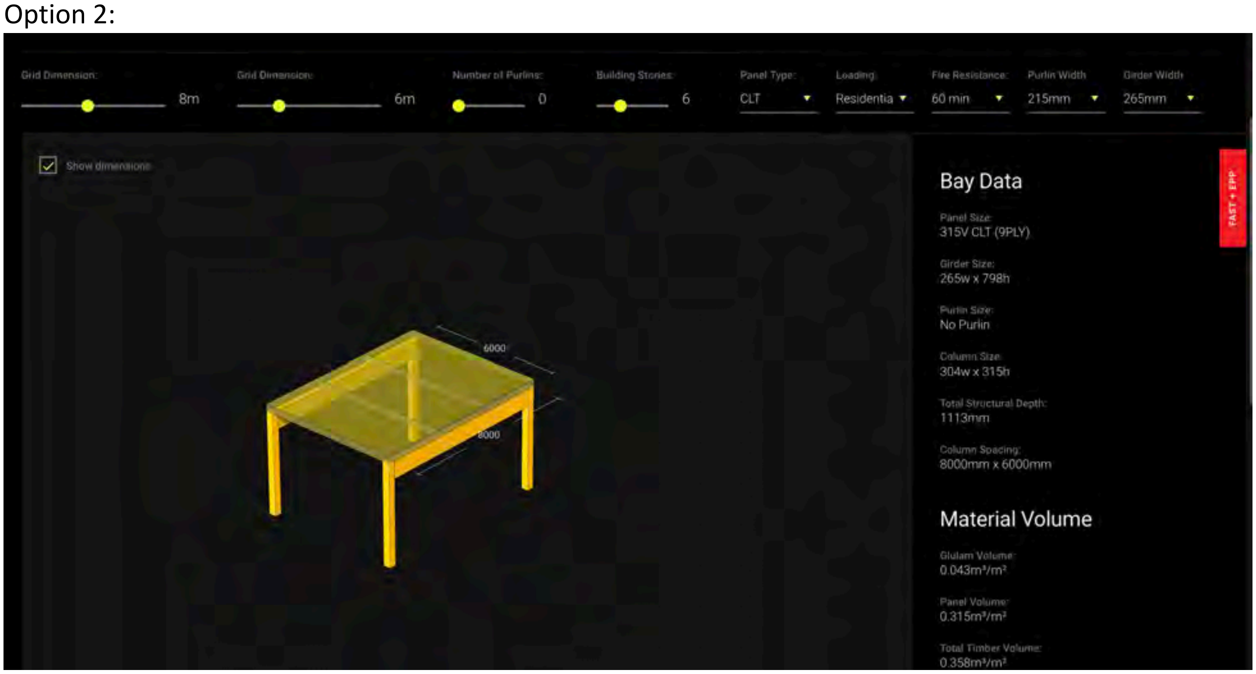
    ***Describe the advantages and challenges in design choices available for the scenario.***

**<u>Scenario A</u>**




2 purlins reduce the girder size – mechanical distribution must be carefully considered
Reduced floor to floor heights

Option 2:




No purlins – increase girder size
More flexibility for mechanical distribution
Greater structural depth, height to be considered

## 2.22 Hybrid System

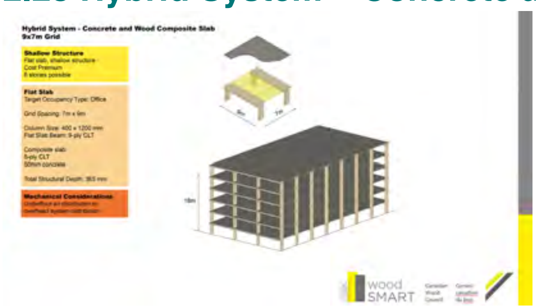
In some cases, an all-wood structural system may not provide the most preeminent system. This may be due to structural requirements, fire requirements, design, flexibility or costs.

Hybrid systems combine various materials in structural components. The various properties of the materials can be combined to optimize the overall strategy to meet specific objectives. The combination of materials or construction methods can range significantly.

Timber and concrete can be combined at the floor slab to provide for longer spans, provide better vibration, enhance acoustics, and mitigate against deflection and sagging conditions. As well, concrete may be utilized to accommodate heavier loads. Concrete under compressive stress bonded to timber decking can create a shear-resistant action.

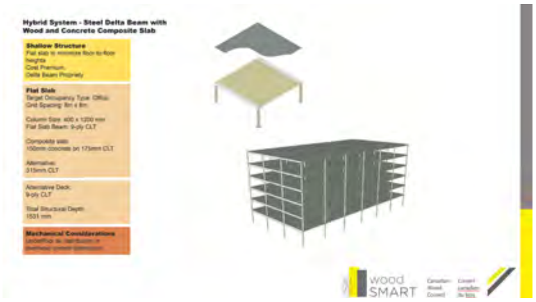
Timber and steel can be combined to support heavier loads and span longer distances between structural supports. Also, using steel for the horizontal load distribution can result in shallower structural depths. It may reduce overall floor to floor height that may be the determining factor in achieving six storeys in a long span condition.

## 2.23 Hybrid System – Concrete and Wood Composite Slab




## 2.24 Example


## 2.25 Hybrid System – Steel Delta Beam




## 2.26 Example


## 2.27 Example – 80 M Street, Washington D.C.


## 2.28 Panelized System

## 2.29 Cross-Laminated Timber Panelized System

Panel systems comprise solid wall and floor panels arranged in two directions that carry vertical and horizontal loads. Panel wall systems can be constructed out of light-frame construction as well as mass timber components. Cross-Laminated Timber has become an ideal material for the panel system due to its high strength.

The panel system can have many advantages, including acting as a loadbearing wall. This may have benefits and use panel systems on exterior walls; however, combustible construction on exterior walls is limited in the mid-rise code requirements. Encapsulated or other fire rating strategies may be required. Panel systems often result in a compartmentalized design that can work well with residential-type occupancies. And considering panel systems, openings must be carefully considered so as not to compromise the structural capacity.

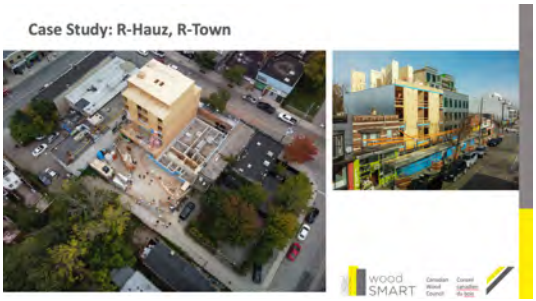
## 2.30 Example - The Cube – Hamburg, Germany


## 2.31 Case Study: R-Hauz, R-Town – Toronto, Ontario

## 2.32 R-Hauz, R-Town


The R-Hauz, R-Town in Toronto, Ontario, is a multi-unit stacked townhouse complex designed using cross-laminated timber panels as the structural system on twenty-foot modules. Located at Queen St. East and Coxwell Avenue, this pilot project for R-Hauz is the first all-wood, mass timber, six-storey building in Ontario. The project utilized an all-wooden elevator shaft and stairwell, although it required a detailed alternative compliance approval, accelerated overall construction timelines. The building design responded to a narrow infill site, maximizing the use of wood according to mid-rise provisions.

## 2.33 R-Hauz, R-Town




Construction of the complex utilized the rear laneway system and thoroughly considered each CLT panel and crane size to avoid road closures when unloading and tilting into the prefabricated panels.

The off-site prefabrication of the mass timber structure provided a less wasteful system and easier to build. In addition, the prefabricated elements reduced the number of trades on-site, making the on-site traffic management and coordination less onerous.

Knowledge and repeatability of the systems are key in optimizing costs in the mass timber townhouse complex. In considering the cost-efficiencies over time, an Integrated Program Delivery model was followed to benefit from inherent knowledge of the skills and trade team over time.

The construction sequencing was carefully considered in the design of the building and mass timber panels. The strategy included a tilting up process utilizing a hoist-crane located in the rear of the property. Forty feet of the site area was maintained in the rear of the site to accommodate the construction process and at grade parking. The building utilized a slab-on-grade construction to prevent disruption to the streetcar system along Queen Street East. Together, these strategies added in reducing overall costs.

## 2.34 Case Study: YWCA Supportive Housing, Kitchener-Waterloo

## 2.35 Case Study: YWCA Supportive Housing


The YWCA project is a 41-unit supportive housing project as part of Canada's Rapid Housing Initiative. Cross-laminated timber panels are used in both the structure and the prefabricated envelop system. The CLIP envelop system provided by Element5 is cross-laminated panels in a complete envelope system, are prefabricated off-site in a controlled factory environment. The system offers shortening construction timelines, facilitating rapid building enclosure while increasing the quality and energy performance of the building envelope.

## 2.36 Case Study: YWCA Supportive Housing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Design efficiencies are realized by working as an integrated project team, where close communication between the architect, developer and mass timber fabricator establishes an efficient and cost-effective housing solution. Through close collaboration, cost savings are enabled by reducing construction time, reducing waste and optimizing the use of the CLT panels.

The mass timber will be fabricated locally by Element5's newly completed Ontario mass timber manufacturing facility. In addition, the wood used will be supplied by Ontario forests, minimizing transportation of the product while supporting the local economy.

## 2.37 Case Study: YWCA Supportive Housing


One of the key drivers in this cost-efficient system is the speed of construction. The CLT panels are designed to span two units, optimizing the product while reducing construction time by limiting the number of lifts, creating efficiency and construction speed. The elevator and stair cores are also designed with CLT panels and placed on the floor plate's outer edge, simplifying the main floor plate design. The mass timber for the project will be locally supplied by Element5, including the raw materials from Ontario forests.

