carbon wise
sustainable innovation

FIRE HALL CASE STUDY

City of NELSON

CONTENT

STUDY OVERVIEW

Objectives & Approach

The City of Nelson's Low Carbon Homes Pilot commissioned Carbon Wise to conduct a Whole-Building Life Cycle Assessment (WB-LCA) and cost analysis to inform the planning of its upcoming firehall. This study explores **how design and material choices affect both embodied carbon and cost**, with a focus on **identifying strategic decisions that align sustainability goals with financial feasibility.**

To support this objective, the Creston Emergency Services Building was identified as a similar project, offering a unique opportunity to capitalize on the design development undertaken in Creston, due to its design evolution from an initial timber concept to a final tilt-up concrete structure. The relatively high level of design detail available for both these options represented a rare opportunity to compare two distinct approaches to a functionally equivalent structure. This allowed for an evidence-based analysis of how the design approach and the construction systems used shaped the carbon and cost implications of the buildings across their lifecycle.

By studying both scenarios, the case study highlights where environmental and financial performance align and where trade-offs arise. The findings will guide design decisions for Nelson’s future firehall and demonstrate how lifecycle assessments can be integrated earlier in civic planning. More broadly, the project contributes to a growing knowledge base on how municipalities can lead by example and deliver low-carbon, cost-conscious public infrastructure.

Key Findings & Recommendations

01 Design Integration and Delivery Strategy

Design maturity shaped outcomes: The concrete design benefited from value engineering, prefabrication, and clearer detailing, while the timber design remained conceptual. These differences influenced both cost and carbon outcomes.

Prioritize early-stage integrated design processes (IDP) to align systems and avoid cost escalations.

Prefabrication reduces redundancy and coordination burden: Concrete panels embedded structure, enclosure, and insulation; while the timber design required multi-trade, multi-stage site installation, plus metal siding.

Choose prefabricated envelope assemblies where possible to reduce trades, sequencing conflicts, and site labor.

Material choice alone doesn't determine performance: Efficiency, integration, and detailing had a greater impact on outcomes than whether the structure was timber or concrete.

Design with system simplicity and sequencing in mind, optimize detailing, and avoid layered assemblies.

02 Cost Performance

Higher overall cost for timber

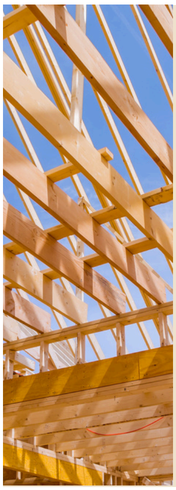
The timber design had a normalized cost of $1,718/m² compared to $1,271/m² for concrete, a 35% premium. This was driven by design immaturity, complexity, and site-built assemblies, not just material choice.

Engage trades and suppliers early to refine scope, reduce redesigns, and control layered costs.

Multi-trade coordination and layered assemblies drive cost

The timber design required more trades, separate envelope components, and on-site sequencing, contributing to higher costs and construction complexity.

Streamline scopes through system integration by coordinating assemblies early and minimizing overlaps between trades.



Lighter timber systems showed savings

Some elements in the timber design were more cost-effective thanks to reduced structural demands; for example, slab-on-deck and structural steel costs were 78% and 45% lower, respectively. This shows potential to align cost and carbon savings when timber is well-integrated.

Leverage lighter systems to reduce structural steel and concrete where possible. Optimize spans and grids accordingly.

Different systems, different savings levers

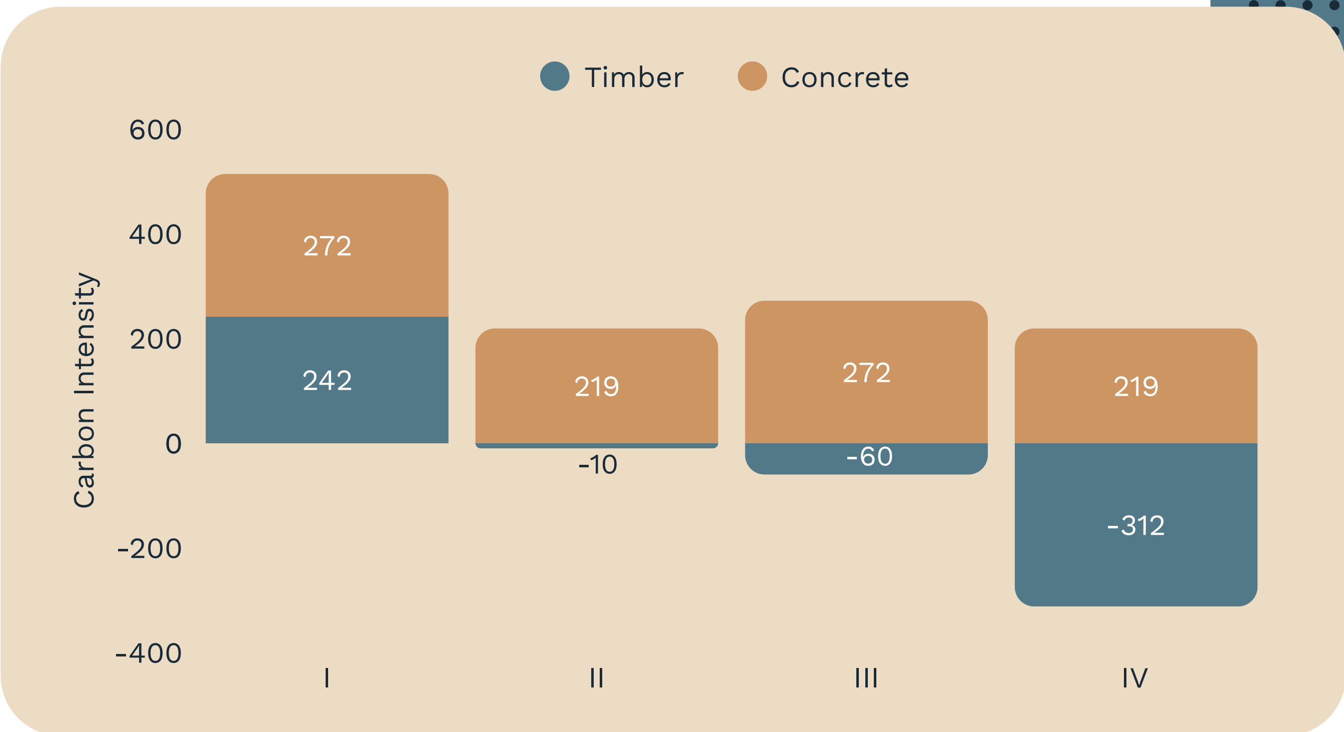
Timber costs are driven by materials, especially engineered wood, while concrete relies more on labor and equipment. This means timber cost savings hinge on innovation and manufacturing scale, while concrete depends on site efficiency. As timber prefabrication advances, it may offer more scalable savings long term.

Focus timber cost strategies on supply chain, standardization, and prefab innovation, not just site labor.

03 Carbon Performance

Timber offered lower embodied carbon intensity

I: Modules A-C: 11% lower intensity
II: Modules A-D: 106% lower intensity
III: Modules A-C with biogenic carbon: 122% lower intensity
IV: Modules A-D with biogenic carbon: 242% lower intensity



Module D (End-of-life) offers major benefits, but it is assumption dependent

The timber design receives large modeled carbon credits based on the reuse or recycling of wood components at end-of-life. **These assumptions may not reflect real-world demolition practices and should be viewed as potential rather than guaranteed outcomes**.

Design for disassembly and reuse to make Module D benefits more feasible in real-world demolition and salvage contexts.

Biogenic carbon is a dynamic system, not permanent offset

Carbon stored in timber during its growth contributes to strong early-stage results, but this advantage only holds if materials are reused or prevented from decomposing. Without circular strategies, the stored carbon is eventually released, reducing long-term climate value.

Treat biogenic storage as conditional, maximize longevity, and reuse potential to retain its climate value.

Modeling assumptions matter

Results from both Module D and biogenic carbon are sensitive to assumptions about reuse, recyclability, and long-term carbon storage. Their benefits are real but conditional.

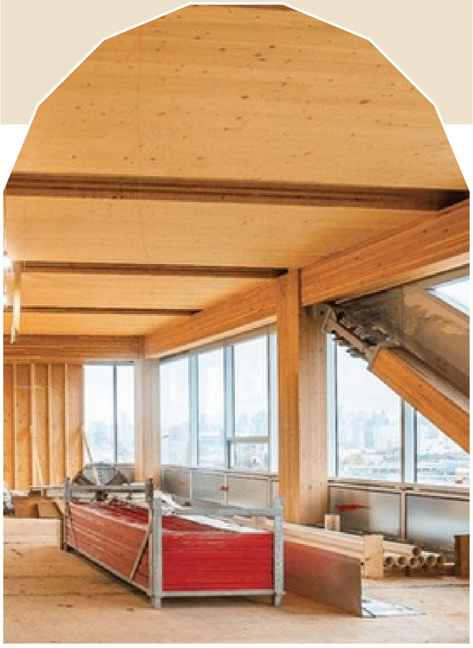
Interpret carbon results as part of a broader strategy. Consider how design intent, material use, and long-term planning interact to shape true climate performance.

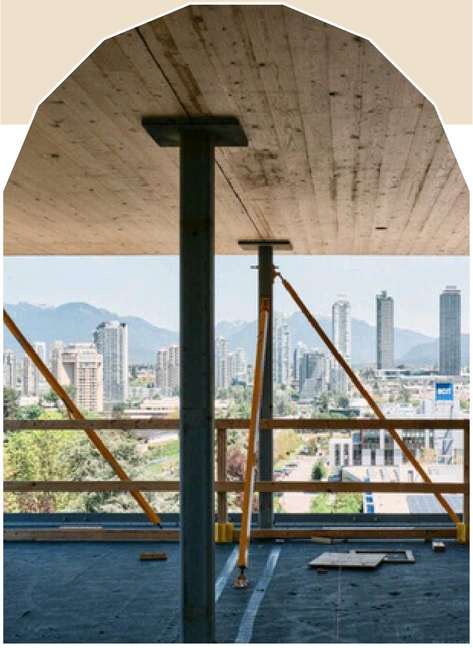
04 Mass Timber Potential

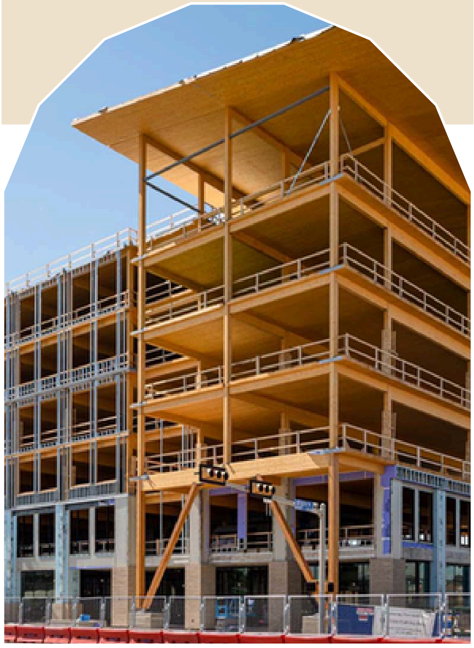
The timber design in Creston relied on light wood framing, limiting the typical benefits of a mass timber system.

