EXPLORING THEORETICAL DESIGN OPTIONS TO ACHIEVE 50% REDUCTION IN EMBODIED CARBON EMISSIONS

A Case Study of the UBC Sauder School of Business Powerhouse Expansion Project

THE UNIVERSITY OF BRITISH COLUMBIA
Sustainability Hub

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AUTHORSHIP

This case study describes a theoretical 50% embodied carbon emissions reduction assessment commissioned by UBC Campus + Community Planning (C+CP) on the University of British Columbia (UBC) Sauder School of Business Powerhouse Expansion project. The emissions reduction assessment described here was conducted by the Sauder Expansion project team:

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The case study was developed by the UBC Sustainability Hub, based on the UBC Sauder School of Business Expansion Embodied Carbon Case Study report and the UBC Sauder School of Business Expansion Building Permit wbLCA report by reLoad Sustainable Design Inc., as well as the project documentation and consultations with the project team. UBC Sustainability Hub contributors include:

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This project was undertaken with the financial support of the Government of Canada.
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Canada

Cover image: 3D Visualization of UBC Sauder School of Business Powerhouse Expansion project, courtesy of ACTON OSTRY + Patkau Architects, rendered by Mute Images.

Figure 1: Visualization of the Sauder Expansion project, level 1 atrium (Source: Design by ACTON OSTRY + Patkau Architects, renders by Mute Images).

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1 INTRODUCTION

Embodied carbon in buildings refers to the total amount of greenhouse gas (GHG) emitted throughout the lifecycle of the materials that go into a building, including resource extraction, production, construction, use, and disposal. Embodied carbon makes up a large portion of a building's overall carbon footprint, and reducing it is important for lowering carbon emissions and combating climate change. As a building's operational emissions decrease through energy efficiency measures and renewable energy use, the embodied carbon in a building's total carbon footprint becomes more significant.

The University of British Columbia (UBC) is committed to reducing GHG emissions on its campuses. The 2030 Climate Action Plan (CAP 2030) sets a 2030 target to reduce embodied carbon emissions in new building designs and major renovations by 50% below a UBC 2010 baseline. The 2018 Green Building Action Plan (GBAP) outlines steps to reach this target, such as the use of Whole Building Life Cycle Assessments (wbLCA) to measure and lower embodied carbon emissions in new buildings and standardized reporting of embodied carbon emissions. To support this effort, the Whole Building Life Cycle Assessment Guidelines was published in 2023 by Campus + Community Planning (Vancouver) and UBC Campus Planning (Okanagan) to provide guidance for project teams conducting wbLCA for building projects on both campuses.

To test the feasibility of achieving 50% embodied carbon emissions reduction compared to a typical campus building, UBC Campus + Community Planning conducted a theoretical wbLCA on a current development project, being undertaken by the UBC Sauder School of Business. The Sauder Expansion project is a new 11-storey academic building at the center of the Vancouver campus.

To conduct the theoretical wbLCA, the project team employed an iterative and collaborative design process that involved brainstorming and refining a short list of alternative building designs and evaluating them based on their embodied carbon emissions, costs, and other considerations for construction. The project team based their work on the UBC Sauder School of Business Powerhouse Expansion's 50% Design Development documents and focused on the building's structural systems and materials as the source of the highest proportion of total building embodied carbon emissions. The LCA consultant assessed both industry-average and low-carbon materials and products for all the alternative design options, and the construction manager provided a preliminary estimate of labour and capital material costs and construction timelines.

Life Cycle Assessment (LCA): A method to track and analyze the environmental impacts of a product or process at every stage of its life—from raw material extraction to manufacturing, use, and disposal or recycling.

Whole Building Life Cycle Assessment (wbLCA): Life cycle assessment applied to a whole building or a significant part of a building, and used to inform design decisions or to report on environmental impacts in compliance with building regulations.

Operational carbon emissions: GHG emissions released from building operations, mainly due to energy used for space heating and cooling, lighting, water heating, and ventilation. Measured in kilograms (kg) or metric tons (t) of CO_2 equivalent (CO_2e) per year.

Embodied carbon emissions: GHG emissions released from production, transportation, construction, maintenance, and disposal of building materials and products. Measured in kilograms (kg) or metric tons (t) of CO_2 equivalent (CO_2e) per square meter (m^2) of building area or per unit of material.

Net-Zero operational emissions: A state where GHG emissions from a building's operations in combination with the related removal of an equivalent of GHG from the atmosphere are as close to zero as possible.

2 UBC GHG EMISSIONS REDUCTION GOALS

UBC has set a goal to reach net-zero GHG operational emissions for both campuses by 2035. The CAP2030 outlines three emissions reduction targets for the UBC Vancouver campus:

1. 45% collective reduction from the 2010 baseline in emissions from extended impact resources, which includes commuting, business air travel, food, waste, and embodied carbon (by 2030);
2. 85% reduction in campus operational GHG emissions below the 2007 baseline by 2030, and
3. 100% reduction in operational greenhouse gas emissions by 2035.

In addition to these three CAP 2030 goals, UBC plans to establish a baseline and align new buildings and major renovations with a 50% embodied carbon emissions reduction target. Key actions and interim targets on this objective are outlined through various plans and guidelines as summarized in Table 1.

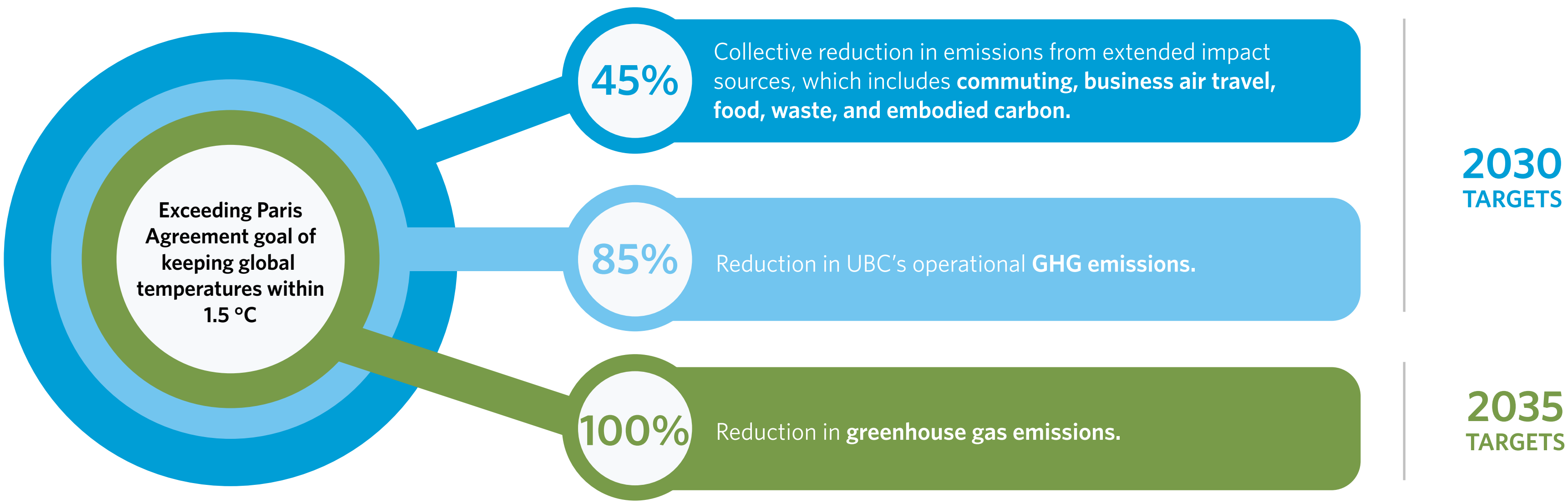


Figure 2: UBC CAP 2030 targets (Source: UBC Vancouver Campus Climate Action Plan 2030).

Table 1: Summary of UBC action plans and guidelines relevant to embodied carbon emissions reporting and reductions in buildings (Source: information provided by UBC Campus + Community Planning).