## 2.38 Case Study: YWCA Supportive Housing


The speed of construction is noted to be one of the key elements in reducing overall costs. The design utilized cross-laminated timber panels for floor and wall construction. The CLT floor slab spans the distance of two units, optimizing the CLT material while reducing construction time by reducing the number of lifts. CLT elevator and stair cores are also utilized and placed on the outer edge of the floor plate to increase construction time and simplify connections.

## 2.39 Designing for Fire Protection

## 2.40 Fire Protection – Key Considerations


For fire protection of mass timber buildings, building codes require all buildings to perform to the same level of safety regardless of materials. Wood buildings can be designed to meet rigorous performance standards, so building codes are being modified to allow for design in wood.

Many misconceptions exist regarding the fire performance of wood buildings. Many of these are due to experiences of light-frame structures as opposed to heavy timber or engineered mass timber construction.

Wood products such as the large beams used in heavy timber construction and cross-laminated timber may perform better in a fire situation than non-combustible materials. Because these products are thick and solid, they char on the outside at a slow and predictable rate while retaining strength, slowing combustion and allowing time to evacuate the building. The char protects the wood from further degradation, helping to maintain the building's structural integrity and reducing its fuel contribution to the fire, which lessens the fire's heat and flame propagation.[2]

Key considerations in Fire Protection include:

- Code requirements
- Passive Fire Protection strategies
- Active Fire Protection strategies
- Fire Protection during construction

## 2.41 Passive Fire Protection Strategies


Passive fire protection is what resists a fire at its point of origin. Components and systems are intended to contain a fire or slow the spread of fires through fire-resistant building elements. The requirements for passive fire resistance strategies will be greatly dependent on the building's use and occupancy classification.[3]

- Fire-resistant rating of structure in floors
- level of encapsulated material
- fire rating of egress routes
- fire separation requirements

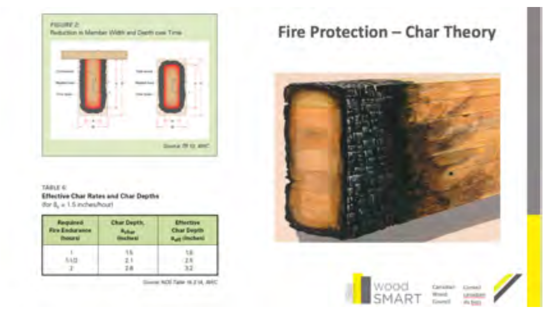
## 2.42 Active Fire Protection


[2] Jeffrey B. and Stone and David P. Tyree, “Think Wood Continuing Education on Designing for Fire Protection,” 2015, www.awc.org/codes/dcaindex.html.
[3] Stone and Tyree.

Active Fire Protection is characterized by detection and response systems. Detection of fire through smoke or heat sensors initiates a chain reaction of events that reduces the threat of fire. Once a detection system is activated, a chain reaction of events will occur that may include:

- fire dampers
- closure of automatic doors
- fire sprinklers activated
- fire suppression system activated

## 2.43 Char




As timber burns, a layer of char begins to form, an insulating element that prevents and rise in temperature within the section.

Wood products such as the large beams used in heavy timber construction and cross-laminated timber may perform better in a fire situation than non-combustible materials. Because these products are thick and solid, they char on the outside at a slow and predictable rate while retaining strength, slowing combustion and allowing time to evacuate the building. The char protects the wood from further degradation, helping to maintain the building's structural integrity and reducing its fuel contribution to the fire, which lessens the fire's heat and flame propagation.[4]

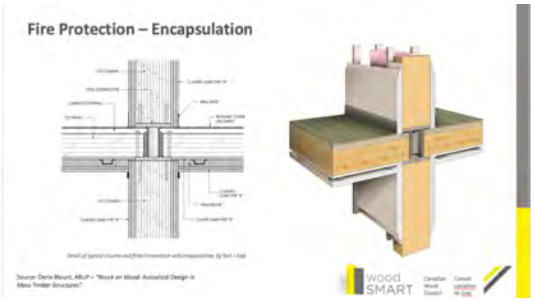
It is possible to provide a fire-resistant rating through char theory. The additional thickness must be added to the structural section requirements of the timber member to do so.

Advantages include exposure to the mass timber for experience and aesthetics. However, additional costs are endured as every member exposed and are required to have a fire-resistant rating must be oversized.

Depending on the building occupancy and building code requirements, it may be required that only a percentage of the overall building may be exposed to mass timber.

## 2.44 Fire Protection - Encapsulation

[4] Stone and Tyree.




Encapsulation Mass Timber Construction (EMTC) refers to a construction type involving the encapsulation of the mass timber using an approved rated material, such as fire-rated gypsum board. EMTC assemblies have been tested and, incoming updates to the National Building Code are anticipated to be an acceptable method of fire protection for structures up to 12 storeys in height.

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


High-Rise Mass Timber Construction

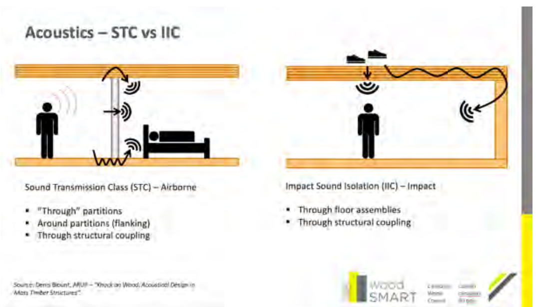
- Less than four levels of unprotected wood during construction.
- Protection of wood structural elements by installing a layer of Type X gypsum board and concrete topping as the structure is built.
- Functional standpipe in concrete cores.
- On-site security and fire watch

## 2.46 Carbon 12 – Portland Oregon

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

## 2.47 Designing for Acoustics and Vibration

## 2.48 Acoustics – STC vs IIC




Lower frequency sounds transfer more easily through the walls:

Acoustics has a direct impact on the user experience of a building. It can impact mental and health well-being, in addition to maintaining privacy for the inhabitants.

In dealing with mass timber, or any building, there are two acoustic concerns:

1. Sound Transmission Class (STC)
2. Impact Sound Isolation (IIC)

The building codes prescribed minimum requirements for these ratings depending on use.

As a general description, STC is airborne noise that can travel through partitions or around partitions known as flanking. On the other hand, IIC is the noise that occurs through the impact that affects typically affects floor assemblies. (Blount)

Because mass timber is a lightweight material, noise and acoustics are of particular concern as noise travels more easily through these systems. As a general rule, more mass means better noise control. Because it is lighter than concrete, lower frequency sounds transfer more easily through the wood. But that doesn't necessarily mean that a wood building will be noisy. With proper design, it can be as quiet as one built with concrete. This could mean incorporating a dropped ceiling below the wood structure or using a raised floor system to achieve satisfactory sound separation of floors and ceilings.[5]

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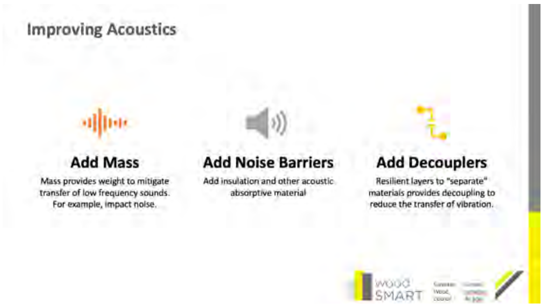
[5] Tim Preager, "Top 5 Things You Should Know Before Building a Mass Timber Project | Aercoustics," accessed June 4, 2021, https://aercoustics.com/top-5-things-know-building-mass-timber-project/.

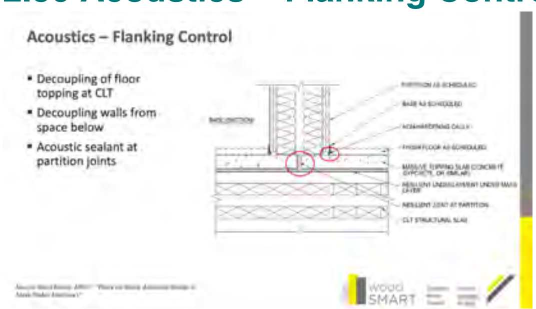
## 2.49 Improving Acoustic Performance




There are three main ways to improve an assembly's acoustical performance: [6]

1. Add mass
2. Add noise barriers
3. Add decouplers

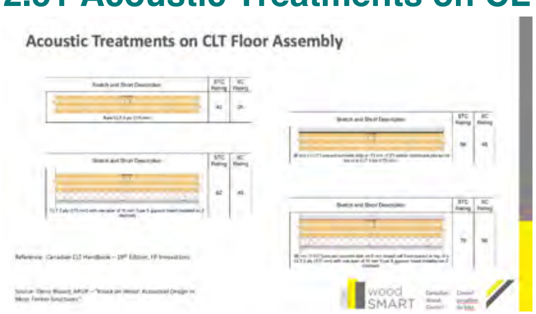
## 2.50 Acoustics – Flanking Control




Methods in flanking control:

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

## 2.51 Acoustic Treatments on CLT Floor Assembly

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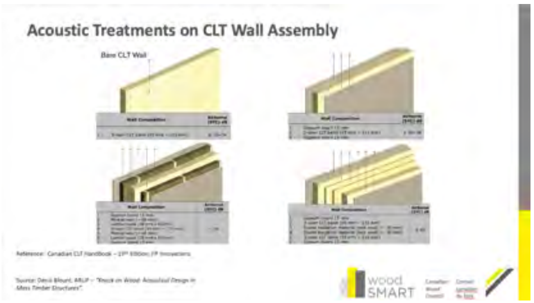
[6] Richard McLain, "Acoustics and Mass Timber: Room-to-Room Noise Control," Civil + Structural Engineering Magazine, accessed June 4, 2021, https://csengineermag.com/acoustics-and-mass-timber-room-to-room-noise-control/.

