EMBODIED CARBON CASE STUDY

Evaluating the potential for cost savings and embodied carbon reductions through design efficiency and delayed strength in below-grade concrete structure.

AT A GLANCE

Building Characteristics

- Multi-family Residential Rental Building
- Location: Vancouver, BC
- 248,758 ft² above grade
- 81,860 ft² below grade
- Reinforced Concrete, 20% - 25% SCM Average for GUL cement, aligned with Concrete BC Baseline.
- 34 storeys & 5 below-grade parking floors.
- 275 units
- 142 parking stalls
- 3 elevators

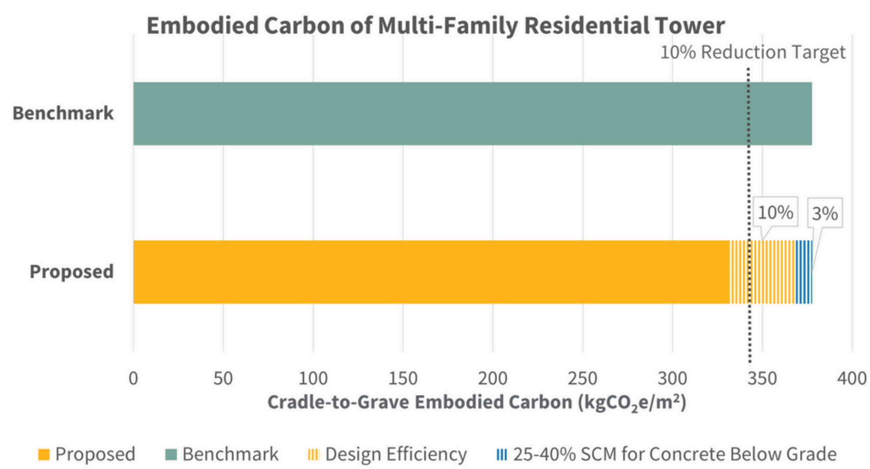
CREATED BY

TANGIBLE

OBJECTIVES & METHODOLOGY

The objective of this case study is to demonstrate the potential for reducing embodied carbon in multi-family residential projects in British Columbia, Canada, through both design efficiency and delayed strength in below-grade concrete structures. The case study evaluates strategies to achieve over 10% reduction in embodied carbon across A1-C4, excluding B6, of the structure and enclosure, while analyzing the potential cost savings.

The development project selected for this case study is a 34-storey multi-family residential rental building in Vancouver, Canada, with about 250,000 ft² above grade and 82,000 ft² below grade over 5 parkade floors. 20-25% SCM GUL concrete was specified for this reinforced concrete project, and the mixes' environmental product declarations (EPDs) align with the Concrete BC Baseline for Ready Mix Concrete (2022).



This study aligns with the City of Vancouver Embodied Carbon Guidelines (2023). The City of Vancouver outlines two methodologies for calculating a project's Embodied Carbon Benchmark: the Absolute Path or the Baseline Path. The Absolute Path requires buildings to use 400 kg CO_2e/m^2 as the benchmark for emission reduction calculations, whereas the Baseline Path measures an early design iteration of the building that is functionally equivalent to determine the embodied carbon benchmark. This case study uses the Baseline Path, comparing an early design iteration to the proposed version, in order to prove the embodied carbon savings from design efficiency. The Baseline embodied carbon intensity for this project is 361 kg CO_2e/m^2.

EMBODIED CARBON CASE STUDY

INSIGHTS

Reductions & Savings

- 3% embodied carbon reduction using an average of 25-40% SCM mix for concrete below grade.
- 10% embodied carbon reduction through design efficiency.
- 2% cost savings through higher SCM % for below-grade concrete.
- 7% savings on hard costs through design efficiency, increasing profit over cost by 6%.

SOLUTIONS

Below Grade Concrete

The developer optimized below-grade concrete to reduce embodied carbon while maintaining construction timelines and project budgets. By increasing the SCM percentage of GUL cement from the 20-25% baseline to 25-40%, total embodied carbon was reduced by 2.8% compared to the benchmark. Furthermore, the hard cost for below-grade concrete decreased 2%. One of the priorities for the developer was to limit construction schedule delays due to curing time; thus, only the below-grade concrete was considered.