With early integration of mass timber and collaboration with manufacturers, future projects can reduce layering, shorten construction timelines, and cut both cost and carbon.

A well-executed mass timber strategy could support regional suppliers while showcasing climate leadership and efficient public infrastructure delivery.







Adopt a true mass timber system (e.g., CLT, glulam) early in design, not as a material substitution.

Engage local mass timber suppliers (e.g., Kalesnikoff) during schematic design to align structural grids and prefabrication strategies.

Engage with local experts and expose timber where possible to reduce finishes and highlight its functional and aesthetic value in public buildings.

Building Comparison and Limitations

Although the Creston Fire Hall's timber and concrete designs aimed to deliver the same core functionality, several differences in layout and structural approach affected their direct comparability (Table 1). In particular, the tilt-up concrete design likely underwent greater refinement, including value engineering and prefabrication strategies that streamlined construction and reduced redundancies. In contrast, the timber design remained in a more conceptual phase, with limited integration of layered assemblies and on-site construction requirements that introduced added complexity. These differences in design maturity and delivery approach (Table 2) affected material quantities, labor demands, and construction processes, making it difficult to isolate the impact of material choice alone on cost and embodied carbon. As a result, the comparative findings must be interpreted with these contextual differences in mind.

Table 1. Comparison of floor area and footprint differences between timber and concrete designs

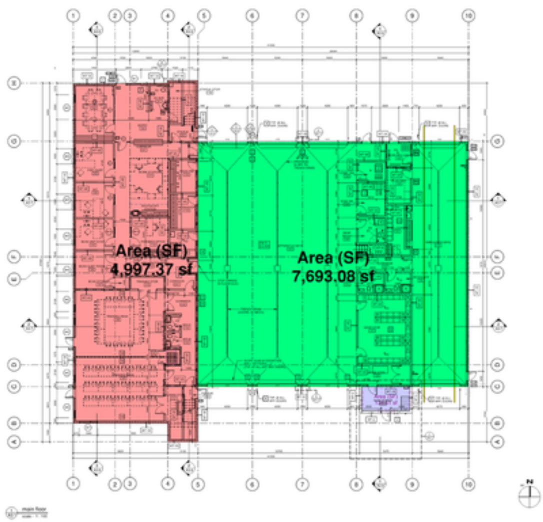
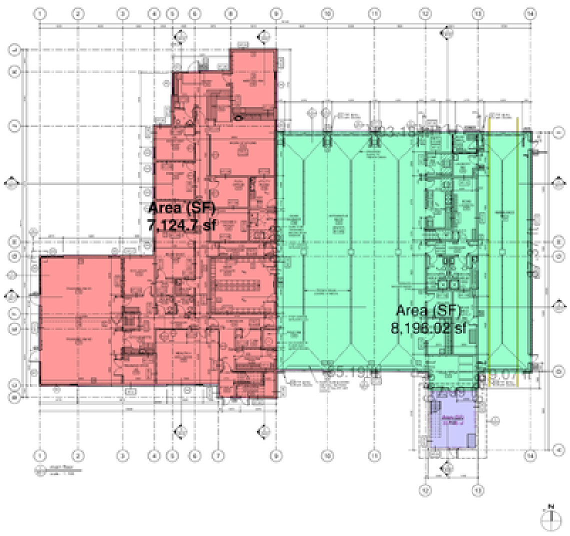
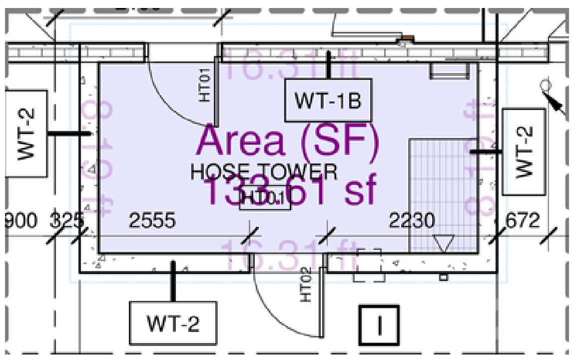
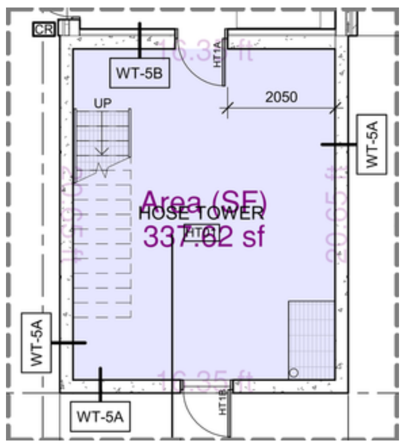
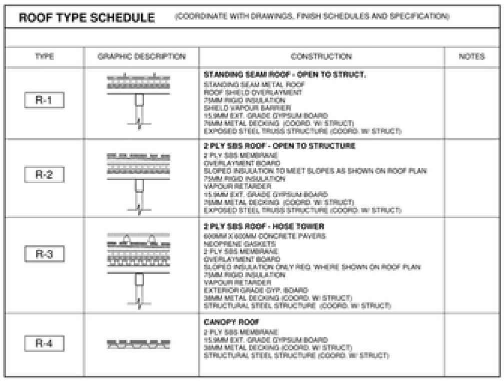
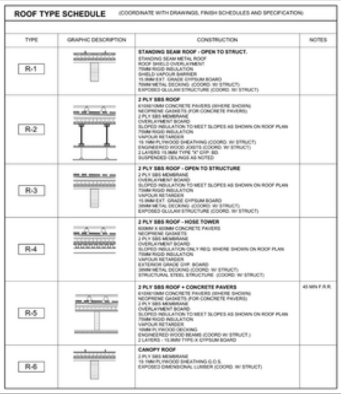
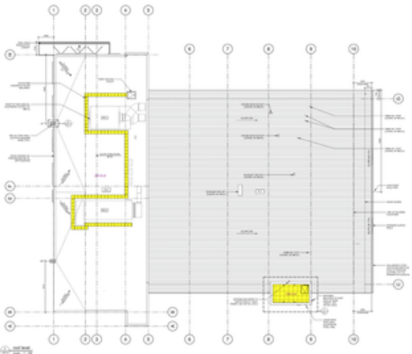
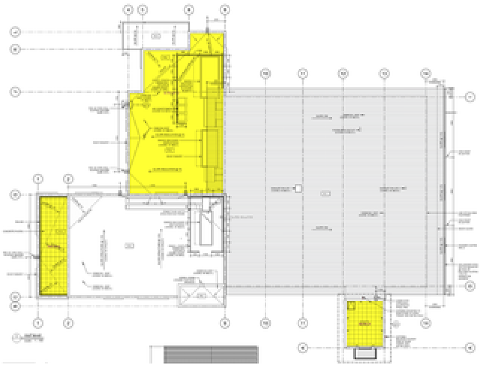
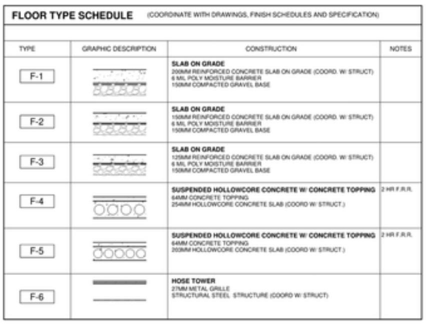
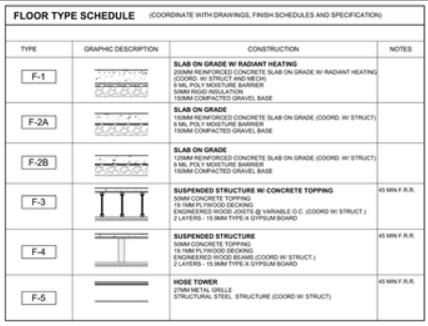
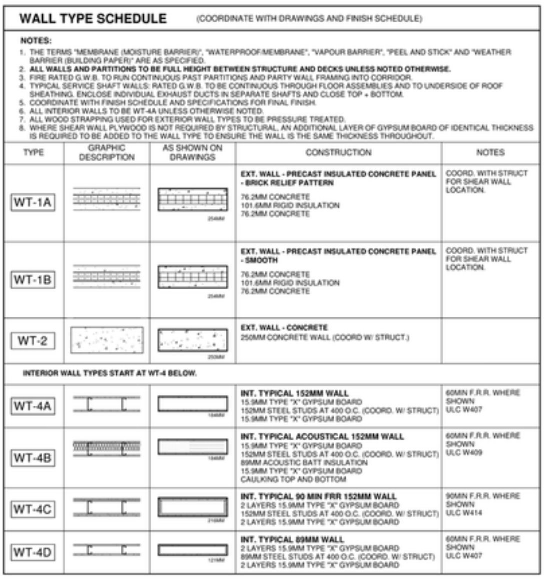
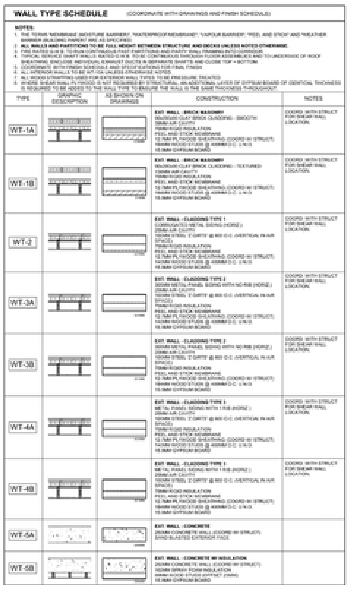
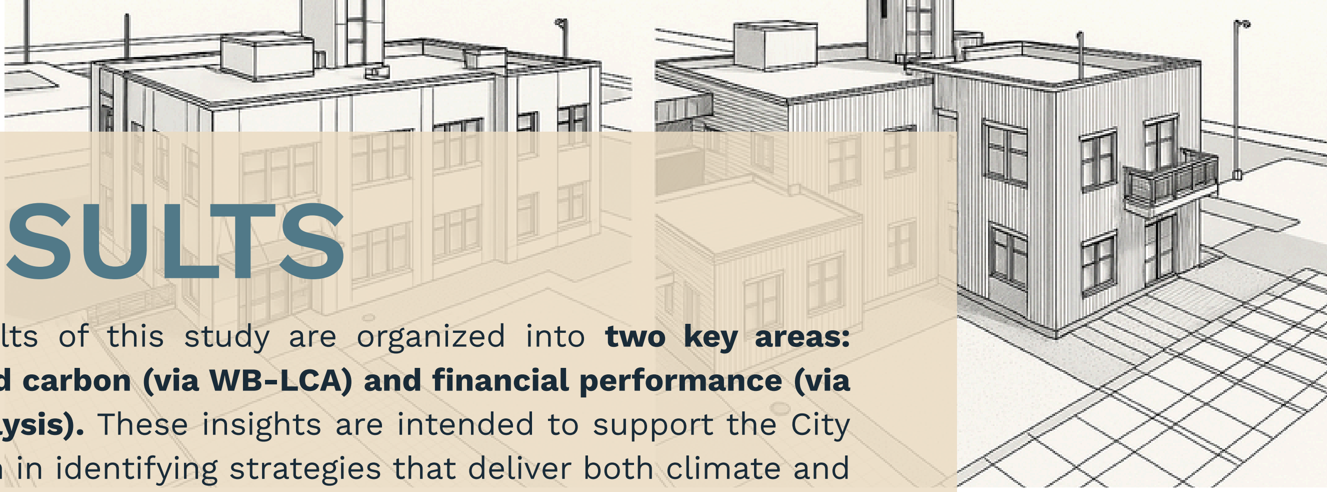
	Concrete Design	**Timber Design**
Total Floor Area	1,653 m² / 17,793 ft²	2,064 m²/ 22,216.7 ft² (+ 24.9%)
Overall Footprint		
Observations	The majority of the additional floor area is in the office portion of the building. This is the area that has 2 levels, where the bays do not have a 2nd level. The hose tower in the two designs is also significantly different in size.	
Hose Tower Footprint	12.4m² / 134 ft² 	31.4m² / 338 ft² (+ 153.2%) 