## 2.52 Acoustic Treatments on CLT Wall Assembly




Not all mass timber performs equally. Controlled laboratory Sound Transmission Class (STC) testing found CLT performs slightly better than other options as the laminates are cross-oriented in a panel and have less susceptibility for small holes and cracks.[7]

## 2.53 Other Design Considerations


There are several design considerations in designing any type of building. For a mass timber building, below are a number of additional items that require specific attention.

- Full-scale mockups
  - Consider mockups during design and early in construction to ensure details and construction sequencing is tested
- Fireproofing of connectors
- Vibration and Acoustics
- Approval Process and AHJ
  - Each code a
- Insurance Requirements
  - With any new technology or building method, there comes a level of risk associated. Owners should Insurance companies should be consulted early on in the design process to mitigate uncertainly and risk. As well, contracts and professionals should also understand the level of risk and insurance requirements associated.
- Temporary fire protection during construction

[7] Preager, “Top 5 Things You Should Know Before Building a Mass Timber Project | Aercoustics.”

    - Fire safety during construction is an important consideration that may impact design direction. Authorities having jurisdiction or insurance companies may require specific requirements and precautions to be taken that may impact construction sequencing that may impact design decisions.
- On-site Security and Protection
- Supply Chain
    - Mass timber is a growing industry in Canada; however, the interest and demand are currently higher than can be supplied – especially in some regions of the country. Being proactive with suppliers will determine lead times of product delivery and requirements.

## 2.54 Activity: Understanding Fire Protection and Acoustics

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

    *Passive*

    - *Fire-resistant rating of structure in floors*
    - *level of encapsulated material*
    - *fire rating of egress routes*
    - *fire separation requirements*

    *Active*

    - *fire dampers*
    - *closure of automatic doors*
    - *fire sprinklers activated*
    - *fire suppression system activated*

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

    *Sound Transmission Class (STC)*
    *Impact Sound Isolation (IIC)*

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

    *Add mass*
    *Add noise barriers*
    *Add decouplers*

## 2.55 Retrofits and Adding Storeys to Existing Buildings

## 2.56 Adding Stories to Existing Buildings


Wood construction offers an advantage in that it is lightweight, and in the case of mass timber and some lightweight wood-framing systems, prefabricated. In some cases, this can reduce the need to reinforce existing structures and foundations to accommodate additional storeys. In addition, considering modular and kit-of-parts components can lend itself well to constricted urban sites. This can potentially reduce adverse effects during construction to the lower storeys and neighbours as prefabricated buildings tend to be constructed quicker, reducing construction time, and are often less noisy than other traditional building materials.

Currently, the need for housing is a priority, and as we move into the future and the world's population continues to increase, urban densification will be critical in addressing population growth. Across Canada, three to four-storey buildings can be commonly seen on main streets. Adding stories to existing buildings can be an essential method of adaptive reuse of existing buildings and increasing density in cities and towns.

## 2.57 Consideration of Mass Timber and Adding Stories

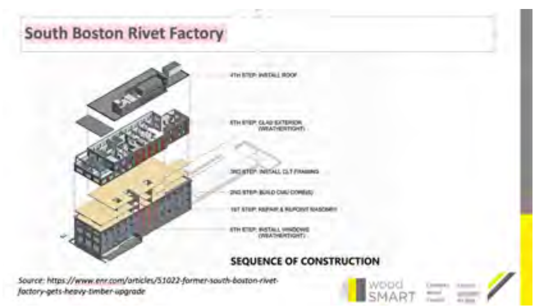

In working with existing buildings, there are many complex issues to consider, including.

- Strategies for managing the variations existing with older buildings against the precision of mass timber members must be carefully planned out early on in the design process.
- Managing aesthetic of new construction with existing.
- When heritage resources are involved, carefully considering the attributes of the heritage resource and working closely with Authorities Having Jurisdiction.
- Adequate protection of existing structures during construction and managing water and thermal barriers to minimize water penetration.
- Carefully considering thermal and moisture transition details between old to new.
- Structural capacities of existing structure and foundation to manage additional loads.

## 2.58 South Boston Rivet Factory


South Boston Rivet Factory. This 120-year-old masonry and heavy timber structure underwent a two-storey addition using Cross-Laminated Timber (CLT). The lightweight nature of mass timber eliminated the need to reinforce the existing foundations to support the additional. As well, the prefabricated kit-of-parts approach to the new mass timber building structure lent itself well to the constricted urban site. Challenges included that the existing structure was not plumb, and careful consideration was required to tie in the fairly precise CLT members with the irregularities of the existing structure. To navigate this issue, a concrete spandrel beam was installed at the perimeter of the existing structure for the CLT structure to be placed on top. The mass timber structure of the proposed addition was erected in six days. Source: Engineering News-Record.

## 2.59 South Boston Rivet Factory




Sequence of construction at the South Boston Rivet Factory.

## 2.60 Resources

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McLain, Richard. “Acoustics and Mass Timber: Room-to-Room Noise Control.” Civil + Structural Engineering Magazine. Accessed June 4, 2021. https://csengineermag.com/acoustics-and-mass-timber-room-to-room-noise-control/.

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# 1 Module 1: Project Planning and Optimizing Design

# 2 Module 2: Design Considerations

# 3 Module 3: Early Construction Sequencing

## 3.1 Automation and Industrialization of Mass Timber


The construction industry is increasingly adopting methods of automation and industrialization.

The prefabricated building consists of parts and components that are premanufactured in factories. With this, there is an increasing interest to fabricate building components off-site and growing interest in Design for Manufacturing and Assembly (DfMA) to suit modular construction. Off-site fabrication in a controlled environment can offer better quality control, reduce material waste, and potentially reduce time on site, lending to over-schedule and cost savings.

## 3.2 Benefits of Prefabrication


Benefits of prefabrication:[1]

- Less noise, dust and site disruption
- Improved health and safety
- Continuity of employment
- Workforce upskilling
- Predictable product performance
- Lower product operational costs

[1] ARUP, "Rethinking Timber Buildings," 2019, 100.

## 3.3 Benefits of Mass Timber and Prefabrication

The production of engineered mass timber is a highly sophisticated process utilizing computer numerically controlled (CNC) equipment to precisely cut and shape the products. This precision in the construction process requires that all aspects interfacing with the mass timber structure must be fully coordinated ahead of manufacturing to avoid on-site modification.

- Mass timber is easily machinable, making it an excellent fit with CNC-based factory processes used
- Timber can be spliced and laminated timber, giving a vast array of prefabricated products and possibilities.
- Timber's lightweight nature and ease of assembly make it possible to construct varying degrees of prefabrication – from modular components to fully volumeter module units.
- Mass timber offers a speed of construction that can potentially generate overall cost savings.

## 3.4 Building Information Modeling (BIM)


Building Information Modeling (BIM) is an intelligent 3D model-based process that gives architecture, engineers, construction professionals a platform for data management and shared resources to enable efficient planning, design, construction and building management. The utilization of BIM in the development and fabrication of mass timber is critical.

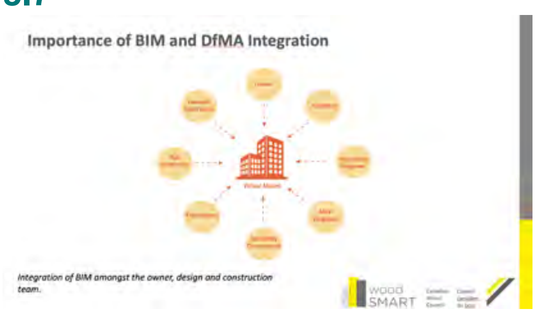
## 3.5 Design for Manufacture and Assembly (DfMA)


Design for Manufacture and Assembly (DfMA) is a design approach that focuses on ease of manufacture and efficiency of assembly. By simplifying the design of a product, it is possible to manufacture and assemble it more efficiently, in the minimum time and at a lower cost[2].
In DfMA processes, every aspect of the building is broken down into prefabricated building components like walls, columns, beams, stairs, and volumetric components such as bathrooms. The intent is that each component's design is optimized for efficiency in manufacturing and assembly to ensure efficiency in material, cost, on-site assembly, and durability. Below are the impacts that a DfMA process can have:

- Reduce Cost
- Reduce Schedule
- Improve Site Safety
- Reduce Waste
- Reduce On-Site Labour
- Higher Productivity
- Improved Environmental Performance
- Higher Quality
- Increased airtightness performance
- Ease of Reuse & Deconstruction

## 3.6 Importance of BIM and DfMA Integration

## 3.7




BIM and Virtual Design and Construction (VDC) – an integrated process that contains intelligent information of a building design that aids in visualizing the construction site to optimize sequencing and

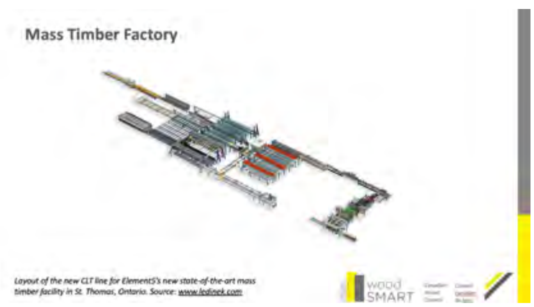
[2] (Design Buildings 2020)

schedule and DfMA processes. This can significantly reduce risk, on-site change orders, allow thorough planning of safety procedures, and accelerate the construction schedule.