UBC Action Plan/Guidelines	Building type		Key Highlights
	Institutional	Residential	
UBC Neighbourhood Climate Action Plan (2024)		✓	• Sets goals to ensure embodied carbon emissions in new buildings is reduced by 40% versus the baseline building by 2030.
WBLCA Guideline v1.1 (2023)	✓	✓	• Provides guidance on the methodology for performing wbLCAs for UBC buildings on both the Vancouver and Okanagan campuses.
Residential Environmental Assessment Program (REAP) 3.3 (2023)		✓	• Targets a 10% to 20% reduction in embodied carbon emissions for neighbourhood residential buildings by mandating wbLCA.Encourages the use of low-carbon structural materials (like mass timber) and other responsibly sourced building products.Recommends strategies to optimizing designs for material efficiency and adaptability.
UBC Integrated Sustainability Process Guide (2022)	✓	✓	• Outlines a framework for integrating sustainability goals into UBC's major capital projects, with a step-by-step guide for developing a project design brief, and outlines possible sustainability goals and performance reporting requirements. • Encourages project teams to integrate embodied carbon emission considerations into design decisions and present the results through sustainability workshops.
LEED v4.1 Implementation Guide (2022)	✓	✓	• Provides procedures, examples, and expectations for project teams to achieve LEED BD+C v4.1 certification for buildings in the UBC campuses, while aligning with UBC policies and goals. • Reminds that all major capital projects (>$5 million and over 1,000 m^2) at UBC campuses are required to achieve LEED Gold certification and under the LEED BD+C v4.1 Material and Resources (MR) category: to earn at least three points under Building Life-Cycle Impact Reduction, as well as at least one point under the Environmental Product Declarations credit.

Table 1 (continued): Summary of UBC action plans and guidelines relevant to embodied carbon emissions reporting and reductions in buildings (Source: information provided by UBC Campus + Community Planning).

UBC Action Plan/Guidelines	Building type		Key Highlights
	Institutional	Residential	
UBC Vancouver Climate Action Plan 2030 (2021)	✓	✓	• Sets goals for establishing an embodied carbon baseline and ensuring new building and major renovations with a 50% reduction target by 2030. • Sets goals for 45% campus-wide reductions on extended emissions (commuting, food, business air travel, embodied carbon, waste and materials, and paper) from the 2010 baseline. • Commits to: - Develop clear guidance for embodied carbon LCA studies for new buildings and renewals, and introduce a pilot target of 20% reduction over a baseline building. - Develop guidance for reducing embodied carbon emissions in buildings to discourage, reduce, or potentially eliminate materials with the highest embodied carbon impacts. - Update the method for campus-level reporting on embodied carbon emissions in UBC's GHG inventory and carbon reporting. - Develop embodied carbon emissions reduction targets for UBC buildings by type and for the campus as a whole, for application on projects in 2025-2030. - Conduct a study to model the impacts on embodied carbon emissions for various on-campus housing scenarios to help inform future land use planning.
Green Building Action Plan (2018)	✓		• Sets goals to implement policies for reduced embodied carbon emissions in institutional buildings, starting with a requirement to report embodied carbon emissions, followed by incremental reductions.
		✓	• Commits to requiring incremental reductions in the environmental impact of residential building materials. • Targets to create an integrated policy for residential building materials that considers life cycle analysis.

3 UBC SAUDER SCHOOL OF BUSINESS POWERHOUSE EXPANSION PROJECT

The UBC Sauder School of Business is a globally recognized business school on the Vancouver campus. It combines world-class education, research, and industry connections to train future-ready leaders and foster entrepreneurial thinking.

The Sauder Expansion project will develop a new building to support a growing student population with more specialized learning opportunities by providing state-of-the-art facilities designed to support innovative, collaborative, and hands-on learning experiences.

Following sections describe the design of the Sauder Expansion project at the 50% Design Development stage, which was used for the theoretical 50% embodied carbon reduction assessment. The actual building design has since been revised.

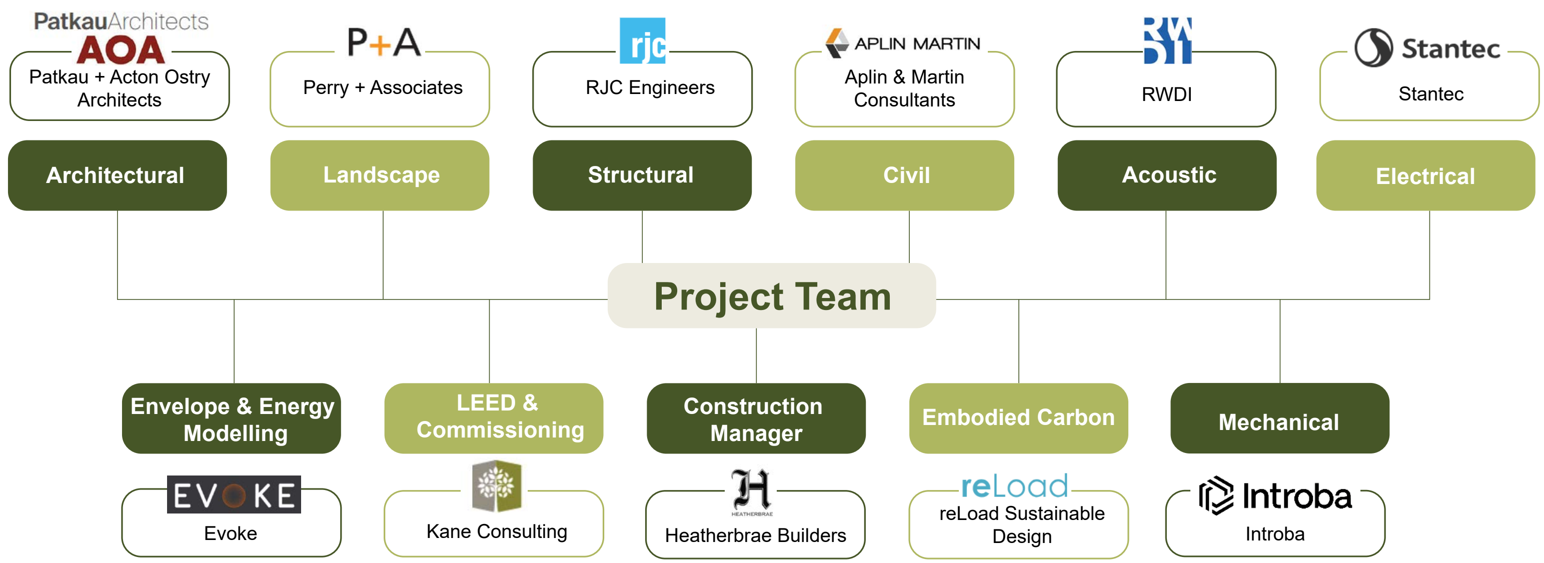


Figure 3: Sauder Expansion project team, adapted from Design Brief report.

Figure 4: Visualizations of the Sauder Expansion project (Source: Design by ACTON OSTRY + Patkau Architects, renders by Mute Images).

3.1 Project Overview

The new UBC Sauder School of Business academic building will serve as a hub for collaborative learning and expanded student engagement.

The structure will consist of 11 storeys, with a 3-story podium and a tower for levels 4 to 11. Ground floor includes a spacious lobby, a lecture theatre, and an atrium for community gatherings and events. The atrium extends through levels 2 and 3, which house a variety of multi-functional spaces and open concourse areas. Level 4 is for administration offices, and levels 5 to 9 contain classrooms, labs, breakout rooms, informal learning spaces, and study areas. Level 10 includes a flexible event space with outdoor terraces and a catering kitchen. Mechanical and electrical service spaces are on the 11th floor. There are no underground levels or below-grade parking facilities.

The Sauder Expansion project began in 2022, with design and permitting in 2023. Construction began in early October 2024 and will be completed in 2027.