Table 2. Comparison of assembly differences and design features between timber and concrete designs

	Concrete Design	Timber Design
Roof		
Roof Pavers	 36m² / 387ft² / of pavers resulting in 546.77 kgCO2e or .33kgCO2e/m² (A-C fossil)	 329m² / 3,541ft² (+ 814%) of pavers resulting in 5,437.34kgCO2e or 3.29kgCO2e/m² (A-C fossil)
Supporting Structure	R1 T2 R3 Steel truss, R4 Structural steel	R1 R3 Glulam, R2 TJI, R4 structural steel, R5 R6 GLT
Floors		
Walls		



RESULTS

The results of this study are organized into **two key areas: embodied carbon (via WB-LCA) and financial performance (via cost analysis).** These insights are intended to support the City of Nelson in identifying strategies that deliver both climate and financial value.

Embodied Carbon

01 Core Life Cycle Impacts - Modules A to C

The total embodied carbon (Modules A to C) over a 60-year lifecycle was estimated at **499,594 kgCO_2e** for the timber design and **449,428 kgCO_2e** for the tilt-up concrete design (Table 3, Figure 1). This represents an **11% increase** in total fossil emissions in the timber design when omitting emissions and credits beyond the building life cycle (Module D).

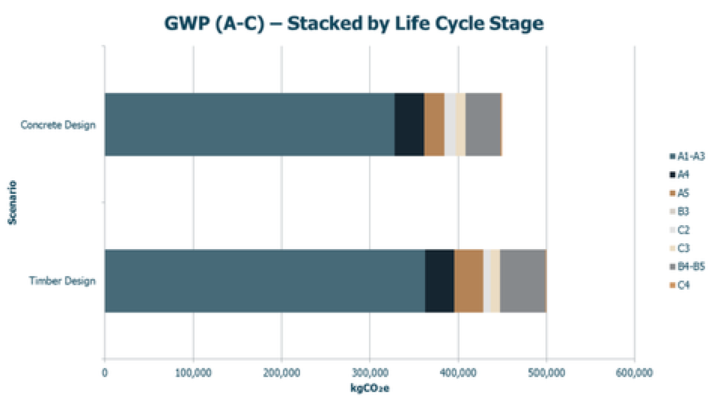


Figure 1. Comparison of total GWP (kgCO_2e) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by life cycle stage.

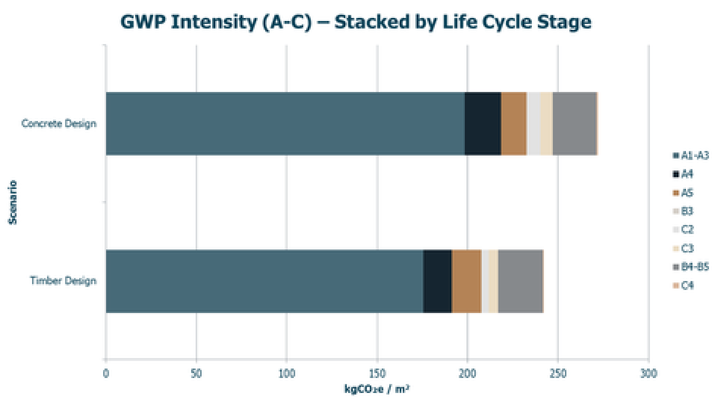
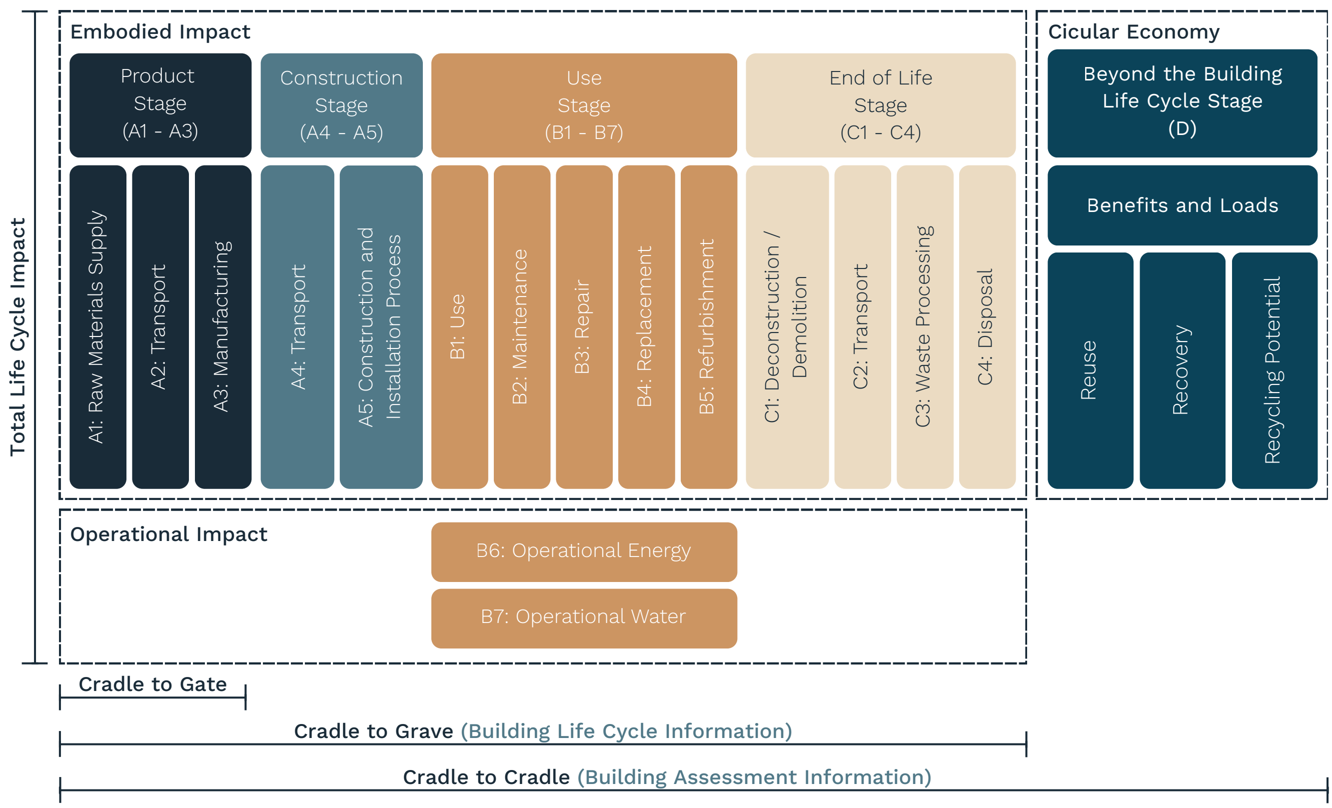


Figure 2. Comparison of total GWP intensity (kgCO_2e / m²) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by life cycle stage.

However, when normalized by building area, the embodied carbon intensity is calculated at **242 kgCO_2e/m²** for the timber structure and **272 kgCO_2e/m²** for concrete (Figure 2). This then reverses the previous comparison showing an **11% reduction in carbon intensity** for the timber design. Carbon intensity is a more appropriate metric for comparison between buildings with differing total floor area. In this case 2,064 m² for the timber design, compared to 1,653 m² for the concrete design (+24.9%).

Across both designs, the embodied carbon profile is dominated by Modules A1-A3, reflecting the upstream impacts of raw material extraction, manufacturing, and product processing, which typically represent the largest share of emissions in whole-building LCAs. Smaller but still meaningful contributions come from A4 (transport to site) and A5 (construction and installation), with the timber design showing a higher A5 burden consistent with a more layered, multi-stage assembly approach, while B4-B5 captures modeled replacements over the 60-year lifespan and is also higher in the timber scenario.

End-of-life impacts in Modules C2-C4 are comparatively minor in both cases, indicating that disposal and waste processing contribute far less to total A-C results than material production.



When results are grouped by building element, both designs show that the majority of embodied carbon is concentrated in the major structural and envelope components, particularly floor slabs, roof assemblies, and associated framing, which represent the largest emissions source in each scenario (Figure 3).

The most notable difference between the two designs is in columns and load-bearing vertical structures, where the timber option contributes a substantially larger share of total GWP, reflecting a greater reliance on distributed framing and gravity structure within the modeled scope. In contrast, the concrete design shows a much higher contribution from external walls and façade, consistent with the tilt-up system's use of concrete wall panels that consolidate structure and enclosure into a single high-impact element.