## 3.8 Virtual Design and Construction Modelling


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

## 3.9 The Mass Timber Factory




The mass timber industry has extensively adopted the process of DfMA to enable modular and off-site construction. The use of sophisticated equipment and manufacturing processes is evolving the construction industry from on-site construction to off-site, highly sophisticated, computerized manufacturing facilities.

## 3.10 Digital Twin / Virtual Design and Construction Model


The digital twin is a virtual representation that serves as a real-time digital counterpart of a physical object or process. It permits the measurement of real-world building performance against a simulated proxy to head off problems before they occur.[3]

Digital twin in construction is increasingly being used to aid construction projects by accelerating automating traditional design, production, and operational processes. It can serve as the backbone for prefabrication and as a more significant means for achieving industrialized efficiency.

This process can help reduce the uncertainty during the construction process and can:

- Reduce risk through improved analysis during design
- Improve project efficiency and construction quality control
- Reduce downtime during construction
- Streamline pre-planned processes,
- Enhance coordination of trades and suppliers [4]

## 3.11 Video – Digital Twin, Virtual Design and Construction Modeling


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

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[3] John Bleasby, "UBC's Brock Commons Goes 'to BIM and beyond' with Digital Twins - Constructconnect.Com," 2020, https://canada.constructconnect.com/joc/news/technology/2020/08/ubcs-brock-commons-goes-to-bim-and-beyond-with-digital-twins.

[4] Bleasby.

## 3.12 Next Generation of Automation


Industry and researchers worldwide collaborate with robotic manufacturers, construction companies, and timber suppliers to develop the "next-generation" of prefabrication and assembly technologies. This track-mounted industrial robot by ABB uses spatially aware software to re-position itself while fabricating a modular timber wall creating greater flexibility and versatility both on and off the construction site.[5]

## 3.13 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.***

- Less noise, dust and site disruption
- Improved health and safety
- Continuity of employment
- Workforce upskilling
- Predictable product performance
- Lower product operational costs

[5] Volker Helm et al., "Mobile Robotic Fabrication on Construction Sites: DimRob," *IEEE International Conference on Intelligent Robots and Systems*, 2012, 4335–41, https://doi.org/10.1109/IROS.2012.6385617.

## 3.14 Systems Integration

## 3.15 Prefabrication and System Integration


Early Mechanical, Electrical, Plumbing and Fire (MEPF) system coordination can positively impact overall aesthetics, costs, and maintenance. On average, structural systems account for 20-25% of the total building costs and MEPF account for 30-35%.[6] In any project, diligent coordination of these systems can reduce undesired design outcomes and reduce extra costs during construction.
Early in the design process, engaging all members of the integrated design team in a systems workshop can avoid later coordination and interference issues. Earlier in the process, the team must review the structural and MEPF systems carefully to decide on the best approach to address the program, cost constraints, aesthetic and sustainable needs – just to name a few.

- Floor-to-floor heights
- Sustainability targets
- Program needs
- Fabrication, constructability and sequencing
- Future maintenance requirements

## 3.16 System Integration


In mass timber buildings, it is often the desire to expose the structure. Thoughtful exposure of service systems must be planned carefully. A strategy for placement of surface mounted conduit for plugs, switches, light fixtures and running of pipe and ductwork will be considered early. It will play a significant role in the overall aesthetic. Mass timber beams are often fairly deep; therefore, the route of any MEPF systems should be carefully considered to ensure the required head height is maintained.
Key considerations in MEPF coordination:

- Routing and mounting of electrical conduit for plugs, switches and lights.

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[6] Roy Anderson et al., "North American Mass Timber," 2020, https://masstimberreport.docsend.com/view/n6c8qap47cjd99ac.

- For smaller conduits, it may be possible to coordinate routing through mass timber members; however, the exact location and size must be carefully considered and designed before fabrication.
- Overhead mechanical distribution versus at floor in a raised access floor system.
- Dropped ceiling versus exposed.
- Penetrations through structural members and floor systems.

## 3.17 System Integration


Planning for off-site fabricated components can improve schedule and craftsmanship and reduce overall risk.[7] Involving MEPF subcontractors in the design stage can bring valuable insight into construction sequencing and installation. The use of sophisticated digital modelling programs, such as Building Information Modeling (BIM) and Virtual Design and Construction (VDC) modelling, can be an effective way to undergo this level of enhanced coordination.

This level of enhanced coordination is not typical in a traditional building project. Therefore, careful consideration must be given to the appropriate time required to perform this detailed level of design and coordination early in the design stages. This upfront planning and coordination can significantly reduce the construction schedule, extra costs and risks.

## 3.18 Case Study: Brock Commons Digital Twin, Virtual Design and Construction Model (VDC)

## 3.19 Introduction

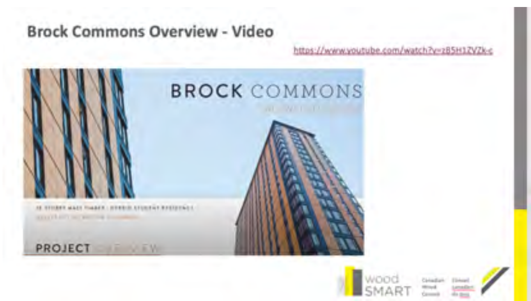

[7] Anderson et al.

Brock Commons is one of the demonstration projects supported by the 2013 Natural Resources Canada and Canada Wood Council competition—the Tall Wood Building Demonstration Initiative—which aimed to advance the design and production of wood products in Canada. This pioneering building showcases innovations in engineered wood products and building techniques. It creates unique research and learning opportunities related to the design, construction, operation, and inhabitation of a tall wood building in a North American context.

Brock Common student residence at the University of British Columbia. Standing at 18m-storey and 54m high, it was the tallest mass timber structure in the world when it opened in 2017.

Brock Commons Tallwood House is unique in the use of a hybrid mass timber structure. The foundation, ground floor, and stair/elevator cores are concrete, while the superstructure is composed of cross-laminated timber introduction (CLT) panel floor assemblies supported on parallel strand lumber (PSL) or glue-laminated timber (GLT) columns with steel connections.

## 3.20 Brock Commons Overview – Video 1




Ch 1: Overview

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

## 3.21 Design Phase – Virtual Design and Construction Modeling


Brock Common student residence at the University of British Columbia was the tallest mass timber structure in the world when it opened in 2017. The building was designed with cross-laminated timber (CLT) floor deck, glulam beams and a concrete stair core.

The tall mass timber structure was a first of its kind, and experience with the structural system, size and complexity were new for those involved – including the architect and builder. As such, digital twin software consultants CadMakers were engaged to prepare the model. Through computer software, the construction sequence was digitally simulated, even before any construction began on site.

## 3.22 Virtual Design and Construction Modelling


As part of Brock Commons' design and pre-construction phase, a virtual design and construction (VDC) model of the building was created. This VDC model was a comprehensive 3D model composed of all building elements, from the structure to interior finishes to the mechanical and electrical systems. The job of the VDC modeller was to maintain the comprehensive 3D virtual model as the consultants designed the systems and provided the information to the VDC modeller.

During the design stage, the virtual model was used to assist in the decision-making process and coordinate between the consultants. The VDC modeller worked with other consultants on 2D and 3D models, providing an exceptional level of detail.

## 3.23 Construction Photo

## 3.24 Construction Photo

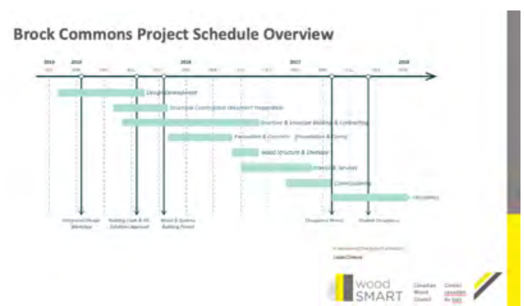

Every party of the consultant team worked closely with Cadmakers, to collaborate on the mechanical, electrical and plumbing design, fabrication, and installation – in a 4D digital assembly detecting clashes and interferences and finding construction efficiencies.[8]

## 3.25 Brock Commons Design Process – Video 2

Ch 2: Design Process

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

## 3.26 The benefit of VOC Modelling




The benefit of the VDC model:

- The detailed level of conflict resolution and clash detection between systems, early in the design stage
- The detail level of system integration and coordination, modelling every penetration and connection to ensure the CLT panels were prefabricated correctly
- Ensure the appropriate clearances are kept
- Enabled 4D simulation of the installation sequence that was developed from the 3D virtual model providing an overview of assembly of the building elements

[8] Think Wood, "Designing Sustainable, Prefabricated Wood Buildings," *Architect* 107, no. 7 (2018): 42–45.

- Assisted in visualizing the construction process and aid in resolving issues before construction commencing reducing potential site delays and extra costs
- In addition, it aided in trades understanding the scope of work relative to the project as a whole, reducing misunderstandings as well as providing a higher level of understanding to obtain more accurate costing

## 3.27 Pre-Construction Phase – Full-Scale Mock-Up


During pre-construction, the VDC model was used to create a full-size, proof-of-concept mock-up of part of two floors of the building.

The proof of concept helped validate the VDC model and benefit from acquiring trade input to help make decisions on design and detail elements.