	Baseline Building	Design Efficiency Improvements	Increase SCM %: 25-40% Below Grade
***Total Embodied Carbon** (kg CO2e)*	8,722,570	7,883,740	7,662,951
***Embodied Carbon Intensity** (kg CO2e/m2)*	361	341	332
Reduction to Baseline		-10%	-3%
Hard Cost Savings		Project Savings: -$12.5 million (-7%)	Concrete Savings: -$27,500 (-2%)
Profit/Cost		+6%	

Design Efficiency

To reduce total embodied carbon and realize significant cost savings across the project, the developer measured and improved the design efficiency of the building across several levers, including;

- Common circulation spaces
- Amenity size ratio per unit
- Lobby size ratio per unit
- Parking ratio per unit
- Parking layout efficiency
- Removing below-grade double height spaces
- Massing complexity (façade articulation)

By utilizing these metrics and reducing unnecessary area, the project realized a 10% reduction in embodied carbon from the Baseline Path (= 361 kg CO2e/m2). If evaluated against the Absolute Path (= 400 kg CO2e/m2 baseline), a 17% reduction is realized,

Such design efficiency savings also resulted in significant financial benefits, with hard costs reduced by 7.4% and profit over cost (including hard and soft costs) increasing by roughly 6%.

EMBODIED CARBON CASE STUDY

INSIGHTS

Through design efficiency, the project achieved:

- 10% embodied carbon reduction (from 361 to 341 kg CO_2e/m^2, Baseline Path)
- 7.4% hard cost savings, boosting gross profit margin by 6%.
- Effective design levers included minimizing circulation spaces, simplifying building massing, and eliminating double-height parkade areas, all without compromising zoning and development guidelines, livability or marketability.
- Smart design decisions can enhance both environmental and financial outcomes.

APPENDIX - EFFICIENCY METRICS

Metrics Summary

This table compares the baseline and post-design efficiency metrics for the project. The post-design optimization reduced the total building footprint from 259,772 ft^2 (above grade) and 107,250 ft^2 (below grade) to 248,648 ft^2 and 81,860 ft^2, respectively, improving overall efficiency from 76% to 79.40%. Key reductions include common corridor space, amenity areas, lobby space, alongside a simplified façade and below-grade parking efficiency. These changes reduced the total embodied carbon from 8,722,534 kg CO_2e to 7,883,740 kg CO_2e, lowering the embodied carbon intensity from 361.43 kg CO_2e/m^2 to 341.28 kg CO_2e/m^2. This demonstrates significant environmental and spatial efficiency gains without compromising the 275 units or the net square footage per unit (700 ft^2).

Typology	Baseline Building	Post-Design Efficiency
Above Grade Sqft	259,772	248,648
Below Grade Sqft	107,250	81,860
Common Corridor Sqft	35,148	29,664
Amenity Sqft	8,250	4,675
Lobby Sqft	3,300	2,475
Façade Sqft	168,852	124,324
#level BG	6.23	4.75
#level AG	39.36	37.67
Efficiency	76%	79.40%
Typical Floor Efficiency	82%	83.60%
Typical Floor Size Sqft	6,600	6,600
Housing Net Sqft	197,427	197,427
# Units	275	275
Net Sqft/Unit	700	700
Gross Sqft/Unit	1,335	1,202
Parking Stalls	178.75	143
Parking Sqft/Stall	600	585
Parking Ratio/Unit	0.65	0.52
Lobby Sqft/Unit	12	9
Amenity Sqft/Unit	30	17
Corridor Sqft/Typical floor	893	787
Corridor Sqft per unit	127.81	107.87
Sqft Envelope/Sqft Enclosed	0.65	0.50
***Total EC** (kgCO2e)*	**8,722,534**	**7,883,740**
***EC Intensity** (kgCO2/m2)*	**361.43**	**341.28**
CO2e/m2 Below Grade	240.81	240.81
CO2e/m2 Above Grade	262.00	262.00
kgCO2e/unit	31,718	28,668

EMBODIED CARBON CASE STUDY

APPENDIX - EFFICIENCY METRICS

Common circulation space

Circulation space, including unsalable areas like elevator lobbies, corridors, and stairs, is frequently overdesigned. For this project, the total area allocated to these spaces was optimized from 760.23 ft^2 to 709.33 ft^2 per floor, reducing the building footprint. This adjustment lowered embodied carbon emissions by minimizing material use.