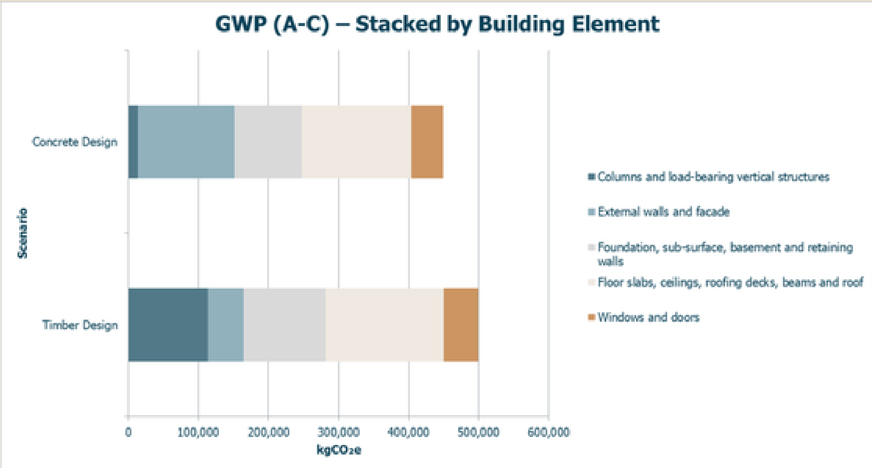


Figure 3. Comparison of total GWP results from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by building element.

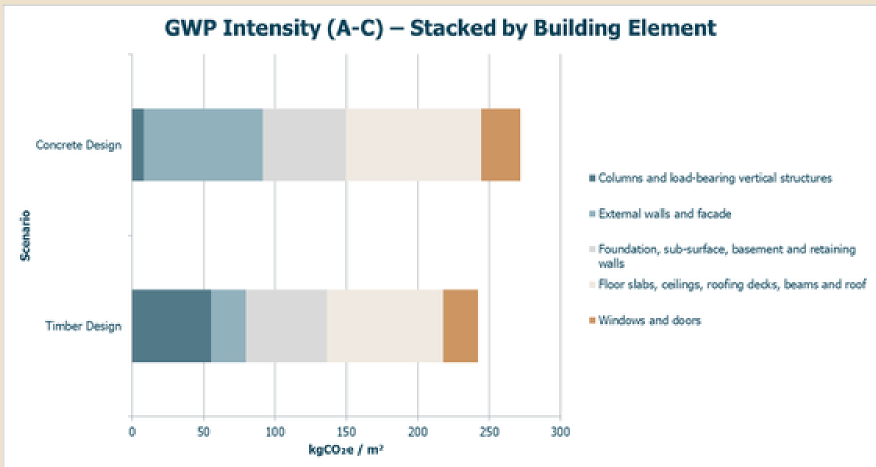


Figure 4. Comparison of total GWP intensity ($kgCO_2e$ / m^2) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by building element.

Foundations and below-grade elements remain significant in both designs, reflecting the material intensity of concrete in substructure work regardless of the above-grade structural system, while windows and doors contribute a relatively similar share across both scenarios. When normalized by floor area, the overall pattern remains the same, but the timber design's larger floor area reduces its per-m^2 impacts across most elements, reinforcing how intensity-based results provide a fairer comparison between schemes of different size (Figure 4).

02 End-of-Life and Circularity Potential (Module D)

500%

Greater in end-of-life credit

105%

Reduction in carbon intensity

When potential benefits beyond the building life cycle (Module D) are included, the gap between the two systems widens substantially. The timber design receives a much larger end-of-life credit of **-520,615 $kgCO_2e$**, approximately **500% greater** than the **-86,771 $kgCO_2e$** credit modeled for the concrete design (Table 3, Figure 5), shifting the timber option from a higher total A-C footprint to an overall net-negative life cycle outcome of **-21,021 $kgCO_2e$**.

In contrast, the concrete design remains net-positive at **362,658 $kgCO_2e$**, reflecting more limited circularity benefits. When normalized by floor area (Figure 6), this difference becomes even more pronounced, with the timber design reaching **-10 $kgCO_2e/m^2$** compared to **219 $kgCO_2e/m^2$** for concrete, representing a **105% reduction** in A-D carbon intensity and reinforcing how Module D assumptions can fundamentally change comparative outcomes when assessed on both a total and intensity basis.

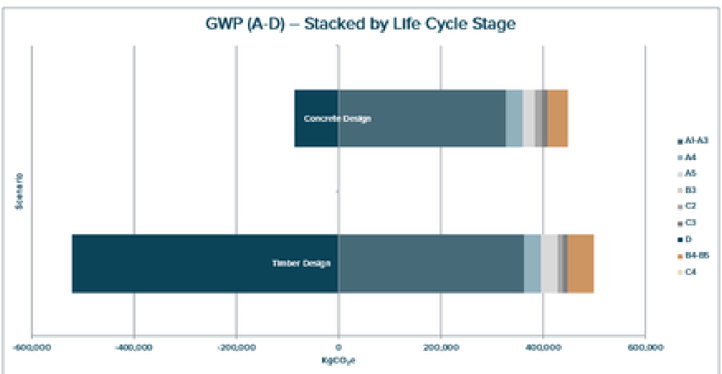


Figure 5. Comparison of total GWP ($kgCO_2e$) from the WB-LCA (Modules A-D) of timber and concrete designs, stacked by life cycle stage

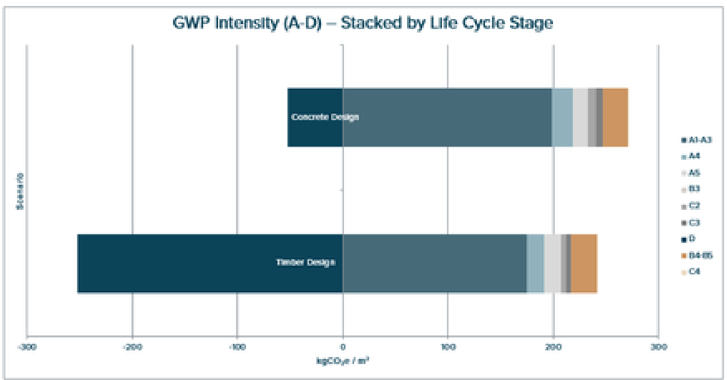


Figure 6. Comparison of total GWP intensity ($kgCO_2e$ / m^2) from the WB-LCA (Modules A-D) of timber and concrete designs, stacked by life cycle stage.

At the life cycle stage level, the distribution of emissions across Modules A-C remains consistent with the previously presented results, with most impacts still driven by A1-A3 material production, followed by smaller contributions from A4 (transport), A5 (construction), and B4–B5 (replacements). The key shift occurs in Module D, where timber receives substantial modeled avoided emissions tied to the assumed reuse, recycling, or recovery of bio-based products. In One Click LCA, components such as glulam beams, softwood lumber, and plywood are treated as stored-carbon materials that can generate downstream benefits if they displace virgin materials in future systems, consistent with the principle of system expansion. By comparison, the concrete design receives a smaller Module D credit because mineral-based elements have fewer reuse pathways and are more often downcycled, with most modeled avoided burdens coming from recycling structural steel rather than concrete itself.

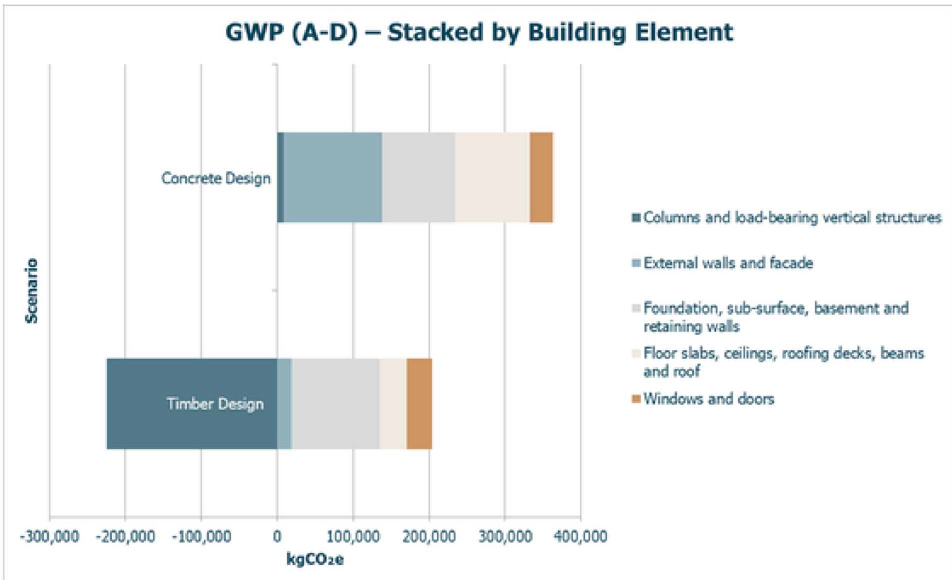
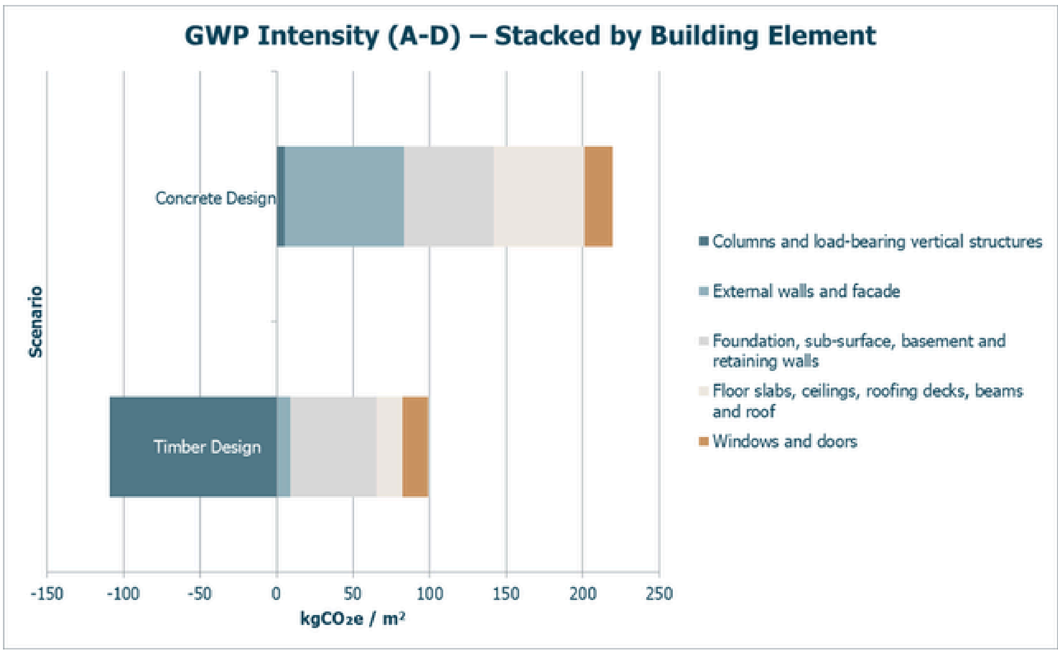


Figure 7. Comparison of total GWP results from the WB-LCA (Modules A-D) of timber and concrete designs, stacked by building element.