It also provided an opportunity to study constructability and installation procedures. To test communication procedures for prefabrication, select installation equipment and identify options for efficiencies. These experiences and knowledge informed the construction planning, including sequencing and prefabrication of assembly packages. The VDC model was also the basis for the fabrication model used directly by the CNC machines for the CLT panel stress tests.[9]

The project team used the mock-up to:

- test and validate design details,
- constructability of the structural system
- connections between structural components – ie. Colours and floor assembly
- the connection between the mass timber panel and concrete core
- connections between the mass timber panel and the prefabricated envelop panels

The virtual design models and physical mock-ups were analyzed to improve the accuracy of fabrication and the coordination of components and assemblies.

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[9] Think Wood.

## 3.28 Construction Planning


During construction, the VDC modeller worked closely with the construction team. The schedule for the project was aggressive, which, along with the small size of the site, placed importance on the coordination of the production, storage, delivery and installation of all the building components.[10]

This highly collaborative process was facilitated given the construction management procurement process where the builder was on board from the start to provide input in construction and sequencing. The construction management process provided access to trades, including the mass timber manufacturer and installer, early in the process – for a highly collaborative and integrated design process.

During the design stage, the VDC model was used to simulate construction sequencing – including delivery, installation and safety procedures.

Also known as time-based construction modelling, these animations were highly detailed and based on one-hour increments. The animation was essentially a virtual construction process for the building, which allowed the construction manager and the trades to work through the installation procedures in 3D and
confirm their feasibility before actual construction.[11]

## 3.29 Prefabrication and System Design


A significant strategy used at Brock Commons was the prefabrication of a "kit-of-parts" structural and envelop system.

[10] Think Wood.
[11] Think Wood.

Mass timber offers a high degree of precision. With this, a +/- 2mm tolerance can be expected. This is a benefit on many levels; however, it can also make interfacing with other systems that cannot achieve the same level of tolerances, for example, steel and concrete components, tricky.

The VDC modelling helped resolve these issues, where a strategy for managing the tolerances was established before construction.

Another advantage of VDC modelling is the integration of Mechanical, Electrical and Plumbing (MEP) systems. Typically, engineers design the systems and leave a level of spatial layout to the construction trades to decide on-site. Because of the prefabrication of the mass timber system and the extremely tight tolerances, it is essential that all MEP layouts and penetrations are decided before manufacturing the mass timber panels. This level of detail is required for the prefabrication of the CLT panels so that the cutouts for each penetration could be made during fabrication rather than on-site to maintain the quality of the panel and speed of construction.

Prefabrication and just-in-time delivery decreases the time on-site and increases the quality of products. VDC modelling becomes a critical component on various stages of the project to facilitate very detailed decisions and sequencing prior to construction, where changes and time delays can be costly.

## 3.30 Brock Commons Construction Process – Video 3


Ch 3: Construction Process

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

The construction process was animated.

During the design phase, the virtual model was used primarily to assist in design development and decision-making. The model was also used for coordination amongst the disciplines in terms of systems layouts, construction sequencing and preparation for fabrication of certain building elements.

The VDC model also functioned as a tool for communicating with the construction trades prior to tender. It helped describe the scope of work relative to the project as a whole and demonstrate that the design, while innovative, was not complex or highly risky.

## 3.31 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 project's success?*

- The detailed level of conflict resolution and clash detection between systems, early in the design. The detailed level of system integration and coordination of every penetration and connection to ensure the CLT panels were prefabricated correctly
- Ensure the appropriate clearances are kept
- Enabled 4D simulation of the installation sequence that was developed from the 3D virtual model providing an overview of every building element
- Assisted in visualizing the construction process and aid in resolving issues prior to construction commencing reducing potential site delays and extra costs
- In addition, it aided in trades understanding the scope of work relative to the project as a whole, reducing misunderstandings as well as providing a higher level of understanding to obtain more accurate costing

## 3.32 Envelop and Moisture

## 3.33 Envelop and Enclosure


En

Moisture management of the mass timber structure during construction is a critical component of the planning and design process. It is critical to ensure that there is proper provision on managing rain and other moisture issues that occur during the time frame of construction.

Some degree of moisture can be mitigated on mass timber. Preventing the mass timber from saturation as well as allowing the wood to dry properly when it does get wet are all key considerations. Another consideration is staining that may occur on the mass timber. In the case of exposed mass timber as part of the final aesthetic, the first step is to prevent the mass timber from excess water as best as possible, consider proper sealers and have a management plan.

## 3.34 Temporary Protective Roofing


There are various ways to protect the mass timber during construction. In Europe, tenting the structure during construction is common. However, this is most suitable for lower structures, and the additional cost of the tent and any support structure must be considered. In urban conditions, where the site may have limited space, the coordination of the tent structure will want to be considered carefully.

This prefabricated envelope system allowed the building to be rapidly enclosed as the structure is erected to protect the wood components from the weather. The prefabricated portion is composed of the rainscreen cladding system up to the steel studs. The vapour barrier, batt insulation and the interior layer of drywall were applied on-site.

## 3.35 Prefabricated Envelops


Given the prefabricated nature of the mass timber structural system, prefabricated exterior envelopes are an effective method of protecting the mass timber during construction. Mass timber and envelop erection sequencing can be strategically managed to reduce the time that the mass timber is exposed to the elements.

As the mass timber is being erected, the prefabricated envelope will follow behind.

In the case of Brock Commons, the fully prefabricated exterior wall panels were constructed off-site. As every two floors of the mass timber panel were assembled on-site, the envelop arrived just in time for the installation, minimizing the time that the mass timber structure was exposed.

With prefabricated exterior envelope systems, consideration of connection, thermal bridging, air leakage and continuity of the vapour barrier must be carefully considered.

At Brock Commons, a full-scale mock-up was used to demonstrate and test the installation of the panels to the structural system. Sequencing of lifting, placing and connection were testing, allowing the design and manufacturing team to refine details and provide a training opportunity to the installation crew.

As mentioned, ensuring the performance of the envelope is critical. Performance testing on the full-scale mock-up occurred prior to installation, ensuring that the performance designed can be maintained.

## 3.36 Managing the Risk of Water Damage During Construction

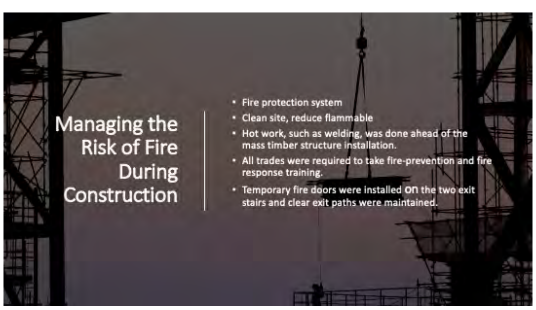

A thorough water-management plan with multiple prevention and mitigation strategies is a critical part of the design and construction planning.

Consideration includes:

- The enclosure of the building as quickly as possible
    - At Brock Commons, the prefabricate envelop developed was installed one floor behind the installation of the mass timber structure.
- Consideration of the seasonal precipitation and plan construction so that the erection of the mass timber is during the dry months (avoid rainy seasons)
- Consider water protection and taping of joints of the erected mass timber once installed
- Continuous moisture monitoring of the mass timber
- Establish proper drying methods, and ensure that the mass timber is returned to the acceptable levels of moisture if the members do get wet

Likely, even when all these measures are taking, having a secondary plan for moisture and staining is wise.

## 3.37 Managing the Risk of Fire During Construction




Managing the risk of fire during construction is critical. A comprehensive fire management plan established prior to construction start is critical and often required by Authorities Having Jurisdiction.

At Brock Commons, the original strategy relied heavily on The Type-X gypsum board, which was installed below the CLT panels for fire protection. However, the encapsulation speed held back the installation of mass timber because the CLT panels had to be fully dry before the drywall could be installed. Therefore, the management plan was revised, with the permission of the authorities, to allow up to six floors of wood structure without gypsum board encapsulation. The mass timber columns did not require immediate encapsulation because they were separated from the CLT panels by the concrete topping. Nonetheless, they were encapsulated concurrently with the ceiling encapsulation of each floor. The additional layers of gypsum board were added during the interior work.[12]

Other fire-management strategies applied during the construction process include:

- Fire standpipes were installed in the concrete and cores. As a safety measure, the fire standpipes were not charged during construction, but they could be easily charged by the fire department if necessary.
- The site was kept exceptionally clean to prevent the buildup of flammable materials and to ensure safe access to exits was maintained at all times.
- 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.

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WoodWorks; "Brock Commons Tallwood House: Construction Overview," n.d. https://wood-works.ca/wp-content/uploads/brock_commons_-_construction_overview.pdf.

[12] WoodWorks;, "Brock Commons Tallwood House: Construction Overview," n.d., https://wood-works.ca/wp-content/uploads/brock_commons_-_construction_overview.pdf.

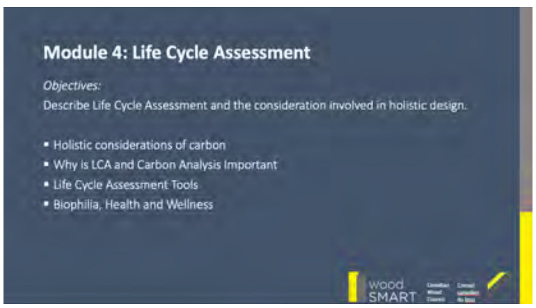
# 1 Module 1: Project Planning and Optimizing Design

# 2 Module 2: Design Considerations

# 3 Module 3: Early Construction Sequencing

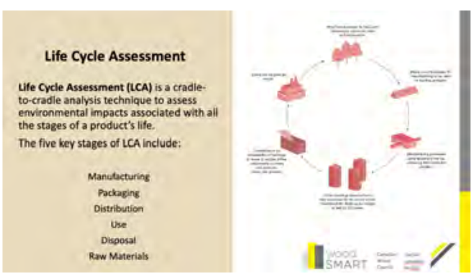
# 4 Module 4: Life Cycle Assessment of Prefabricated Mass Timber Systems

## 4.1 Objectives and Summary




## 4.2 Holistic Considerations of Carbon

## 4.3 Definition: 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:

1. Manufacturing
2. Packaging
3. Distribution
4. Use
5. Disposal
6. Raw Materials

https://cwc.ca/why-build-with-wood/sustainable/green/life-cycle-assessment/

Life cycle assessment (LCA) estimates the environmental burden due to a product over its entire life span, from resource extraction to landfilling and beyond. It's a rigorous methodological technique for measuring and rationalizing "green" choices, applying a holistic cradle-to-grave perspective. Long used in the manufacturing sector for product development, LCA (and its subset, embodied carbon) is increasingly being considered for the complex "products" known as buildings[1].