Building Information

Site Area: 4,972 m^2 (53,519 ft^2)

Gross Floor Area: 14,042 m^2 (151,147 ft^2)

Building Footprint Area: 2,364 m^2 (25,456 ft^2)

Building Height: 48.1 m (158 ft)

Capital Budget: $147,191,000 (Canadian Dollar 2024)

Operational Energy and Emissions Targets:

- Energy Use Intensity (EUI): Maximum of 100kWh/m^2/yr
- Thermal Energy Demand Intensity (TEDI): Maximum of 23 kWh/m^2/yr
- GHG Intensity (GHGI): Maximum of 2.8 KgCO_2e /m^2/yr

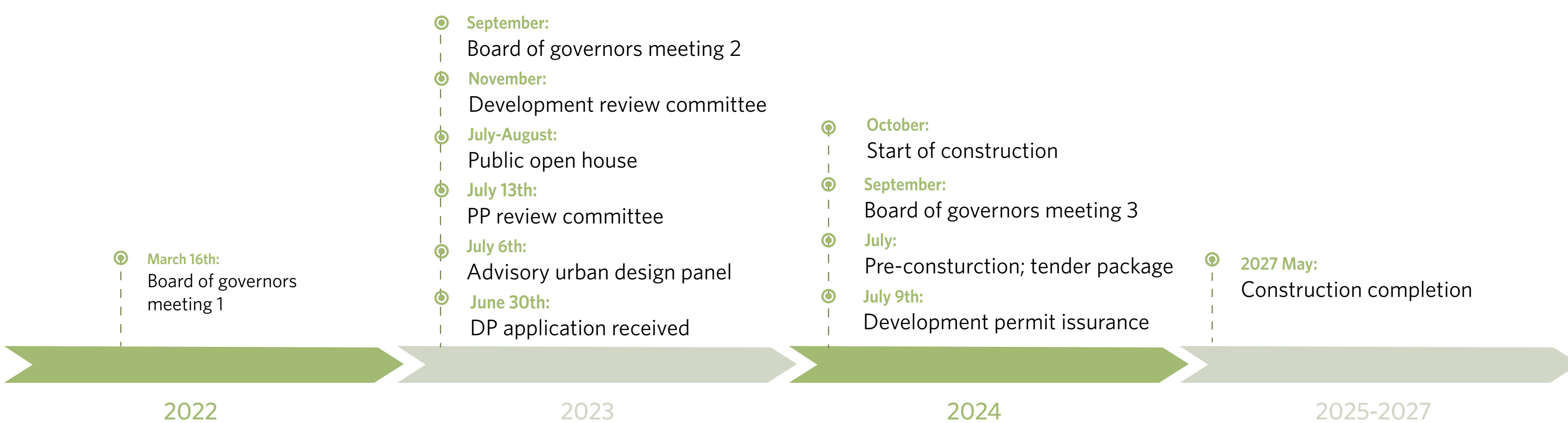


Figure 5: Overview of the project schedule, adapted from project schedule.

3.2 Form and Site

The Sauder Expansion project is an 11-storey, 14,042 m^2 (151,147 ft^2) building that will be located next to the existing Henry Angus building, which houses the main academic and administrative space of the UBC Sauder School of Business building at the UBC Vancouver campus. It is an infill project surrounded by academic buildings that will also shape and organize the surrounding public areas, including a plaza and pedestrian pathways between Main Mall and West Mall.

The building is an irregularly shaped polygon designed to optimize the available site space while maintaining consistency with the campus grid and primary orientation towards the existing facilities.

The landscaping will feature native and adaptive plantings that have been selected for their blooms, colour, branching patterns, and adaptability to future climate change.

Figure 6: Project site and massing, adapted from Design Brief report.

3.3 Structure and Envelope

The building structure is predominantly concrete, with levels 1 to 3 comprised of conventional reinforced concrete, and levels 4 to 11 comprised of post-tensioned concrete slabs for added strength and reduced material usage. Lower-carbon concrete was used in the footings, foundation, columns, and shear walls.

The exterior walls are generally steel stud with exterior grade gypsum board sheathing, mineral wool insulation, and custom profile aluminum cladding. The roof is post-tensioned concrete with a styrene-butadiene-styrene (SBS) system. Interior partitions will be built with steel studs, drywall, and glass-fibre batt insulation, providing both soundproofing and fire resistance.

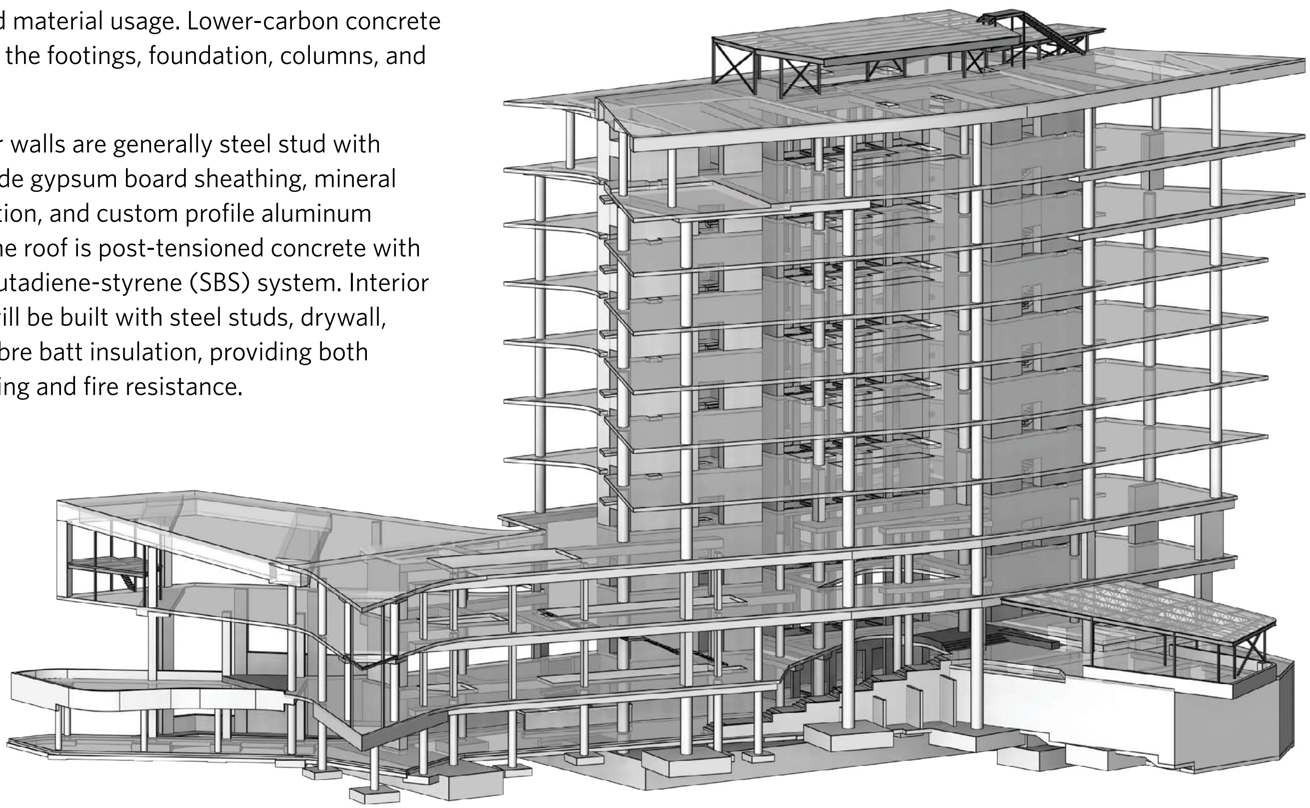


Figure 7: Structural model (Source: 50% Structural BIM model by RJC Engineers).

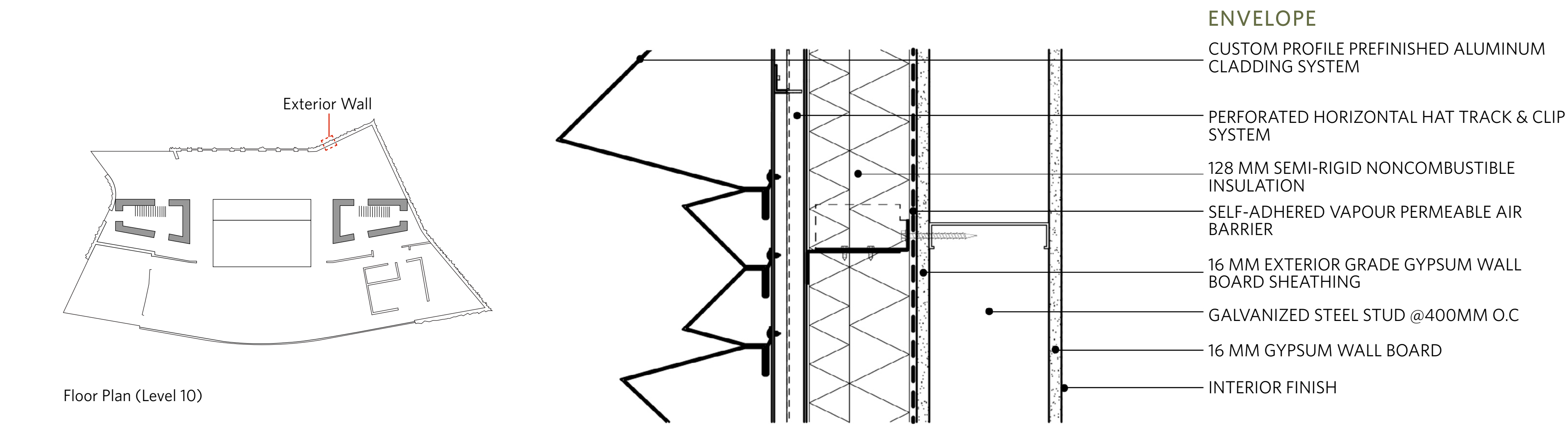


Figure 8: Building envelope assembly, modified construction detail (Source: ACTON OSTRY + Patkau Architects).