When grouped by building element, the influence of Module D becomes especially visible. In the timber design, the largest end-of-life benefit is concentrated in columns and load-bearing vertical structure, which shifts from a major emissions contributor under A-C to a strongly net-negative driver under A-D, reflecting the assumed circularity potential of primary structural timber elements (Figures 7, Figure 8). The concrete design, by contrast, remains dominated by impacts from external walls and façade, foundations, and floor/roof assemblies, with only modest reductions from end-of-life recovery.

Overall, these results highlight that **Module D outcomes are highly sensitive to assumptions** about future demolition practices and material recovery pathways, and are **best interpreted as an indicator of circularity potential rather than a guaranteed climate benefit**.

Figure 8. Comparison of total GWP intensity ($kgCO_2e$ / m2) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by building element.



The end-of-life modeling deepens the environmental distinction between the two designs, emphasizing the circularity potential of bio-based construction in long-term carbon accounting. However, it is important to note that **all impacts and benefits in Module D are theoretical** and highly dependent on the underlying assumptions used in their calculation. This is why they are responsibly reported and considered separately.

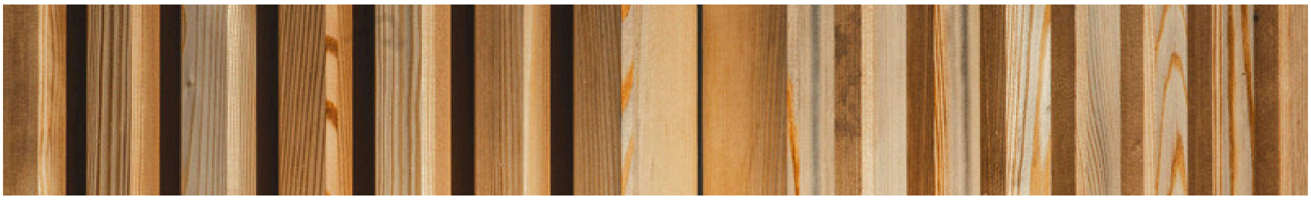


Table 3. Comparative GWP results from the WB-LCA of timber and concrete designs, including absolute and percentage differences (Timber - Concrete). Data reported in $kgCO_2e$ and (%).

Module	Concrete ($kgCO_2e$)	Timber ($kgCO_2e$)	Difference ($kgCO_2e$ (%))
A1-A3	328,283	362,028	+ 33,745 (10%)
A4	32,868	33,176	+ 308 (1%)
A5	23,023	33,065	+ 10,042 (44%)
B4-B5	39,646	50,909	+ 11,263 (28%)
C2	13,014	8,727	- 4,287 (-33%)
C3	11,236	10,661	- 575 (-5%)
C4	1,359	1,029	- 330 (-24%)
D	-86,771	-520,615	- 433,844 (500%)
Total A-C	449,428	499,594	+ 50,166 (11%)
Total A-D	362,658	-21,021	- 383,679 (-106%)
Total A-C intensity	272 $kgCO_2e/m^2$	242 $kgCO_2e/m^2$	- 30 $kgCO_2e/m^2$ (-11%)
Total A-D intensity	219 $kgCO_2e/m^2$	-10 $kgCO_2e/m^2$	- 229 $kgCO_2e/m^2$ (-105%)

03 Biogenic Carbon and Stored Emissions

“Biogenic carbon represents carbon absorbed during tree growth and stored in wood products.”

In addition to fossil-based emissions, the life cycle assessments also account for **biogenic carbon**, which refers to carbon absorbed from the atmosphere during tree growth and stored within wood-based building products. This carbon is reported separately under ISO/EN LCA standards and can appear as a negative emission in early modules when carbon is stored in materials, with its long-term benefit depending on how those materials are managed over the building life cycle. In this analysis, the timber design shows substantial biogenic carbon storage in **Modules A1-A3**, with **260,899 kgCO_2e** sequestered at the product stage, while the concrete design contains negligible biogenic carbon and remains essentially unchanged (Table 4, Figures 9).

When biogenic carbon is included, the timber design shifts to a strongly net-negative result across the A-C boundary. Total A-C impacts become **-123,333 kgCO_2e** for timber, compared to **449,421 kgCO_2e** for concrete, representing a **127% reduction** in total emissions for the timber design before accounting for end-of-life scenarios (Table 4). On an intensity basis, this equates to **-60 kgCO_2e/m²** for timber versus **272 kgCO_2e/m²** for concrete, a **122% reduction** in embodied carbon intensity (Figure 10). At the life cycle stage level, this shift is driven almost entirely by the biogenic accounting applied in A1-A3, while downstream modules such as A4, A5, B4-B5, and C2-C4 remain positive contributors reflecting real emissions associated with transport, construction, replacements, and end-of-life processing.

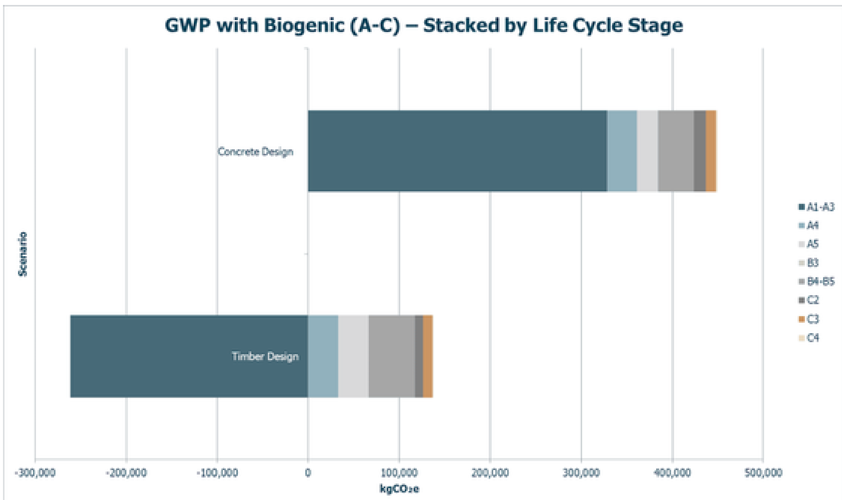


Figure 9. Comparison of total GWP (kgCO_2e) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by life cycle stage, inclusive of biogenic carbon.

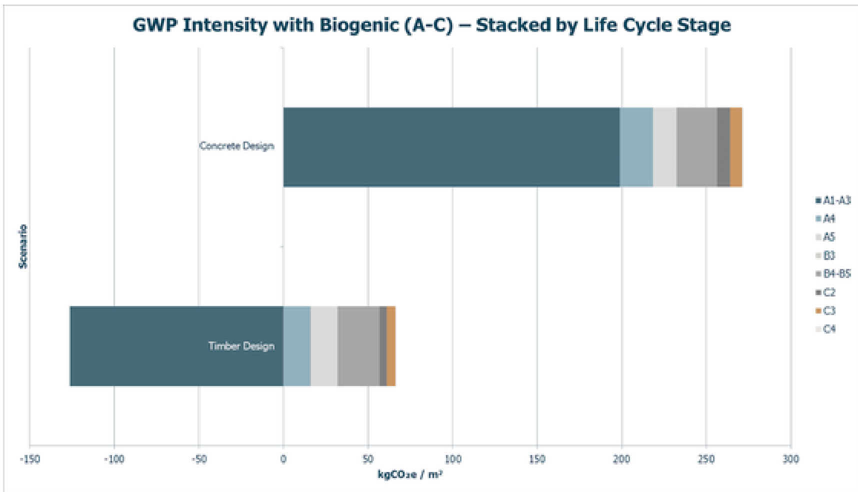


Figure 10. Comparison of total GWP intensity ($kgCO_2e$ / m^2) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by life cycle stage, inclusive of biogenic carbon.

When grouped by building element, the biogenic benefit is concentrated in the timber design's primary structural and enclosure components, with columns and load-bearing vertical structures becoming strongly net-negative and external walls and façade also showing net-negative impacts, reflecting the high volume of stored carbon within wood-based assemblies (Figures 11 and 12). Other elements, particularly foundations and below-grade structure and floor and roof assemblies, remain net-positive due to their continued reliance on concrete and other non-biogenic materials, underscoring that biogenic storage can significantly reshape total results while still coexisting with substantial fossil emissions in key building systems.

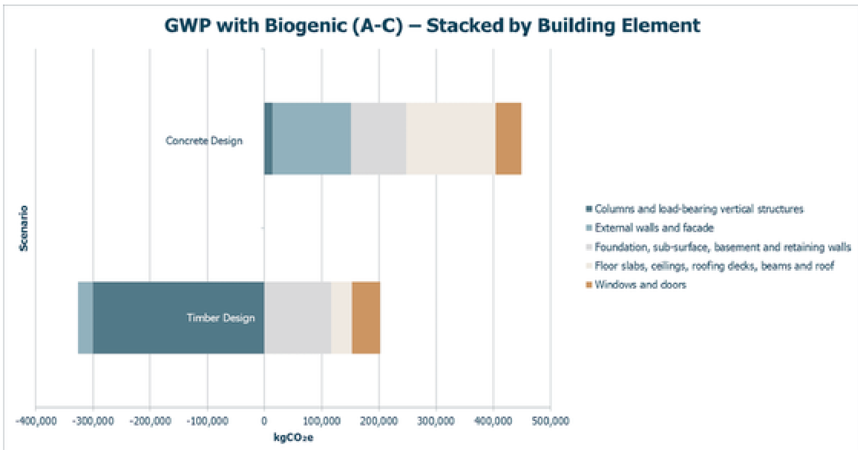


Figure 11. Comparison of total GWP ($kgCO_2e$) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by building element, inclusive of biogenic carbon.

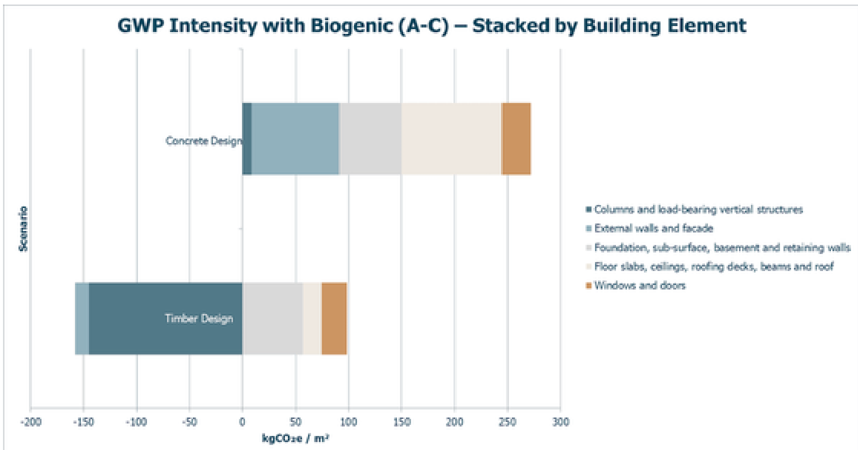


Figure 12. Comparison of total GWP intensity ($kgCO_2e$ / m^2) from the WB-LCA (Modules A-C) of timber and concrete designs, stacked by building element, inclusive of biogenic carbon.