LCA originated in the industrial sector, where it has been used for decades in business decisions to manufacture clothing, detergent and many other products. LCA is a useful tool in guiding sustainability decisions for just about anything.

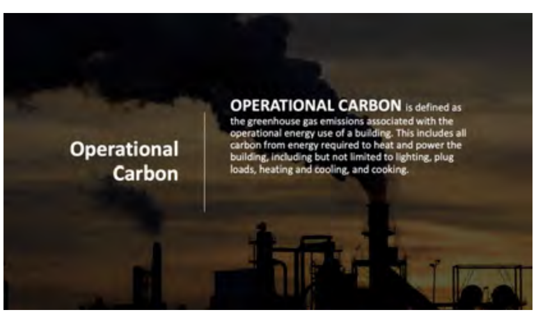
But LCA applied to the building sector is quite complicated for something like a consumer product. Buildings are complex one-off assemblies of thousands of products and materials involving countless participants, a long lifetime (with many changes along the way), and a great deal of uncertainty about what will happen in the future[2].

## 4.4 The Process of Whole-Building LCA


LCA for a building measures the impact between building and the environment over its lifespan and then estimates the resulting impacts on air, land and water.

The cradle-to-grave of a building includes manufacturing and transportation of construction material, the process of construction, building occupancy and maintenance, demolition and removal of waste materials. Carbon emissions are created during every life phase.

## 4.5 Definitions: Operational Carbon

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[1] Athena Sustainable Materials Institute, "About Whole-Building LCA and Embodied Carbon," 2019.
[2] Athena Sustainable Materials Institute.

**OPERATIONAL CARBON** is defined as the greenhouse gas emissions associated with the operational energy use of a building. This includes all carbon from the energy required to heat and power the building, including but not limited to lighting, plug loads, heating and cooling, and cooking.[3]

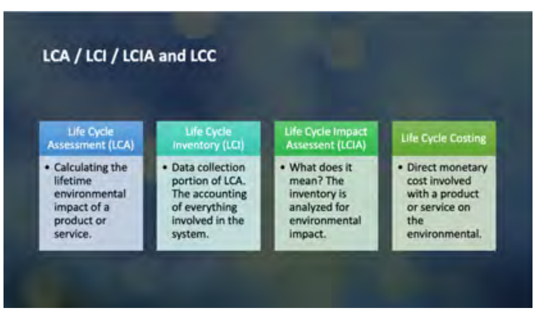
## 4.6 Definition: Embodied Carbon


**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.[4]

## 4.7 Definition: 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.[5]

## 4.8 LCA, LCI, LCIA, LCC: What is the Difference

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[3] International Living Future Institute, "Zero Carbon Standard 1.0 - A Vision Path to Carbon-Positive Future," n.d., https://www2.living-future.org/zero-carbon-standard.

[4] International Living Future Institute.

**Life cycle assessment** (LCA) is a multi-step procedure for calculating the lifetime environmental impact of a product or service. The complete process of LCA includes goal and scope definition, inventory analysis, impact assessment, and interpretation. The process is naturally iterative as the quality and completeness of the information, and its plausibility is constantly being tested.

LCI is the **life cycle inventory**, which is the data collection portion of LCA. LCI is the straightforward accounting of everything involved in the "system" of interest. It consists of detailed tracking of all the flows in and out of the product system, including raw resources or materials, energy by type, water, and emissions to air, water and land by specific substance. This kind of analysis can be extremely complex. It may involve dozens of individual unit processes in a supply chain (e.g., the extraction of raw resources, various primary and secondary production processes, transportation, etc.) as well as hundreds of tracked substances.

LCIA is **life cycle impact assessment**, the "what does it mean" step. In LCIA, the inventory is analyzed for environmental impact. For example, manufacturing a product may consume a known volume of natural gas (this data is part of the inventory); in the LCIA phase, the global warming impact from fuel combustion is calculated. There are various methods globally for categorizing and characterizing the life cycle impact of the flows to and from the environment, which can somewhat complicate the comparability of different LCA studies. Other variables in LCIA include the system boundary (how far upstream, downstream, and sidestream does the analysis go), the functional unit (what is the volume/mass/purpose of the object being assessed), and specific LCIA methods such as allocation (how are impacts assigned to the product and by-products, on what basis). When comparing two LCA studies, these factors are critical to understanding if the comparison is apples-to-apples.

LCI and LCA should not be confused with **life cycle costing**. LCC is another life cycle approach (i.e, cradle to grave), but it looks at the direct monetary costs involved with a product or service and not environmental impact.[6]

## 4.9 Life Cycle Assessment


LCA is a decision-making tool that can help identify design and construction approaches that yield improved environmental performance.

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[6] Athena Sustainable Materials Institute, "LCA, LCI, LCIA, LCC: What's the Difference?," accessed May 21, 2021, http://www.athenasmi.org/resources/about-lca/whats-the-difference/.

Life cycle assessment is often referred to as cradle-to-grave or cradle-to-cradle analysis and is essential for making green decisions, whether in product manufacturing or building design.

It is life cycle thinking applied to a product: what is involved in making a product and transporting it to an installation site;

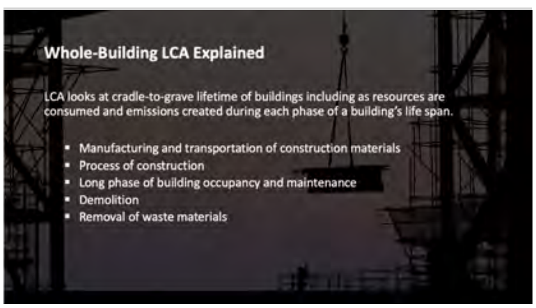
- what inputs and waste will occur related to using the product over its life, and what will happen to the product when it is no longer needed?
- Without measured data, we can only guess about the true footprint of our choices.[7]

Life cycle thinking enables consideration of trade-offs; one decision affects other elements in the larger picture. For example, if we increase recycled content in a product, have we created a problem for further recycling or disposal later?

Sometimes environmental decisions simply shift the burden to another part of the life cycle. LCA ensures a comprehensive perspective to help avoid this.

LCA provides a quantitative basis for environmentally improved designs, removing the guesswork, unintentional greenwashing and burden shifting.

## 4.10 Whole-Building LCA explained




Whole-building LCA looks at the entire environmental burden with a focus on embodied environmental impacts. Embodied impacts become critical las operating consumption, is reduced through optimization of design and building management.

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

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

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[7] Athena Sustainable Materials Institute, "About LCA | Athena Sustainable Materials Institute," accessed May 21, 2021, http://www.athenasmi.org/resources/about-lca/.

This material and resource consumption data is translated into a life cycle inventory (an accounting of all the flows to and from nature), which is then run through a life cycle impact assessment model for LCA results: the impact of the building on global warming, acidification, smog and so forth.

## 4.11 Activity – Life Cycle Assessment

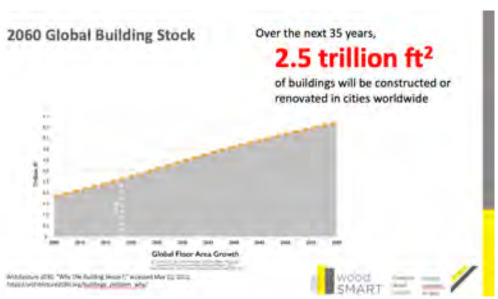
***What is the definition of Life Cycle Assessment, and what are the five stages of consideration? What are the five phases of a building?***

***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:*

1. *Manufacturing*
2. *Packaging*
3. *Distribution*
4. *Use*
5. *Disposal*
6. *Raw Materials*

## 4.12 Why is LCA and Carbon Analysis Important? (Section Title)

## 4.13 2060 Global Building Stock




The world is currently undergoing the largest wave of urban growth in human history. More than half of the global population is now concentrated in urban areas, and by 2060 two thirds of the expected population of 10 billion will live in cities.

We expect to add 2.48 trillion square feet (230 billion m2) of new floor area to the global building stock to accommodate this tremendous growth, doubling it by 2060. This is the equivalent of adding an entire New York City every month for 40 years. This new building stock must be designed to meet zero-net-carbon standards.[8]

- Currently, ½ of the global population is in urban areas.
- 2060 - expected to rise to 2/3 = 10 billion people will live in cities.
- 2.48 trillion SF of new floor area will be required.
- Equals double building stock.

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

- Equivalent to an entire New York city emerging every month for the next 40 years.

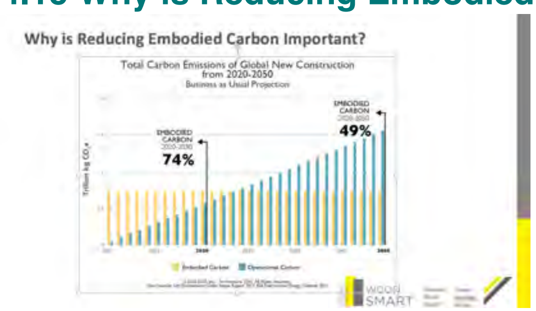
## 4.14 Global CO2 Emissions by Sector


Globally, the built environment constitutes close to 50% of the overall CO2 emissions globally.