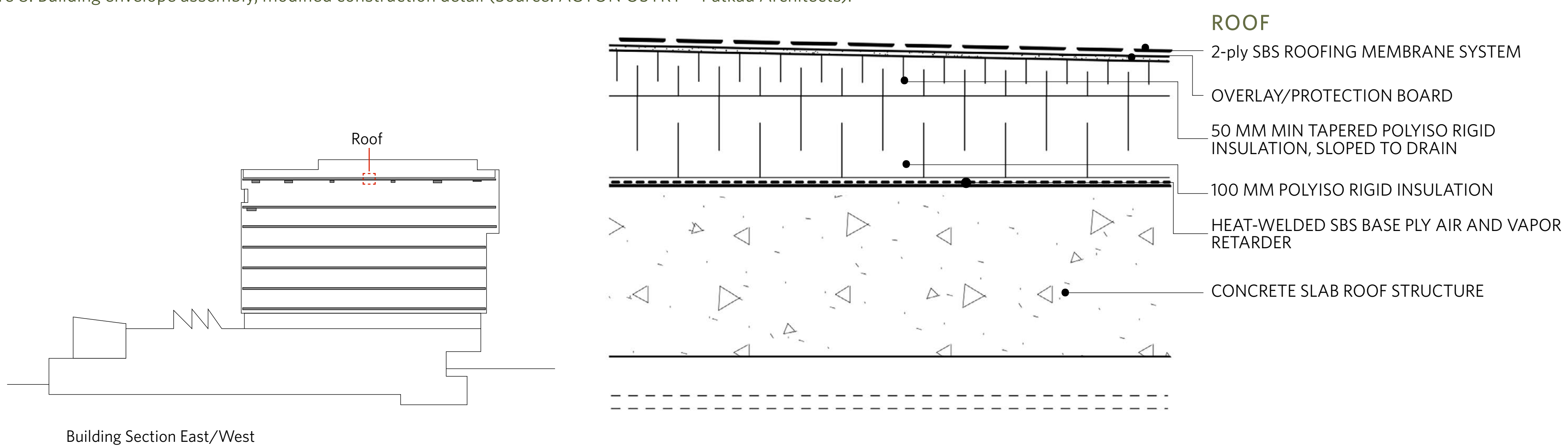


Figure 9: Building roof assembly, modified construction detail (Source: ACTON OSTRY + Patkau Architects).

4 THEORETICAL 50% EMBODIED CARBON EMISSIONS REDUCTION ASSESSMENT

4.1 Process for Design Options

The project team conducted a theoretical 50% embodied carbon emissions reduction assessment based on the Sauder Expansion project's 50% Design Development drawings (referred to in this test study as the 50% Design Development Model). The assessment began with a collaborative brainstorming meeting with the LCA consultant, project architects, structural engineers, the construction manager, and the development team.

Together, they created a long list of possible alternative building designs and material selections that could potentially have lower embodied carbon emissions. Given the higher potential of structural materials to reduce embodied carbon emissions, the team then created a shortlist of options (referred to within the study as Structural Design Alternatives) that were feasible within the project parameters. These parameters included maintaining the building's programming, size, and footprint. Six Structural Design Alternatives were selected, and then they were assessed based on two sets of emissions data: one representing industry-average materials and one representing low-carbon material options. This resulted in a total of 12 Structural Design Alternatives.

Then the project team assessed each option for embodied carbon emissions, construction costs, and construction schedules. Subsequently, these alternative designs were compared to a baseline (referred to within the study as Baseline Model) that was built using the procedures in UBC's Whole Building Life Cycle Assessment Guidelines V1.0, 2023.

Typically, a baseline model uses standard building materials for comparison purposes and is used to understand the extent of embodied carbon emissions reductions that would result from any design changes. Drawing on the 50% Design Development Model, the project team developed a baseline model with the same floor plan as the original design, but used conventional cast-in-place concrete for the entire structure, rather than the post-tensioned concrete slab system used in the original design. This structural change resulted in the baseline building being taller to accommodate thicker slabs while maintaining the same floor-to-ceiling heights, which, in turn, resulted in a larger external envelope area. The Baseline Model also included extra beams and columns on the lower floors to support the additional building load.

50% Design Development Model: The building design for the Sauder Expansion project as drawn in the 50% Design Development documents. At this stage, the project drawings were defined in moderate detail, and the design was not yet finalized for construction. However, this model served as a reference point for identifying and assessing potential strategies to reduce embodied carbon emissions.

Baseline Model: Standard building design used as a benchmark for comparison with the existing design for wbLCA. It has the same functional equivalence (e.g., same scope, size, geometry, function, energy performance, fire safety, and acoustic performance) to meet the building codes requirements. In this study, the Baseline Model was based on the 50% Design Development Model.

Structural Design Alternatives: In wbLCA, the different design choices are compared against the Baseline Model with the same functional equivalence as that model. In this study, the design alternatives were different structural system options chosen by the project team to use in assessing embodied carbon emissions.

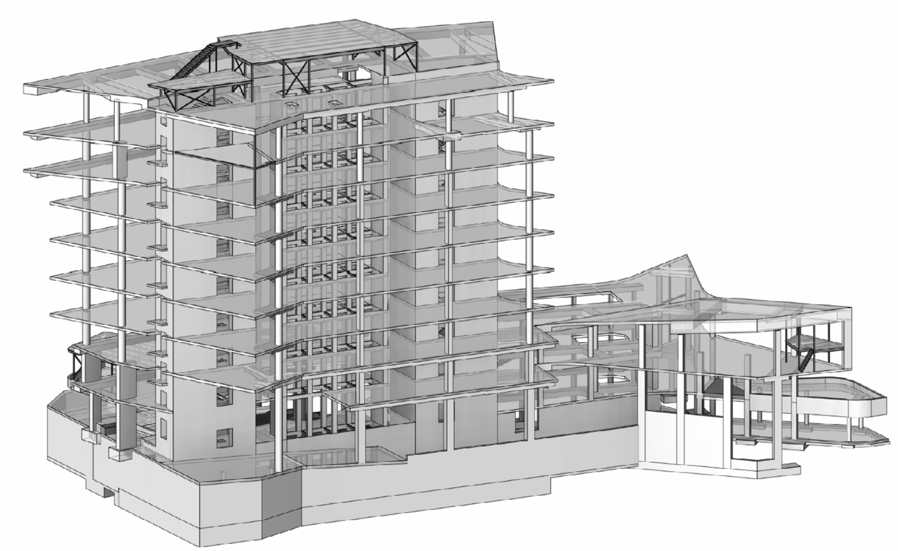


Figure 10: Structural model (Source: 50% Structural BIM model by RJC Engineers).

4.2 Development of Structural Design Alternatives

The project team created six Structural Design Alternatives, with different combinations of structural systems and materials for the building podium (ground floor – floor 4) and tower (floor 5 – floor 11).