04 Biogenic Carbon and Stored Emissions with End-of-Life and Circularity Potential (Module D)

When both **biogenic carbon accounting** and end-of-life benefits **(Module D)** are included, the timber design demonstrates a substantially larger modeled climate advantage relative to the concrete alternative. The timber scenario achieves a net life cycle impact of **-643,948 kgCO_2e**, compared to **362,650 kgCO_2e** for the concrete design, representing a **278% reduction** in total A-D global warming potential (Table 4, Figures 13). On an intensity basis, the timber design reaches **-312 kgCO_2e/m²**, compared to **219 kgCO_2e/m²** for concrete, which translates to a **242% reduction** in total A–D intensity in favour of timber (Figures 13).

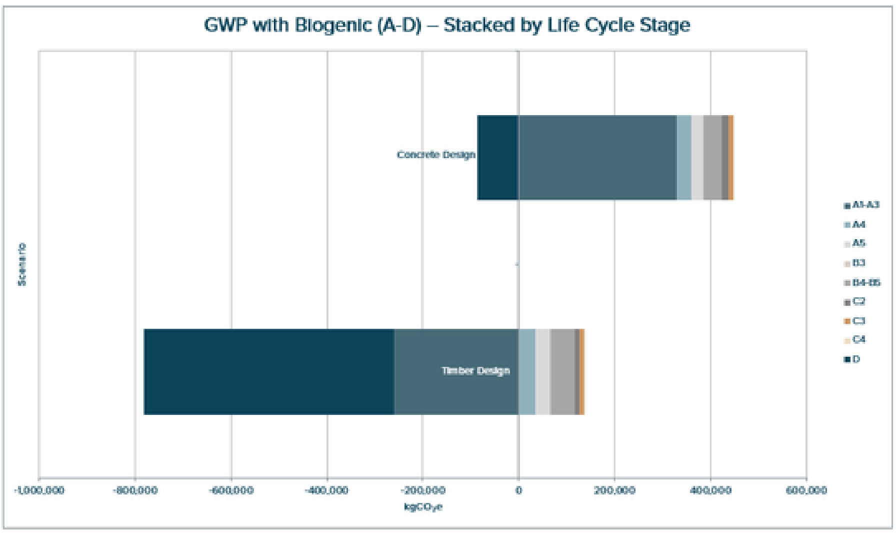


Figure 13. Comparison of total GWP (kgCO_2e) from the WB-LCA (Modules A-D) of timber and concrete designs, stacked by life cycle stage, inclusive of biogenic carbon.

At the life cycle stage level, this shift is driven by the combined effect of net-negative emissions in A1-A3, where biogenic carbon storage is recorded in timber products (-260,899 $kgCO_2e$), and the large modeled avoided burdens in Module D (-520,615 $kgCO_2e$). While transport, construction, replacement, and end-of-life processing stages (A4, A5, B4-B5, C2-C4) remain net-positive for timber, they are outweighed by the magnitude of the stored carbon and the assumed circularity outcomes beyond the building's service life. The concrete design, by contrast, remains largely unchanged under biogenic accounting, and continues to show only modest end-of-life credits in Module D (-86,771 $kgCO_2e$) primarily associated with steel recycling rather than the mineral-based building fabric.

When grouped by building element, the timber design's net-negative outcome is concentrated in major structural components, with columns and load-bearing vertical structures showing the largest benefit (-638,671 $kgCO_2e$), followed by external walls and façade (-58,541 $kgCO_2e$) and floor/roof assemblies (-97,347 $kgCO_2e$) (Figures 15, Figure 16). Foundations and below-grade elements remain net-positive due to their continued reliance on concrete, reinforcing that even timber-forward buildings still carry substantial mineral-based impacts in substructure work. Overall, these results highlight the strong influence of both biogenic carbon treatment and Module D circularity assumptions on whole-life outcomes, and underscore that realizing these modeled benefits in practice depends on long-term material recovery, reuse pathways, and design for disassembly.

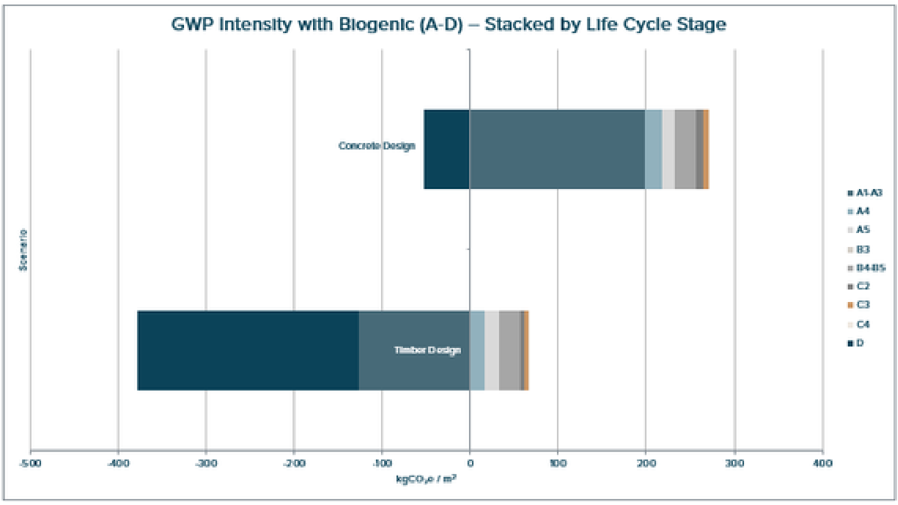


Figure 14. Comparison of total GWP intensity ($kgCO_2e$ / m^2) from the WB-LCA (Modules A-D) of timber and concrete designs, stacked by life cycle stage, inclusive of biogenic carbon.

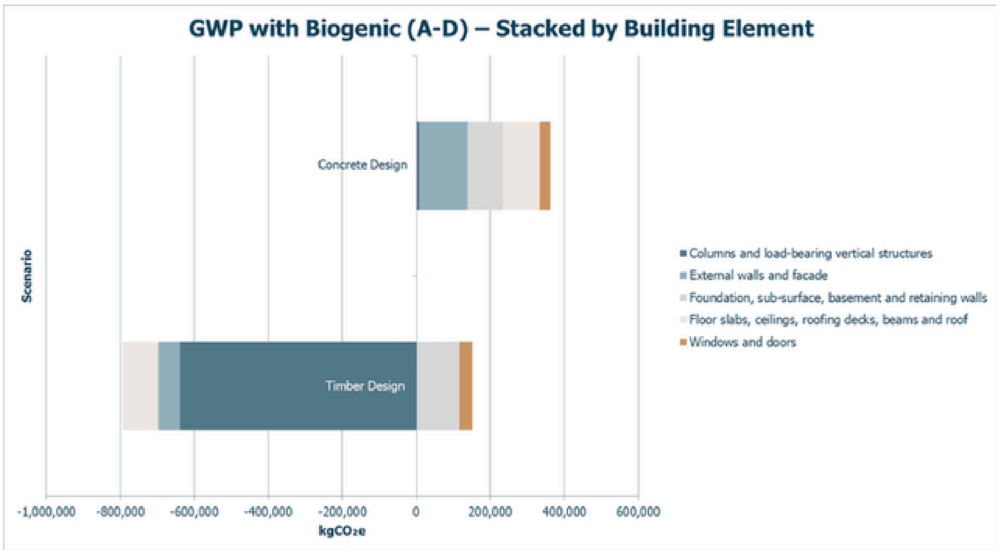


Figure 15. Comparison of total GWP ($kgCO_2$) from the WB-LCA (Modules A-D) of timber and concrete designs, stacked by building element, inclusive of biogenic carbon.

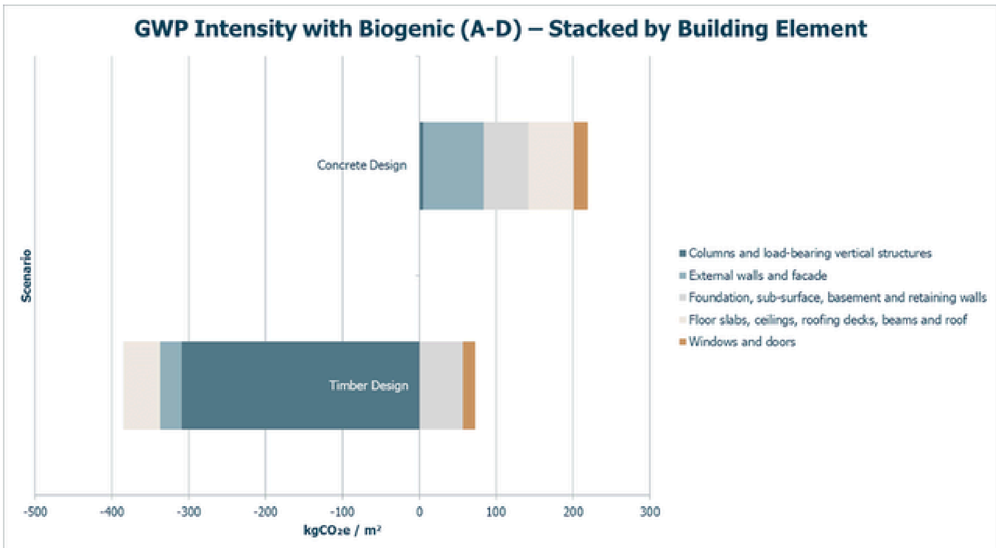
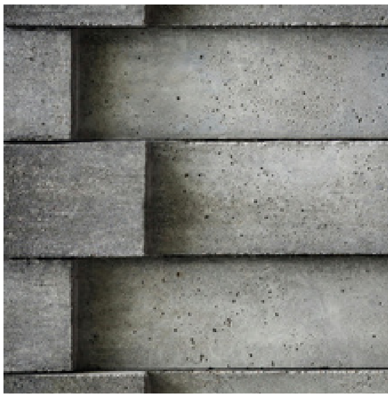


Figure 16. Comparison of total GWP intensity ($kgCO_2e$ / m²) from the WB-LCA (Modules A-D) of timber and concrete designs, stacked by building element, inclusive of biogenic carbon.

Table 4. Impact of biogenic carbon on GWP results from the WB-LCA of timber and concrete designs, including absolute and percentage differences (Timber - Concrete). Only values affected by biogenic accounting and updated totals are shown. Data reported in $kgCO_2e$ and (%).