While there have been worldwide improvements in building sector energy efficiency and growth in renewable energy generating capacity, these have not been nearly enough to offset the increase in emissions from new construction. As a result, building sector CO2 emissions have continued to rise by nearly 1% per year since 2010.

In order to achieve the target set by the Paris Agreement – to limit the rise in global average temperature to below the 2 degrees C threshold – all new construction must be designed to high energy efficiency standards and use no CO2-emitting fossil fuel energy to operate.

## 4.15 Why is Reducing Embodied Carbon Important



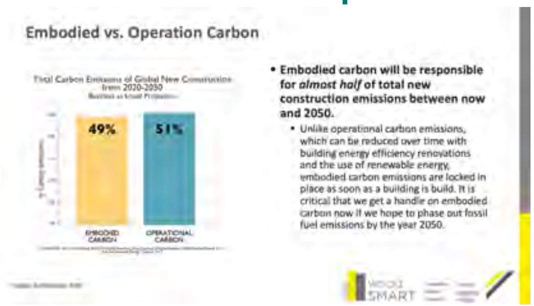

Annually, embodied carbon is responsible for 11% of the global Green House Gas (GHG) emissions and represents 28% of the global building sector.

Operational carbon over time can improve through enhanced performance of equipment and further development of renewable resources. However, embodied carbon is locked in place once the building is complete. We cannot meet the climate goals without also eliminating embodied carbon emissions by 2040.

When we look at all the new construction projected to take place between now and 2050, we see the critical role embodied carbon plays.

Every year, 6.13 billion square meters of buildings are constructed. The embodied carbon emissions of that construction are approximately 3729 million metric tons CO2 per year. By the year 2050, accounting for all new construction in that 30-year span, embodied carbon emissions and operational carbon emissions will be roughly equivalent.[9]

## 4.16 Embodied vs. Operational 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 built. 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.

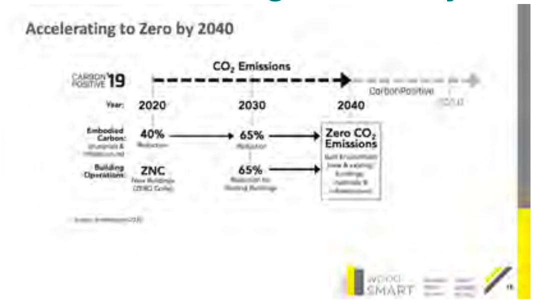
## 4.17 Canada Raising Climate Ambitions


**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

[9] Architecture 2030, "New Buildings: Embodied Carbon – Architecture 2030," accessed May 21, 2021, https://architecture2030.org/new-buildings-embodied/.

## 4.18 Accelerating to Zero by 2040

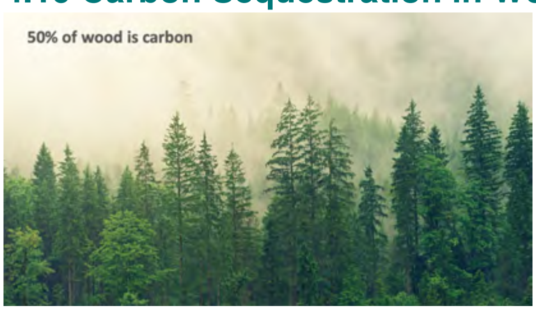



Agencies worldwide are calling for the acceleration of zero-carbon. Architecture 2030 has stated that it is critical to accelerating our carbon targets from 2050 to 2040, less than 20 years away.

This plan is calling for a:

- 65% reduction in embodied carbon by 2030
- Net-zero operational carbon on new buildings today
- 65% reduction of operational carbon on existing buildings by 2030
- Net Zero Carbon on both new and existing buildings by 2040
- Carbon positive towards 2050

## 4.19 Carbon Sequestration in Wood




Wood is a renewable and naturally growing material that can sequester carbon from the earth's atmosphere. The manufacturing of wood products for construction produces low carbon emissions from fossil sources than other building materials, offering a low embodied carbon solution. Prefabricated processes commonly used for products like mass timber create less waste and use less energy than traditional building materials. In addition, the potential available in reducing on-site construction are all factors that benefit the environment.
Carbon sink: approx. 50% of the weight of wood is solid carbon, absorbed as CO2
Renewable Resource
Less waste in construction through prefabrication, lamination of smaller elements in a controlled environment
Tangible/material commitment to the environment
only building material grow

## 4.20 Sustainable Forest Strategy


## 4.21 Activity – Building and the Impact on Climate

***Define the following terms:***

- ***Operational Carbon***
- ***Embodied Carbon***
- ***Net-Zero Carbon***

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

## 4.22 Life Cycle Assessment Tools

## 4.23 Life Cycle Assessment Workflow


Life Cycle Assessment aims to bring comprehensive data into sustainable decisions to validate decisions through the design process.

The benefits include providing “evidence” and scientific data to environmental choices.

This can help direct the decision-maker's attention to critical issues and provide supporting evidence to make more sustainable choices and compliance with green building programs and policies.

Currently, there are limitations for LCA – below are three main concerns that will hopefully resolve as LCA becomes more widely used in practice.

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

In all cases, LCA is an estimated science and not an exact one. It is essential to recognize these gaps when inputting data and to analyze the results of the LCA.

## 4.24 Tools: Gestimat


Gestimat is an analysis tool that facilitates the assessment of the carbon footprint of buildings. The tool was designed mostly for understanding the material selection for predesign of a building. It offers
The modelling of scenarios can be done using the estimation of the quantities of materials according to typical buildings or by entering quantities of materials specific to a given project.

Understanding the performance and embodied carbon of a building early in the design process is a valuable tool as decisions on materials and systems are often determined early on in the process.

## 4.25 Comparative Analysis – Gestimat


The Gestimat tools allow one to work with a typical base building in order to provide high-level analysis or input the values of the buildings as separate components to create a unique design.

## 4.26 Gestimat – Comparing Results


The program calculates the quantity of materials and the potential GHG emissions associated with determining the embodied carbon.

The program utilizes an easily updatable transparent Green House Gas (GHG) regional database of life cycle assessment data provided by CIRAIG. At this time, the data focuses on fabrication and transportation.

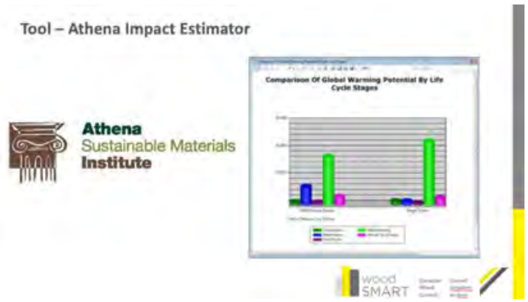
The program provides analysis for the following structures:

- Light-frame wood
- Mass timber
- Concrete
- Steel

## 4.27 Gestimat – Precalculated Typical Buildings


- There are currently two precalculated buildings in the system that can be used as a basis for design.
- The program allows you to calculate and compare scenarios.
- Currently, the program has inputs for Ontario and Quebec.
- There are two typical buildings in the system