Diagram 1

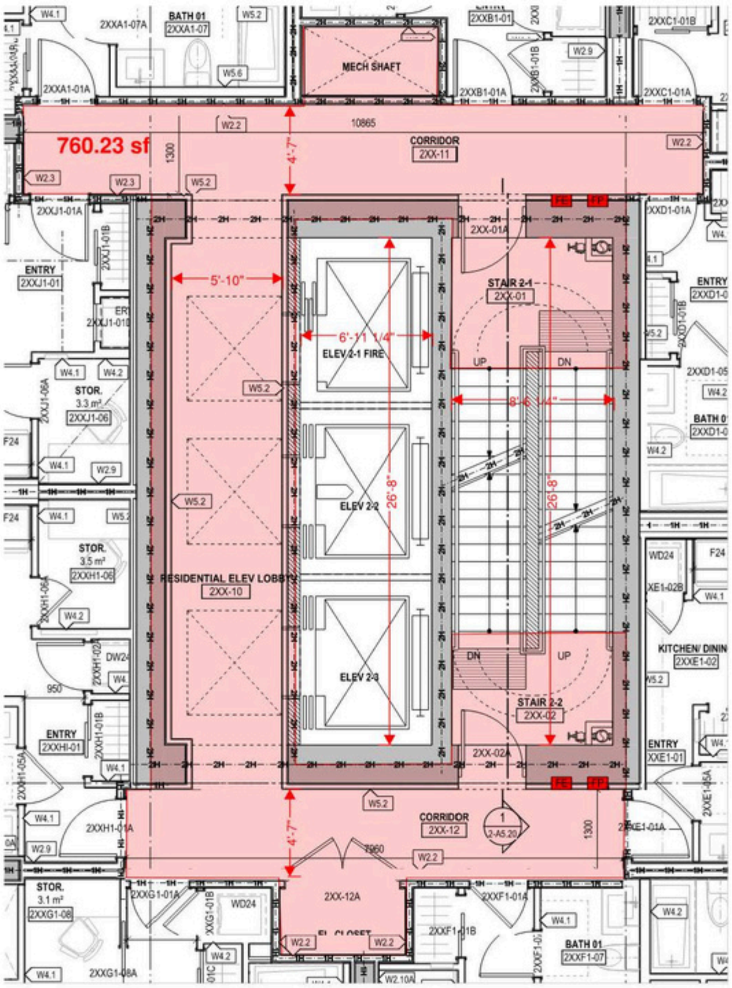
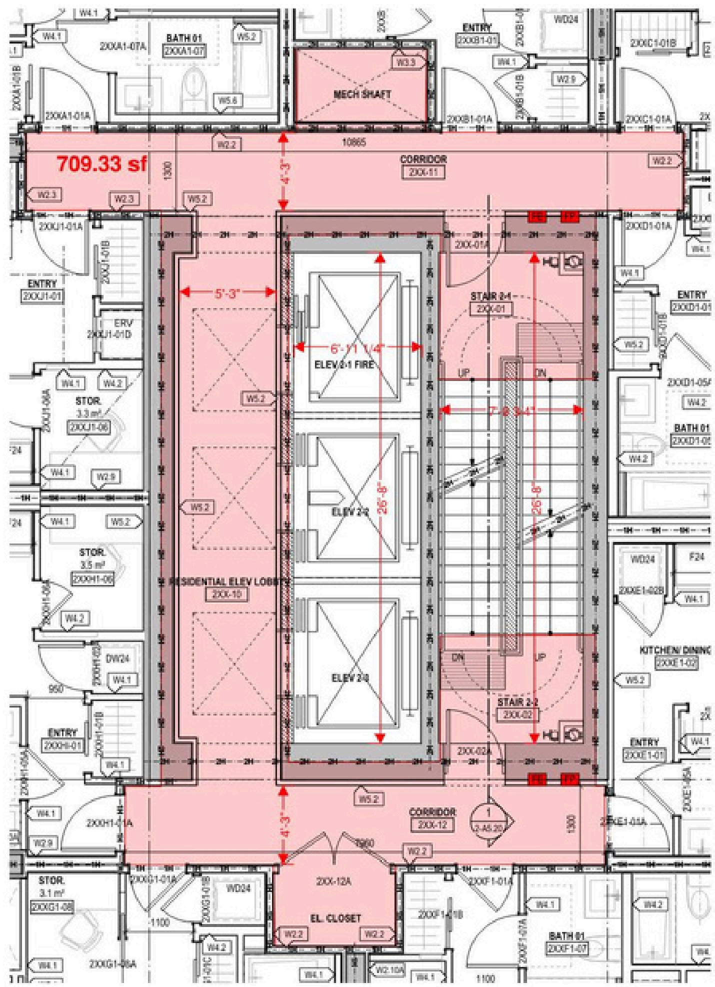