Module	Concrete ($kgCO_2e$)	Timber ($kgCO_2e$)	Difference ($kgCO_2e$ (%))
A1-A3	328,275	-260,899	- 589,174 (-179%)
Total A-C	449,421	-123,333	- 572,754 (-127%)
Total A-D	362,650	-643,948	- 1,006,598 (-278%)
Total A-C intensity	272 $kgCO_2e/m^2$	-60 $kgCO_2e/m^2$	- 332 $kgCO_2e/m^2$ (-122%)
Total A-D intensity	219 $kgCO_2e/m^2$	-312 $kgCO_2e/m^2$	- 531 $kgCO_2e/m^2$ (-242%)

Cost Analysis



A comparative analysis of total construction costs between the two design options reveals a substantial difference. The tilt-up concrete firehall was estimated at a total cost of **$2,100,500**, while the timber design was estimated at **$3,546,700**. This results in an absolute cost difference of **$1,446,200**, representing a **69% increase** in total construction cost for the timber design. It is important to note that **these estimates account only for materials and labour**. They do not include land acquisition costs, referendum expenses, or any other ancillary costs a city may incur in building a firehall.

When normalized by floor area, with the concrete design covering 1,653 m² and the mass timber version covering 2,064 m², the respective costs are approximately **$1,271 and $1,718 per m²**. This still reflects a **normalized cost increase of $447 per square meter, or 35% higher for the timber option** compared to the concrete alternative. However, these figures should be interpreted with caution, as they reflect not just differences in material choice but also the maturity of each design.

The cost breakdown (Table 5, Table 6) highlights substantial differences between the timber and concrete designs, particularly in structural and envelope-related scopes. While individual line items show where specific systems incur higher costs, **a more holistic view reveals how material strategies, system integration, and design efficiencies influence overall outcomes.** Importantly, many of these efficiencies stem from the fact that the concrete design likely underwent several rounds of value engineering and cost optimization as the selected option. In contrast, the timber design remained in an earlier stage of development, and likely would have incorporated additional cost-saving measures had it progressed further.

At the item level, the most significant cost delta is seen in framing, where the timber design incurs $991,500, compared to just $20,000 in the concrete design. This reflects the choice of primary structural system: the timber design uses a combination of glulam beams, light wood framing, and other conventional elements, all of which require multiple trades and complex on-site assembly. In contrast, the concrete design uses tilt-up panels that consolidate structure, enclosure, and insulation into a single prefabricated system, accounting for $161,000 and reducing the need for separate framing, cladding, and contractors.

The higher cost of the timber approach also reflects the relative novelty of wood-based construction in this building typology, particularly when considering future timber applications where fewer precedents and standardized detailing practices exist. While the Creston design used light wood framing, this still highlights broader opportunities to support the local forest sector and suppliers, including regional mass timber manufacturers such as Kalesnikoff.

Future projects that pursue a mass timber approach could benefit from **early collaboration with such suppliers to optimize both design and fabrication, helping reduce costs, improve constructability, and generate economic value through local material use.**

Similarly, insulation costs in the timber design ($239,500) are significantly higher than in the concrete version ($65,500), because insulation had to be installed onto the enclosure after on-site construction, and in multiple stages as different building components were completed. In contrast, insulation is embedded directly into the tilt-up panels, eliminating redundancy and lowering direct costs in this scope. A similar logic applies to metal siding, present only in the timber design ($296,000) to complete the exterior wall assembly, while the concrete panels serve as finished exterior surfaces in the other version.

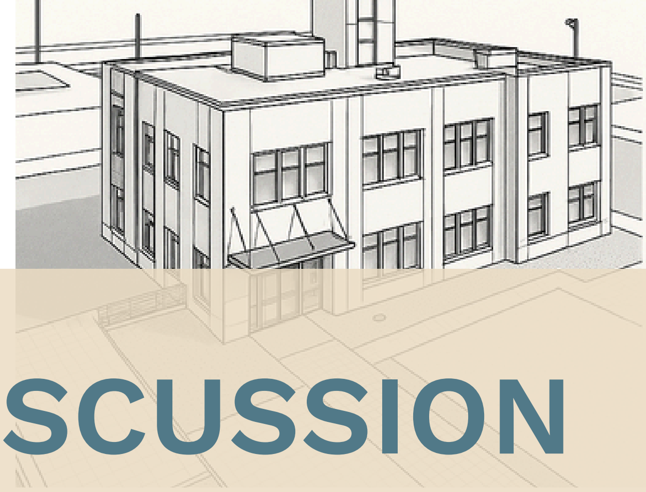
Conversely, several components showed cost reductions in the timber version. For instance, concrete slab on deck costs dropped by 78% ($19,000 compared to $86,000), reflecting a lighter structural system. Similarly, structural steel costs were 45% lower, given the reduced reliance on steel for load-bearing support in the timber structure.

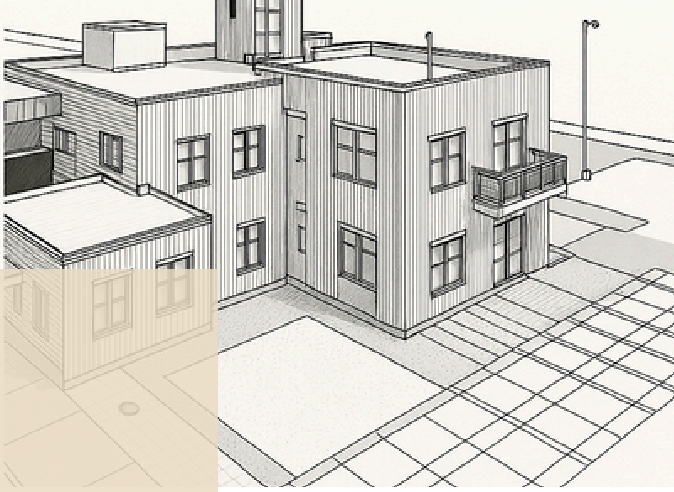
Table 5. Comparative cost breakdown of major material categories between the concrete and timber designs. Values are presented as absolute costs in Canadian dollars ($) for each design, along with the difference in both dollars and percentage (Timber - Concrete).

Material	Concrete ($)	Timber ($)	Difference ($ (%))
Framing	20,000	991,500	+ 971,500 (4,858%)
Metal Siding	N/A^A	296,000	+ 296,000 (N/A)
Insulation	65,500	239,500	+ 174,000 (266%)
Concrete Roof Pavers	2,000	106,000	+ 104,000 (5,200%)
Membrane Roofing	225,000	295,000	+ 70,000 (31%)
Concrete Slab on Grade	106,500	162,000	+ 55,500 (52%)
Drywall	55,000	108,000	+ 53,000 (96%)
Standing Seam Metal Roof	410,000	445,000	+ 35,000 (9%)
Windows & Exterior Doors	211,500	236,500	+ 25,000 (12%)
Steel Stairs*	130,000	130,000	+ 0 (0%)
Specialty Steel - Floor Grates*	20,000	20,000	+ 0 (0%)
Garage Door & Opener	231,500	231,500	+ 0 (0%)
Concrete Footing & Foundation	146,500	140,700	- 5,800 (-4%)
Concrete Slab on deck	86,000	19,000	- 67,000 (-78%)
Structural Steel	230,000	126,000	- 104,000 (-45%)
Concrete Tilt Up Panels	161,000		- 161,000 (-100%)
Total	**2,100,500**	**3,546,700**	**+ 1,446,200 (69%)**

Table 6. Comparative cost breakdown of major material categories between the concrete and timber designs, normalized by floor area to account for differences in building size. Values are shown in Canadian dollars per square foot ($/m²), along with the difference in both absolute and percentage terms (Timber - Concrete).

Material	Concrete ($/m²)	Timber ($/m²)	Difference ($/m² (%))
Framing	12	480	+ 468 (3,870%)
Metal Siding	N/A^A	143	+ 143 (N/A)
Insulation	40	116	+ 76 (193%)
Concrete Roof Pavers	1	51	+ 50 (4,145%)
Membrane Roofing	136	143	+ 7 (5%)
Concrete Slab on grade	64	78	+ 14 (22%)
Drywall	33	52	+ 19 (57%)
Standing Seam Metal Roof	248	216	- 32 (-13%)
Windows & Exterior Doors	128	115	- 13 (-10%)
Steel Stairs	79	63	- 16 (-20%)
Specialty Steel - Floor Grates	12	10	- 2 (-20%)
Garage Door & Opener	140	112	- 28 (-20%)
Concrete Footing & Foundation	89	68	- 20 (-23%)
Concrete Slab on deck	52	9	- 43 (-82%)
Structural Steel	139	61	- 78 (-56%)
Concrete Tilt Up Panels	97	0	- 97 (-100%)
Total	**1,271**	**1,718**	**+ 447 (35%)**





DISCUSSION

This case study provided a rare opportunity to examine two design iterations of the same civic facility, each pursuing the same programmatic goals through different structural and material strategies. However, while the timber and concrete designs were developed for the same site and general use, **the comparison is not without limitations**. Differences in layout, structure, and detailing introduce variables that affect both cost and carbon performance, making direct one-to-one comparisons challenging.

01 Interpreting Comparative Results: Design Divergence and Analytical Constraints

The timber design was developed earlier in the process and remained at a more conceptual stage. It included a larger program area, different roof strategies, and greater use of secondary assemblies that had not been fully integrated with each other.

The tilt-up concrete design, by contrast, likely underwent additional refinement and value engineering as it became the selected approach for construction.

This resulted in greater resolution of structural systems, more compact use of floor area, and clearer material integration. These differences shaped the outcomes of both the life cycle assessment and the cost analysis, which are best understood not as absolute measures but as indicators of how **design direction and delivery strategy influence environmental and financial performance.**

Concrete roof pavers are a good example of how similar materials were deployed differently across the two designs. The timber design includes approximately 330 m² of concrete pavers used across multiple locations, including the ladder tower roof, a rooftop deck, and a significant portion of the office roof. These pavers sit on manufactured adjustable pedestals, allowing for a level walking surface and sloped drainage beneath.

In contrast, the concrete design includes only about 35 m² of concrete pavers, limited to the hose tower and a simple walking path for mechanical access. These are free-standing tiles and do not include the pedestal system. The difference in quantity, complexity, and assembly logic contributed to a higher overall material use in the timber design.

Both systems met the basic performance objectives of a modern firehall, but the development trajectories and material choices diverged significantly. These divergences limit the ability to isolate material impacts alone. For example, certain envelope components were embedded within the structural system in the concrete design, while they were layered on separately in the timber version. Similarly, insulation, roofing, and cladding decisions were handled through different assembly logics. These differences are not faults in either design but reflect the path each approach took through planning and design. However, they do complicate comparative interpretation for both environmental and financial performance.