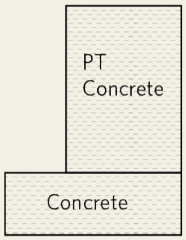
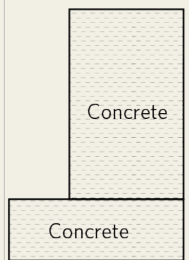
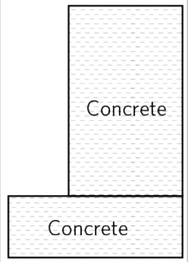
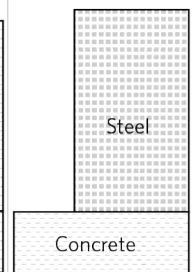
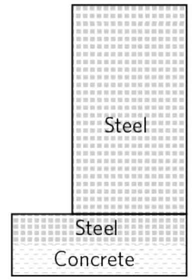
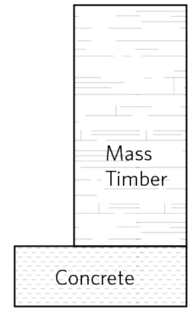
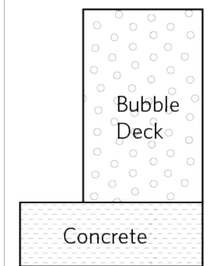
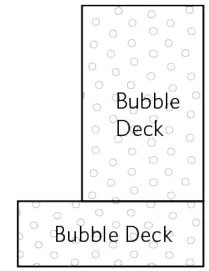
1. **Zero Carbon Cement:** cast-in-place concrete podium and tower using a zero carbon cement mix
2. **Steel Tower:** cast-in-place concrete podium and structural steel tower
3. **All Steel:** cast-in-place concrete foundation and partially below-grade levels 1 and 2, with structural steel on floors 3 - 11
4. **Mass timber Tower:** cast-in-place concrete podium and mass timber structure tower
5. **BubbleDeck® Tower:** cast-in-place concrete podium and BubbleDeck tower
6. **All BubbleDeck®:** BubbleDeck podium and tower

All the Structural Design Alternatives maintained the same functional equivalency as the 50% Design Development Model and Baseline Model. The building floor plans and column locations remained the same; however, building heights were adjusted to account for the varying slab thicknesses of the different structural systems while keeping the same ceiling-to-ceiling height. The different building heights led to different total exterior envelope areas; however, the total window area was kept the same. The size of the foundations was also adjusted to account for differences in building weights based on different structural materials, but the size of the two stair and elevator cores was kept consistent.

All fire and life safety requirements and ratings were maintained across the design of the 50% Design Development Model, Baseline Model, and Structural Design Alternatives. The project team also selected products that were currently available in the market and met regulatory and performance requirements for the Sauder Expansion project.

Table 2 summarizes the design and material choices across the 50% Design Development Model, Baseline Model, and all Structural Design Alternatives.

Table 2: Design overview of the 50% Design Development Model, Baseline Model, and Structural Design Alternatives (Source: information provided by UBC Sauder School of Business Expansion Embodied Carbon Case Study Report and reLoad Sustainable Design).

Shortlist	Design Development and Baseline Models		Structural Design Alternatives					
	50% Design Development	Baseline Model	1 Zero Carbon Cement	2 Steel Tower	3 All Steel	4 Mass Timber	5 BubbleDeck® Tower	6 All BubbleDeck®
Visual Depiction								
Building Height (m)	48.1	52.8	52.8	53.1	53.5	55.2	52.5	52.7
Podium Structural Design (Levels 1-4)	Lower embodied carbon concrete specifications for footings, cores, and columns. Conventional cast-in-place concrete.	Conventional cast-in-place concrete.	Same as Baseline Model but with Heidelberg Zero Carbon Cement.	Same as the Baseline Model.	Levels 1 and 2 remain concrete due to partial below-grade areas. Levels 3 and 4 use structural steel. Slabs: 114mm Concrete topping on steel deck.	Same as Baseline Model.	Same as Baseline Model.	Slabs: 285 mm BubbleDeck. Concrete beams and columns.
Tower Structural Design (Levels 5-10)	Conventional cast-in-place concrete with post-tensioned slabs.	Conventional cast-in-place concrete. Added two columns to allow for shorter spans in the tower lobby.	Same as Baseline Model but with Heidelberg Zero Carbon Cement.	Slabs: 114mm Concrete topping on steel deck. Beams and columns are structural steel.	Slabs: 114mm Concrete topping on steel deck. Beams and columns are structural steel.	Slabs: 50 mm Concrete topping on 245 mm (7-ply) Cross-Laminated Timber (CLT). Glue Laminated Timber (GLT) columns and beams (steel connections were used).	Slabs: 285 mm BubbleDeck. Concrete beams and columns.	Slabs: 285 mm to 340 mm BubbleDeck. Concrete beams and columns.

4.3 Structural Design Alternatives and Emissions Data Sources

For each Structural Design Alternative, the project team assessed emissions data from two sources: industry-average emissions and product-specific emissions for a low-carbon option. The industry-average emissions data primarily came from either Canadian or North American industry-wide Environmental Product Declarations (EPDs). The low-carbon material emissions data came from the Building Transparency EC3 EPD database. For two low-carbon Structural Design Alternatives—zero carbon cement and mass timber—the same materials were used in both the industry-average and low-carbon scenarios, as lower-carbon versions of these materials were not available on the market. As such, the key difference between the two options came from other materials—such as rebar and fibreglass windows—that used low-carbon specific EPDs.

Table 3 summarizes the building materials and emissions data sources for each Structural Design Alternative.

Environmental Product Declaration: Standardized documents that provide transparent and quantified environmental data for building products or services based on an LCA.

Table 3: Building materials and emissions data sources for the six structural design alternatives (Source: information provided by UBC Sauder School of Business Expansion Embodied Carbon Case Study Report and reLoad Sustainable Design).

Design Alternative	Structural Materials and Building Components	Industry Average Materials and Emissions Data Sources	Low(er)-Carbon Materials and Emissions Data Sources
Zero Carbon Cement	Concrete Rebar Window	Zero carbon cement mix from Heidelberg Materials, Edmonton, Canada. * North American industry-average rebar from the Concrete Reinforcing Steel Institute.	Zero carbon cement mix from Heidelberg Materials, Edmonton, Canada. * Rebar from Cascade Steel Rolling Mills. Oregon, USA. Inline Fibreglass Windows, Ontario, Canada.
Steel Tower and All Steel	Steel Concrete Rebar Window	Canadian industry-average structural steel from the Canadian Institute of Steel Construction (CISC) BC-specific industry-average ready-mix concrete from Concrete BC. North American industry-average rebar from the Concrete Reinforcing Steel Institute.	Structural steel from the Gerdau plant in Virginia, USA. Ready mix concrete from Lafarge Canada Inc., Kent Ave., Vancouver, Canada** Rebar from Cascade Steel Rolling Mills in Oregon, USA. Inline Fibreglass Windows, Ontario, Canada
Mass Timber Tower	CLT GLT Concrete Rebar Window	BC-specific industry-average for mass timber products from Forestry Innovation Investment Ltd.* BC-specific industry-average ready-mix concrete from Concrete BC. North American industry-average rebar from the Concrete Reinforcing Steel Institute.	BC-specific industry-average mass timber products from Forestry Innovation Investment Ltd. Ready- mixed concrete from Lafarge Canada Inc., Kent Ave., Vancouver, Canada. ** Rebar from Cascade Steel Rolling Mills in Oregon, USA. Inline Fibreglass Windows, Ontario, Canada.
BubbleDeck® Tower and All BubbleDeck®	Concrete Rebar Window	Ready mix concrete from the Concrete BC's database North American industry-average rebar from the Concrete Reinforcing Steel Institute.	Ready-mixed concrete from Lafarge Canada Inc., Kent Ave, Vancouver, Canada.** Rebar from Cascade Steel Rolling Mills in Oregon, USA. Inline Fibreglass Windows, Ontario, Canada.

* Lower-carbon versions of these materials were not available on the market; both industry-average and low-carbon materials were considered the same for this analysis.
** An extended curing time of 56 days was assumed to maximize carbon reduction for the lowest-carbon option.

4.4 Bill of Materials Generation

For each of the Structural Design Alternatives, the project team quantified the Bill of Materials (BoM) to calculate the embodied carbon emissions associated with their materials inventory. The process began by generating a BoM from the 50% Design Development Model structural Revit model, supplemented by manual quantification of some elements, such as stairs and steel rebar, not captured in the model. The BoMs for the Baseline Model and Structural Design Alternatives were then adapted from this base, with input from the structural engineers and architects to reflect material changes in each scenario.

4.5 wbLCA Models and Assumptions

All of the wbLCAs for the 50% Design Development Model, Baseline Model and Structural Design Alternatives were conducted using One Click LCA—a proprietary LCA software for building construction and manufacturing by Bionova Ltd. The wbLCA models were developed using a cradle-to-grave approach, analyzing GHG emissions associated with all stages of the building's life—from material manufacturing and production through construction and use, to final demolition and disposal of materials at the end of the building's lifespan. Table 4 summarizes the major inputs and assumptions used in the wbLCA calculations.Table 4 summarizes the major inputs and assumptions used in the wbLCAs.