## 4.28 Tools: Athena Impact Estimator

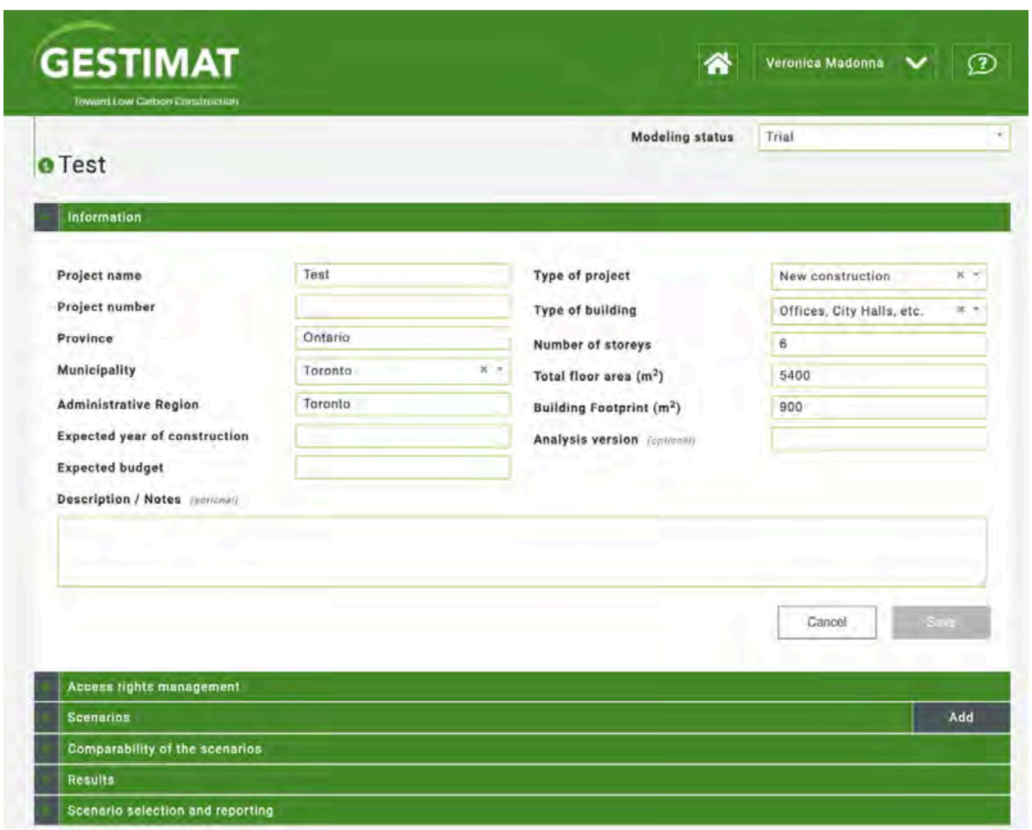


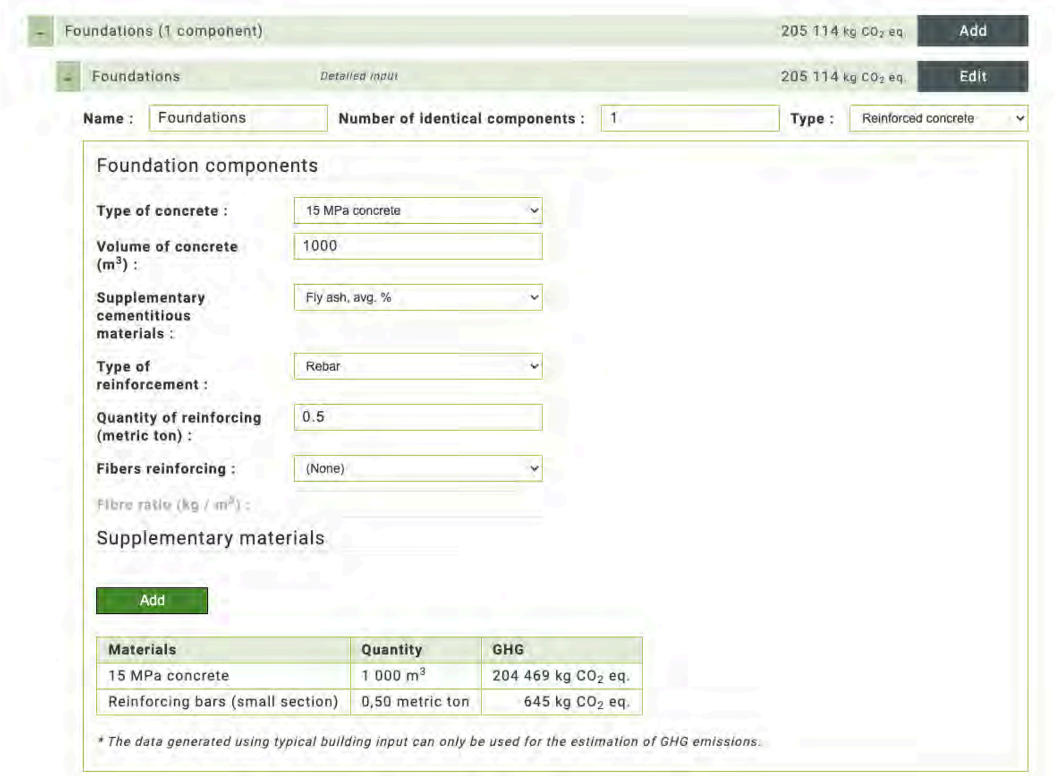

The Athena Impact Estimator for Buildings is a simplified LCA software tool, is provided for free to the sustainable design community to make whole-building LCA feasible in everyday practice.

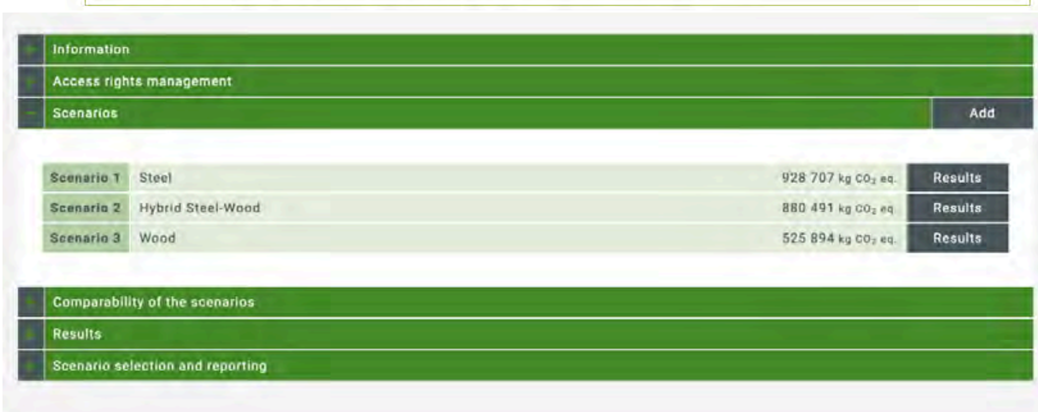
Embodied carbon has long been overlooked in sustainability strategy. This is starting to change. Some green building programs and policies are recognizing the importance of reducing embodied carbon through design decisions.

The Athena Impact Estimator for Buildings is ideal for calculating embodied carbon and exploring tactics for reducing it.

## 4.29 Activity - Embodied Carbon Analysis using Gestimat








Comparability of the scenarios

Information

Access rights management

Scenarios — Add

Comparability of the scenarios

| | | Project information | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|---|
| **Typical building input** | | | Modified | Modified | Modified |
| **Number of storeys** | | 6 | 6 | 6 | 6 |
| **Number of modeled components** | | | 6 | 6 | 6 |
| **Foundations** | **$m^3$ concrete** | | 1 000 | 1 000 | 1 000 |
| **Beams and columns** | **$m^3$ concrete** | | | | |
| | **$m^3$ wood** | | | | 207 |
| | **metric ton steel** | | 160 | 160 | |
| **Floors** | **$m^2$ of floors** | 5 400 | 4 500 | 4 500 | 4 500 |
| **Interior walls** | **$m^2$ of walls** | | | | |
| **Exterior walls** | **$m^2$ of walls** | | | | |
| **Roofs** | **$m^2$ of roofs** | 900 | 900 | 900 | 900 |

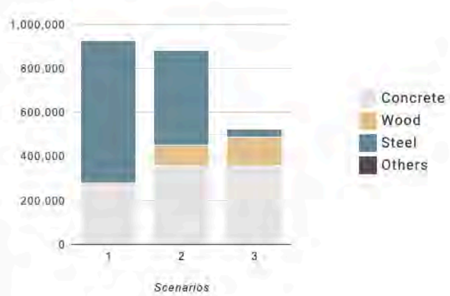
## Comparison of scenarios

Export as PDF

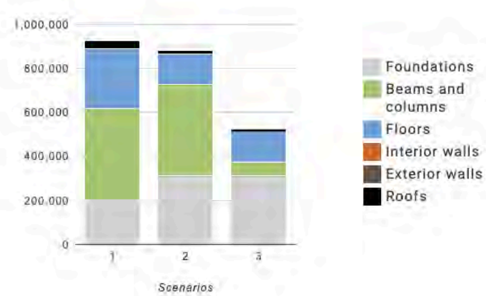
**GHG emissions (kg $CO_2$ eq.)**

| | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Input type | - | - | - |
| Total floor area ($m^2$) | - | - | - |
| **By material** | | | |
| Concrete | 279 366 | 359 632 | 359 632 |
| Wood | | 92 596 | 126 467 |
| Steel | 649 341 | 428 263 | 39 796 |
| Others | | | |
| **By construction system** | | | |
| Foundations | 205 114 | 313 620 | 313 620 |
| Beams and columns | 413 474 | 413 474 | 58 878 |
| Floors | 271 770 | 139 578 | 139 578 |
| Interior walls | | | |
| Exterior walls | | | |
| Roofs | 38 348 | 13 819 | 13 819 |
| **Total** | 928 707 | 880 491 | 525 894 |
| **GHG per $m^2$** | 172 | 163 | 97,39 |

GHG emissions by material (kg $CO_2$ eq.)




GHG emissions by construction system (kg $CO_2$ eq.)




## 4.30 Tools

## 4.31 Info Videos - Gestimate

Video 1 – Access to Gestimat: https://www.youtube.com/watch?v=iYBAbqfa2dM&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=1
Video 2 – Dashboard and Roles: https://www.youtube.com/watch?v=j5wyq_e1Sm4&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=2
Video 3 – Structure of an Analysis: https://www.youtube.com/watch?v=nr3lK-BtSfo&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=3
Video 4 – Analysis Creation, Information and Status: https://www.youtube.com/watch?v=USbga-W8Axw&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=4
Video 5 – Access Rights Management: https://www.youtube.com/watch?v=yLuSeRMH-Mw&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=5
Video 6 – General Structure of a Scenario: https://www.youtube.com/watch?v=mXsn-6UE-1I&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=6
Video 7 – Detailed Modeling of a Scenario: https://www.youtube.com/watch?v=Utra7nkIO_M&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=7
Video 8 – Typical Building Modeling: https://www.youtube.com/watch?v=QP4trN_nbIs&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=8
Video 9 – Comparability of the Scenarios: https://www.youtube.com/watch?v=TAxWV5MKROs&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=9
Video 10 – Results and Scenario Selection: https://www.youtube.com/watch?v=OL-zAd1kFpY&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=10
Video 11 – C1, C2 & C3 Administrators: https://www.youtube.com/watch?v=gAYUJEb6_6A&list=PLMsi5J5-WNp9e6OTBbMJO-fGc9ddeJVlr&index=11

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International Living Future Institute. “Zero Carbon Standard 1.0 - A Vision Path to Carbon-Positive Future,” n.d. https://www2.living-future.org/zero-carbon-standard.