Diagram 2



EMBODIED CARBON CASE STUDY

APPENDIX - EFFICIENCY METRICS

Balcony Area & Massing Complexity

Simplifying massing complexity reduces embodied carbon by eliminating unnecessary materials. For this project, 5,169 ft^2 per floor (highlighted in red) was dedicated to residential units and 900 ft^2 was dedicated to balcony space (about 18% of total built area, see Diagram 1). Since salable area is based on unit size, not outdoor space, reducing balcony space to 15% (783 ft^2) maintained customer appeal while cutting material use. This adjustment lowered embodied carbon by an estimated 2–3% and reduced costs. In Diagram 3, the massing was redesigned into a rectangular shape, reducing façade materials by 15% and cutting embodied carbon and hard costs.

Diagram 1

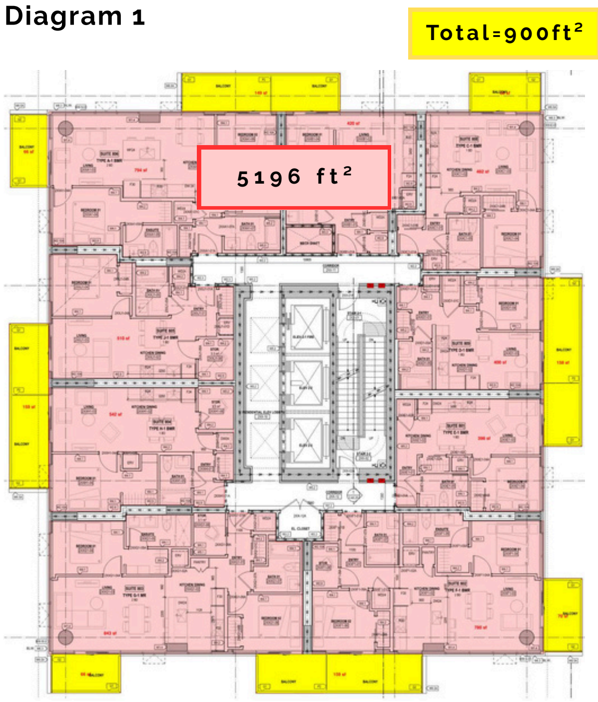


Diagram 2

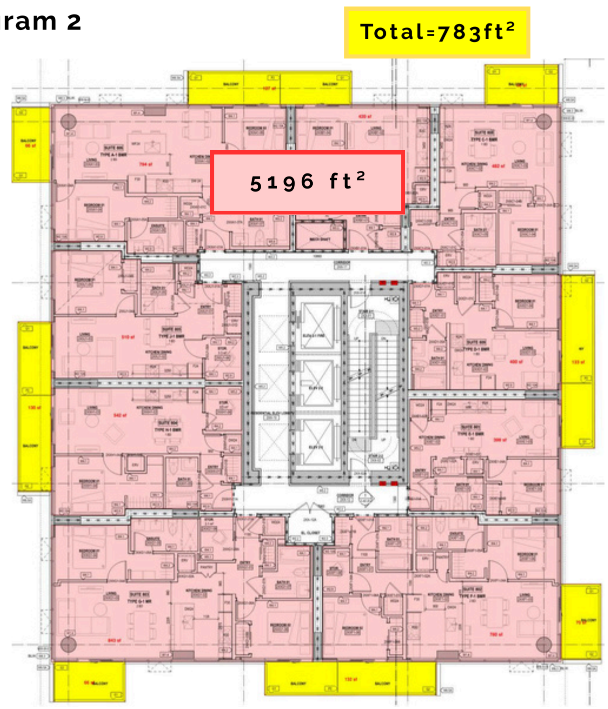
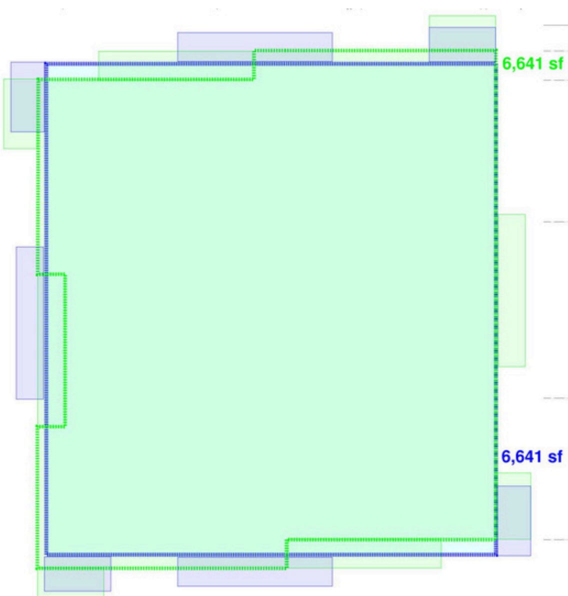