Bill of Materials: The list of product flow quantities included in the building model scope that make up the physical building. In the context of buildings carbon emissions, it serves as input data for assessment process.

Table 4: Summary of general inputs and assumptions for the wbBLCA models and analysis. (Source: information provided by the UBC Sauder School of Business Powerhouse Expansion Embodied Carbon Case Study Report and reLoad Sustainable Design).

Functional Unit	Gross floor area of 14,042 m^2.
System Boundary	Cradle-to-grave, including product (A1-A3), construction process (A4-A5), use (B4-B5), end of life (C1-C4).
Reference Study Period	60 years life span.
LCA Data Source	• 50% Design Development architectural drawings. • Structural Revit model. • Emissions for conventional material alternatives were sourced from industry-average EPDs • Emissions for lower-carbon material alternatives were sourced from the product-specific EPDs in the EC3 EPD database.
LCA Tool	One Click LCA.
LCA Assessment element	• Substructure: foundations, walls for subgrade enclosures, standard and structural slabs-on-grade • Shell: floor construction, roof construction, stairs, exterior walls, windows, doors and grilles, roofing • Interiors: interior partitions, windows and doors, raised floor construction, suspended ceiling construction • Fixtures, furniture, and mechanical, electrical, and plumbing (MEP) systems are excluded
Assumptions and manual cor-rections made to LCA tool de-fault values	• Concrete transportation distance from the plant to the site (module A4) set to 20 km • Curtain walls and windows were assumed to have a service life of 60 years, internal walls were assumed to have a service life of 60 years • Roofing finish and membranes were assumed to have a service life of 20 years, or be replaced twice during the building life span • Acoustic ceilings are assumed to have a service life of 30 years or be replaced once during the building life span • End-of-life scenarios from the EPDs were used for materials like XPS insulation and SBS roofing. • For the zero carbon cement option, a 10% cement by volume of concrete was used to calculate the weight to ship from Edmonton by train

4.6 Embodied Carbon Emissions Estimates

The wbLCAs estimated the total embodied carbon emissions for each of the 50% Design Development Model and Baseline Model, as well as six Structural Design Alternatives. The following section represents and summarizes the results.

Figure 12 shows the estimated total embodied carbon emissions for the 50% Design Development Model, the Baseline Model, and the six Structural Design Alternatives.

Industry-average emissions and low-carbon product-specific emissions are shown for each Structural Design Alternative.

Figure 13 presents the reduction percentage in total embodied carbon emissions for each of 50% Design Development Model and the Structural Design Alternatives, including industry-average and low-carbon versions, relative to the Baseline Model.

Figure 11: Visualizations of the Sauder Expansion project (Source: Design by ACTON OSTRY + Patkau Architects, renders by Mute Images).

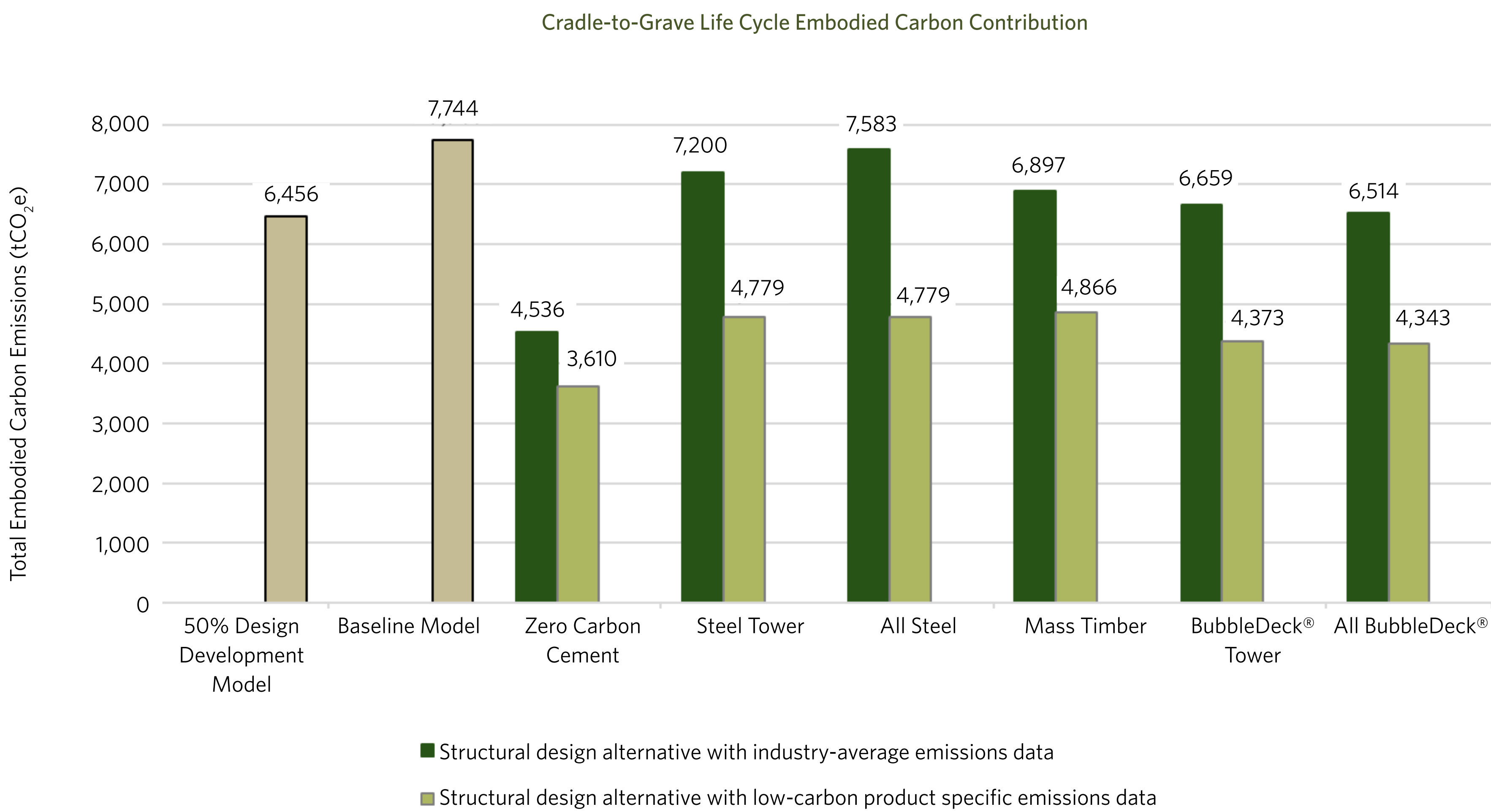


Figure 12: Estimated total embodied carbon emissions for each of the 50% Design Development Model, Baseline Model, and the Structural Design Alternatives, including industry-average and low-carbon versions (Source: information provided by the UBC Sauder School of Business Expansion Embodied Carbon Case Study Report).

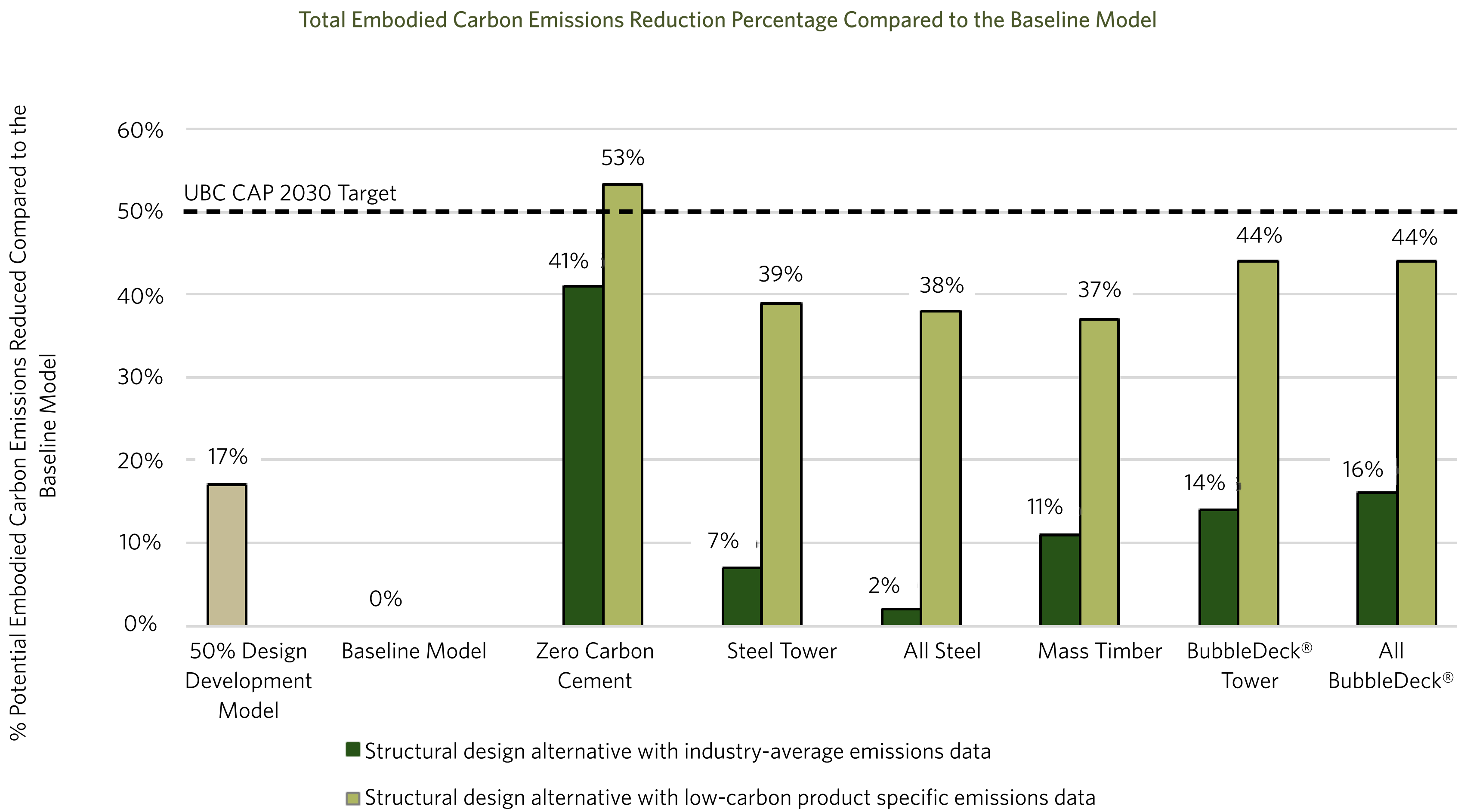


Figure 13: Reduction in total embodied carbon emissions of 50% Design Development Model and Structural Alternative Designs, showing industry-average and low-carbon versions, compared to the Baseline Model (Source: information provided by the UBC Sauder School of Business Expansion Embodied Carbon Case Study Report).

- **Baseline Model**, which uses conventional cast-in-place concrete for the structure, was estimated to have a total embodied carbon emissions of 7,744 tCO_2e (~ 550 $kgCO_2e/m^2$) over the building's full lifecycle.
- **50% Design Development Model** with a total embodied carbon emission of 6,456 tCO_2e (~460 $kgCO_2e/m^2$), this model reduced emissions by 17% below the baseline. This reduction was primarily due to the smaller volume of concrete used in the post-tensioned concrete slab structure for this design option.
- **Zero Carbon Cement** alternatives resulted in total embodied carbon emissions of 4,536 tCO_2e for the industry-average option and 3,610 tCO_2e for low-carbon option, representing reductions of 41% and 53%, respectively, compared to the Baseline Model. As the same zero carbon cement product was used in both the industry-average and low-carbon versions, the additional savings in the low-carbon option were due to lower emissions from emissions from other low-carbon products, including the rebar and the fibreglass windows.
- **Steel Tower** design alternatives had total embodied carbon emissions of 7,187 tCO_2e for the industry-average version and 4,747 tCO_2e for the low-carbon version, representing reductions of 7% and 39%, respectively, compared to the Baseline Model. This wide range reflects the large difference in emissions data between the industry-average and low-carbon steel products.
- **All Steel** design alternatives followed a similar trend to the Steel Tower design alternative, with total embodied carbon emissions of 7,583 tCO_2e for the industry-average version and about 4,780 tCO_2e for the low-carbon version. Compared to the baseline, All-Steel option using average data reduced emissions by 2%; however, the low-carbon specific data reduced emissions by 38%.
- **Mass Timber Tower** design alternatives demonstrated embodied carbon emissions of 6,897 tCO_2e for the industry-average version and 4,866 tCO_2e for the low-carbon version, achieving 11% and 37% reductions, respectively, from the Baseline Model. The same mass timber products were used for both the industry-average and low-carbon versions. As such, the results illustrate the impact of the other low-carbon components—concrete, rebar, and low-carbon fibreglass windows.
- **BubbleDeck® Tower** design alternatives resulted in total embodied carbon emissions of about 6,660 tCO_2e for the industry-average version and 4,373 tCO_2e for the low-carbon version, corresponding to 14% and 44% reductions, respectively, relative to the Baseline Model. The low-carbon scenario reflects the added benefit of use of materials with lower carbon emissions.
- **All BubbleDeck®** design alternatives showed total embodied carbon emissions of 6,514 tCO_2e for the industry-average version and 4,343 tCO_2e for the low-carbon version, representing reductions of 16% and 44%, respectively, compared to the Baseline Model.

4.7 Construction Cost and Schedule Estimates

Following the wbLCA, the construction manager conducted high-level cost estimates for the 50% Design Development Model, Baseline Model, and Structural Design Alternatives, including both the industry-average and low-carbon materials. The estimate included costs for labour and capital materials for the structural and envelope components, as well as a cost estimate for the foundation and concrete cores across all the versions. The construction manager also estimated a high-level construction schedule for all models.

Figure 14 shows the difference in estimated construction costs for the 50% Design Development Model and Structural Design Alternatives as a percentage of the Baseline Model costs. The chart also shows the estimated variations in the construction timeline for the 50% Design Development Model, Baseline Model, and Structural Design Alternatives, presented in days.

The cost estimates were based on material quantities from the BoMs used in the wbLCAs, input from the design team, and information contained in the construction manager's cost database. The estimates did not account for market changes, supply chain issues, project delays, or future inflation.

Estimated Construction Costs and Schedule Change for the 50% Design Development Model and Structural Design Alternatives Compared to the Baseline Model