Diagram 3



ENCLOSURE / ENCLOSED

Floor area = 6641 ft^2

Enclosure = 3480 ft^2 (348 x 10 ft)

3480/6641 = 0.52 ft^2

ENCLOSURE / ENCLOSED

Floor area = 6641 ft^2

Enclosure = 2934 ft^2 (326 x 9 ft)

2934/6641 = 0.44 ft^2

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Below Grade Efficiency - Parking

Optimizing below-grade efficiency is a highly effective strategy for reducing both embodied carbon and construction costs. In Diagram 1, moving the columns back (marked in red) across eight floors enabled the addition of 56 parking stalls and the elimination of an entire parkade floor. In Diagram 2, the project team repositioned the core, placing two of the five elevators in a soft core, with only three extending to the parkade. This adjustment freed space for four extra stalls per floor (highlighted in green), totalling 32 additional stalls, and removed half a parkade level. Overall, the parking stalls per floor increased from 42 to 53, reducing the below-grade area per stall from 492 ft² to 390 ft². These changes reduced excavation depth, lowering both carbon emissions and costs, and increased parking revenue.

Diagram 1

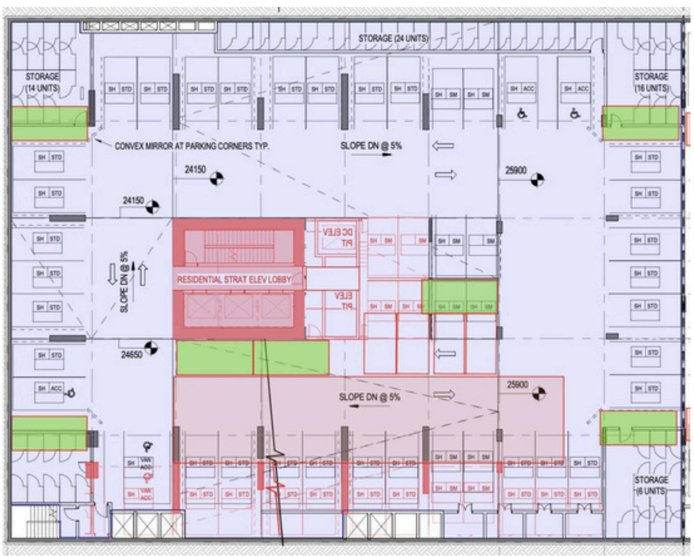
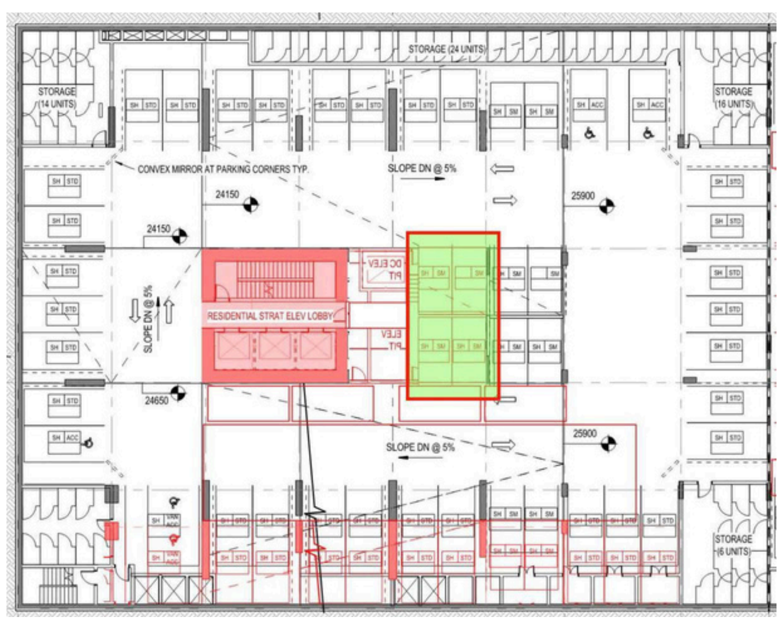


Diagram 2



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Below Grade Efficiency - Double Height Spaces

To reduce excavation depth, double-height spaces were eliminated in the parkade by moving the waste and electrical rooms to grade.