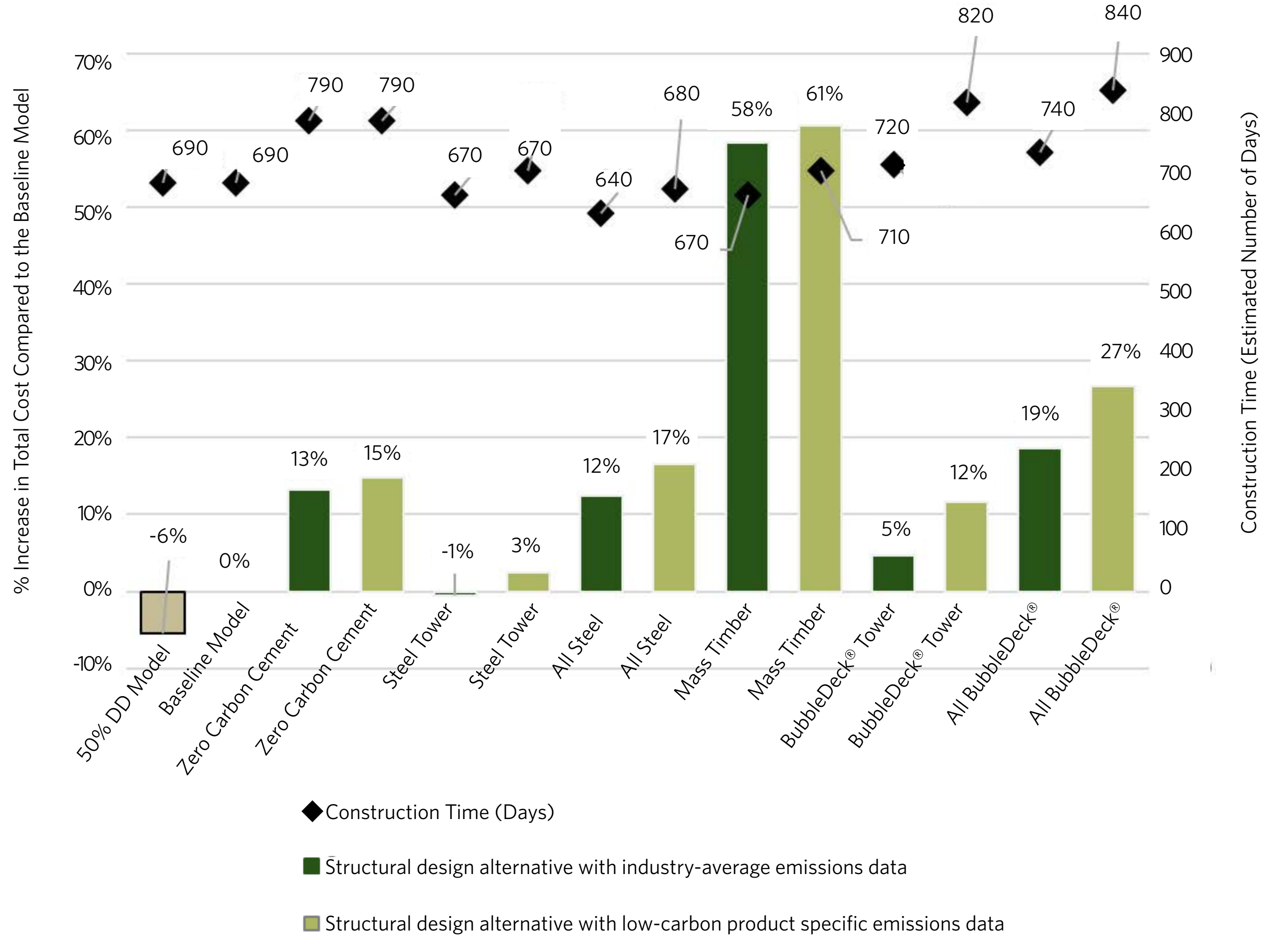


Figure 14: Difference in estimated construction costs and schedule for the 50% Design Development Model and Structural Design Alternatives compared to the Baseline Model (Source: information provided by reLoad Sustainable Design and Heatherbrae Builders).

The cost data for the Baseline Model was considered confidential and was not disclosed in this study. However, it was used as the reference point for estimating percentage changes. The construction manager estimated a 690-day construction schedule for the Baseline Model.

Below is a brief analysis of the impact on construction costs and construction timeline for the 50% Design Development Model and each of the design alternatives compared to the Baseline Model:

- **50% Design Development Model** as estimated to have 6% lower construction costs compared to the Baseline Model, primarily due to its shorter height and smaller volume of materials. The construction timeline remained the same as the Baseline Model.
- **Zero Carbon Cement** options using industry-average data and low-carbon data were estimated to have 13% to 15% higher construction costs, respectively. This was due to higher costs for specially sourced materials and associated labour costs for longer low-carbon cement curing times. The extended curing time resulted in a schedule of 790 days (over three months) longer than the Baseline Model for both models.
- **Steel Tower** design alternatives had estimated construction costs close to the Baseline Model—1% lower for the industry-average version and 3% higher for the low-carbon version. The estimated construction schedule for the industry-average version was shorter than that of the Baseline Model, 670 days; however, the low-carbon version had a longer estimated construction schedule of 710 days, again due to the extended curing time required for the low-carbon cement in the concrete base.
- **All Steel** alternative designs were estimated to have higher construction costs compared to the Baseline Model —12% higher for the industry-average version and 17% higher for the low-carbon version. Both options had shorter construction timelines—640 days for industry-average option and 680 days for low-carbon option—likely reflecting the relative speed of steel construction compared to the extended timeline for concrete structures with added curing time.
- **Mass Timber Tower** design alternatives had the highest construction cost increases—58% for the industry-average version and 61% for the low-carbon version. This difference was due to the design complexity and increased volume of material needed to adapt a mass timber structural system to a building geometry and long-span column layout designed for concrete. The wood materials used in both versions were the same, and the slight cost difference was due to the other low-carbon materials, including window frames, rebar and cement. The estimated construction schedules for the mass timber alternatives varied above and below that of the Baseline Model (670 to 710 days). While mass timber construction typically completes sooner than a cast-in-place concrete tower, the low-carbon cement in the concrete podium requires a longer time for curing, thus extending the construction timeline.
- **BubbleDeck® Tower** design alternatives had estimated construction costs 12% higher for the industry-average version and 15% higher for the low-carbon version, relative to the Baseline Model. The construction schedules were also notably longer (720 to 820 days) due to the complex installation process for the BubbleDeck system, with the low-carbon version with a longer timeline, due to extended concrete curing time.
- **All BubbleDeck®** design alternatives had estimated construction costs 19% higher for the industry-average version and 27% higher for the low-carbon version. Construction schedules were also extended—740 days for the industry-average and 840 days for the low-carbon version—due to the complexity of installing the BubbleDeck system.

4.8 Summary

The result of the embodied carbon case study showed that of the six Structural Design Alternatives assessed in the study, only the low-carbon version of the Zero Carbon Cement alternative was able to reduce embodied carbon emissions by 50% below the Baseline Model. This version used low-carbon product specific emissions data, including zero carbon cement from Heidelberg Materials in Alberta, and incorporated low-carbon rebar and windows sourced from Cascade Steel Rolling Mills in Oregon and Inline Fibreglass in Ontario. Comparatively, it had estimated construction costs about 15% higher than the Baseline Model and a construction schedule over three months longer, mainly due to the extended curing time required for the cement.

While not achieving the 50% target, the other low-carbon versions of the other Structural Design Alternatives still achieved meaningful reductions—ranging from 37% to 44%—demonstrating the impact of using low-carbon products. These options outperformed their industry-average design alternatives, reinforcing the value of using product-specific emissions data. However, they were estimated to have premium costs compared to the Baseline Model, with cost increases ranging from 3% to 61% depending on the design option and material selection. Construction timelines also varied across the alternatives reflecting differences in structural assembly speed and material-specific curing or installation requirements.

Surprisingly, the Mass Timber Tower had relatively high embodied carbon emissions—even its low-carbon solution had higher emissions than most of other alternatives. This result was mainly due to design inefficiencies caused by adapting a timber structure to a layout originally intended for post-tensioned concrete. Imposing a mass timber structure on a column and wall layout that was designed for a concrete structure, as was done in this study, led to a timber structure with deep beams and thick floor panels, resulting increase in storey heights. These constraints limited the effectiveness of the timber design, which required larger timber structural components with greater embodied emissions and higher estimated construction costs. A building designed to be mass timber from the outset would have featured optimized column layouts to provide a more efficient timber system.

When developing the design alternatives, the project team selected only market-available materials that met the performance and regulatory requirements of an academic building in British Columbia. The limited availability of low-carbon products posed challenges—many options were more expensive and required sourcing from greater distances. However, with broader market adoption, the cost premium on low-carbon materials is expected to decline over time.

Relatedly, the difference in results between industry-average and product-specific emissions data highlights the variability of embodied carbon emissions across the same material type. Because EPDs in Canada are not yet standardized, emissions accounting can vary widely depending on the source and supplier.

Designing an efficient structural system that minimizes material use—such as the 50% Design Development Model with a post-tensioned concrete solution—is essential for reducing embodied carbon emissions. Reducing the volume of carbon-intensive materials can be as important as the choice of structural material.

Ultimately, the findings suggest that achieving a 50% reduction in embodied carbon is possible, even within design constraints, through the selection of low-carbon materials and use of high-quality product-specific data. The success of the Zero Carbon Cement alternative proves this potential. Meanwhile, the average ~40% reduction achieved by other low-carbon alternatives shows that meaningful progress is still possible. The project team concluded that integrating embodied emissions targets at the start of a project allows for greater flexibility in meeting reduction goals while managing cost and timeline impacts. Efficient structural design, paired with thoughtful material selection and early planning, is key to reaching stringent embodied carbon reduction targets.

5 REFERENCES

Reports

University of British Columbia Sauder School of Business Expansion Embodied Carbon Case Study Report, 2024, October 15, reLoad Sustainable Design Inc.

University of British Columbia Sauder School of Business Expansion Building Permit wbLCA Report, 2024, July 24, reLoad Sustainable Design Inc.

Additional information

UBC Sauder School of Business Powerhouse Expansion project: https://planning.ubc.ca/SauderExpansion

UBC's GHG emissions targets, requirements and progress: https://planning.ubc.ca/cap2030

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