With these considerations in mind, the following sections explore the implications of each design approach in more detail, starting with carbon outcomes, followed by cost performance, and concluding with a deeper assessment of the role timber could play in improving integration, efficiency, and climate performance in future civic infrastructure, including the planned firehall for the City of Nelson.

02 Carbon Impacts Across Life Cycle Stages

A key strength of this study lies in its layered approach to embodied carbon analysis. The timber and concrete designs were each assessed in three stages: first, Modules A to C without biogenic carbon; second, Modules A to D without biogenic carbon; and third, Modules A to C and Modules A to D with biogenic carbon included. This structure allowed for a more complete understanding of how different materials and design decisions influence climate impacts over time.

Modules A to C without biogenic carbon

Modules A to C reflect emissions from raw material extraction, manufacturing, transport, construction, and in-use replacements. These emissions are either already released or highly likely to occur within the boundaries of our study (60 years), making this the most reliable scope for direct comparisons. In this study, the results revealed only a modest difference between the timber and concrete designs. The timber option produced 11% more total emissions in absolute terms, but when normalized by building area, it produced 11% fewer emissions. This contrast emphasizes **the importance of considering not just total carbon output, but also the efficiency with which space is delivered.** It also highlights how material layering, inefficient detailing, and limited prefabrication contributed to a limited difference in emissions between the timber design and the concrete tilt-up, limiting the extent to which timber's typical advantages could be realized in the scenario analyzed. **These findings show that how a material is used may have as much influence on carbon performance as what material is used in the first place.**

Modules A to D without biogenic carbon

The second stage of analysis extended this to include Module D, which represents potential credits associated with end-of-life reuse, recycling, or energy recovery. These future outcomes can significantly affect total emissions, especially for timber, which is assumed to be reused or recovered at a higher rate. This is not typically the case for the tilt-up concrete design, where components like precast panels have limited potential for reuse and receive smaller credits through standard recycling practices, mostly from recovered steel. However, these scenarios rely on future practices that are uncertain. As a result, **Module D is best understood not as a forecast but as a representation of design potential**. It offers a view of what could be achieved if circular strategies are successfully implemented at scale.

Modules A to C & A to D with biogenic carbon

The final layer of analysis incorporated biogenic carbon, which refers to the carbon absorbed during the growth of plant-based materials and stored in building components. This flow is recognized as a negative emission in the early stages of the life cycle, particularly in Module A1, and contributes significantly to the initial carbon profile of timber structures. Including it in the analysis is important for acknowledging the climate role of renewable materials. However, the long-term benefit of this stored carbon depends on how materials are treated at end of life, as captured in Module D. If wood products are reused, recycled, or otherwise prevented from decomposing or incinerating, the stored carbon may remain sequestered. If not, it is gradually released, reducing or negating the early advantage. This reinforces **the importance of viewing biogenic carbon as part of a dynamic system, not a permanent offset**.

Biogenic carbon was included last because it adds a different kind of complexity to the analysis. While Module D already involves uncertainty about end-of-life outcomes, biogenic carbon introduces additional questions about carbon storage, release, and long-term assumptions that are harder to model and often debated. Still, it plays an important role, especially when assessing renewable materials like timber. It shifts the focus from direct design comparisons to a broader view of environmental systems and longer-term impacts. The value in this part of the analysis is less in demonstrating what may be possible in one design versus another, and more in highlighting that impacts still occur outside the boundaries we draw in our thinking and analysis, and in the importance of considering one step beyond.

Looking across these three analytical stages reveals not only the relative performance of timber and concrete, but also the implications of modeling assumptions and system boundaries. What is included, when it occurs, and whether it is reversible can all significantly influence the outcome.

This reinforces the need to interpret embodied carbon as part of a broader strategy that weighs design intent, material choices, and long-term planning rather than relying on any single figure in isolation.

03 Cost Implications and Design Coordination

While cost data offers a direct and tangible comparison between the two design options, interpreting these findings requires caution. As with the carbon analysis, several underlying differences between the timber and concrete schemes affect how cost outcomes should be understood.

Most significantly, the tilt-up concrete design underwent a more advanced level of refinement. As the selected design, it benefited from value engineering, detailed structural coordination, and integrated prefabrication strategies. These steps allowed structural elements, envelope systems, and even insulation to be bundled into prefabricated components with well-defined installation sequences.

In contrast, the timber design remained at an earlier stage of development. Prefabrication was not incorporated into the structural or envelope strategy, and several key assemblies were layered on separately (eg: cladding, insulation, and fire-rated barriers). This fragmented delivery approach introduced scope redundancies and would have increased both labor and coordination demands. Timber elements, as designed, would need to be built on site, which would extend timelines and compound costs through trade stacking and weather exposure.

From a costing perspective, this lack of integration was particularly visible in framing, where the timber design showed dramatically higher costs despite using relatively simple light wood and glulam systems. This was not because timber is inherently more expensive, but because its application was distributed across multiple trades and did not benefit from centralized fabrication or sequencing. The concrete design, by contrast, concentrated structure and enclosure into tilt-up panels, which simplified scheduling and reduced site work.

Another interesting distinction lies in the underlying cost structure of each system. The timber design is heavily influenced by material procurement, with over two-thirds of framing costs attributed to engineered wood products. In contrast, the tilt-up system relies more heavily on labor and equipment for on-site execution. This reflects a broader economic and theoretical reality: cost reductions in timber construction are more likely to stem from material innovation (eg: prefabrication), manufacturing scale, and/or supply chain maturity, whereas cost control in concrete systems depends more on labor efficiency, which tends to be less flexible over time. This suggests that each system presents a different pathway to cost optimization, with timber potentially offering greater long-term savings as the industry shifts its focus toward standardization, prefabrication, and streamlined delivery.

Additional design choices in the timber design, such as extensive roof pavers and redundant fire separations, further contributed to cost escalation. Many of these would likely have been reduced or rationalized had the design reached the same level of detail as the concrete version. The result is that the cost comparison reflects not only differences in material systems, but also disparities in design maturity, prefabrication planning, and trade integration.

Beyond the numbers themselves, the process of compiling the cost analysis also illustrated a broader challenge. Because the timber design lacked integrated planning, several elements had to be costed through multiple consultants and disaggregated scopes. This fragmentation mirrors what would likely have occurred during construction, where a lack of coordination can result in change orders, delays, and unclear responsibility between trades. In contrast, the tilt-up system would have been delivered with fewer interfaces and more predictable timelines.

> **The efficiency of a system is not determined by material choice alone, but by how that material is deployed, coordinated, and integrated from the outset.**

04 Leveraging Mass Timber to Optimize Performance, Cost, and Embodied Carbon

Mass timber has become increasingly popular for its aesthetic, environmental, and structural benefits. However, realizing its full potential requires more than material substitution. It demands that timber be treated **as a primary structural strategy from the outset**. When integrated early into both architectural and structural design, mass timber can reduce the number of trades, streamline construction timelines, and eliminate the need for added finishes or redundant assemblies. This level of integration is especially important in civic and institutional projects, where durability, clarity of function, and public value are closely linked.

The Creston Emergency Services Building was initially conceived as a timber design, but it ultimately fell short of demonstrating the advantages associated with a mass timber-forward approach. The design relied primarily on light wood framing, concrete panels, and steel decking, with glulam beams playing only a limited structural role. CLT panels were not included, and most assemblies were intended to be constructed on site. Without prefabrication or coordinated system design, the typical benefits of timber were largely unrealized, such as reduced construction time, simplified material assemblies, and lower embodied emissions. These limitations were not due to the material itself, but rather to the way it was introduced late in the design process, without a framework for integration or delivery.

Leveraging Mass Timber to Optimize Performance, Cost, and Embodied Carbon

In contrast, when mass timber is embedded into a project from the earliest stages, it can shape the structural grid, inform envelope design, and reduce material redundancy. Structural components such as CLT panels and glulam beams can act as both structure and finish, eliminating the need for suspended ceilings, secondary fire barriers, or additional wall assemblies. This simplifies detailing, accelerates installation, and reduces overall material use. Because many of these elements can be prefabricated under factory conditions, the approach also reduces on-site labour demands and minimizes exposure to weather-related delays.

Mass timber offers a range of advantages that extend well beyond construction efficiency. Exposed wood interiors can contribute to occupant well-being by creating calming, biophilic environments, a quality that is especially relevant in essential service buildings where users operate under high stress. Fire safety, often cited as a concern, is well addressed in mass timber systems. Properly sized elements char at a predictable rate, preserving structural integrity during fire events. Misunderstandings about fire performance often stem from comparisons to light-frame wood construction; however, mass timber is a fundamentally different system. Today, fully exposed CLT and glulam assemblies are in active use across Canada, demonstrating the material’s proven viability in public and institutional infrastructure.

The environmental performance of timber is equally significant. As discussed earlier in relation to biogenic carbon and Module D, timber materials sequester atmospheric carbon during their growth and offer long-term climate value when designed for reuse or disassembly. **These benefits depend on how the materials are handled over time**, but they remain a core advantage when considered within the full life cycle. When timber is locally sourced, these environmental gains are further amplified through reduced transportation emissions and support for regional forest-based economies. Together, these factors make mass timber a compelling option for both functional and climate-driven performance.

A critical enabler of these outcomes is early collaboration with timber manufacturers. Input on panel sizing, crane logistics, connections, and tolerances allows the design to align with fabrication methods, reducing the need for custom solutions and ensuring smoother installation. This level of coordination must occur during schematic and early design development phases to avoid costly redesigns and maximize prefabrication potential.

In the case of Creston, the timber concept ultimately did not demonstrate these benefits. The use of multiple structural systems (concrete slab and walls, structural steel, light framing, and glulam) resulted in a fragmented approach with little synergy between components, leading to higher costs and a limited carbon advantage relative to the concrete tilt-up alternative. This likely supported the perception of higher cost and limited climate benefit, which ultimately led to the tilt-up concrete design being selected as the preferred option. While the concrete system offered greater simplicity, it did so at the expense of timber's full potential, including opportunities for architectural expression, long-term climate performance, and integrated construction efficiency. The experience highlights an important lesson: **mass timber is not simply a material choice, but a design approach that must be activated early and holistically to deliver on its promise.**

05 Opportunities for Nelson Through Timber-Forward Design

The case study analysis suggests that with a fully integrated design approach, mass timber could offer significant value for Nelson's future firehall. An optimized solution would feature glulam beams and columns to support large spans in the apparatus bays and office spaces, with CLT panels forming the roof and possibly the walls. These elements could remain exposed on the interior, eliminating the need for suspended ceilings or additional finishing layers.

Using a consistent structural grid, such as a 12-foot spacing, would further improve material efficiency by allowing thinner CLT panels and fewer connections. A lateral system using steel bracing or moment frames could be incorporated where necessary to meet seismic requirements without disrupting timber continuity. Wall panels could be prefabricated with insulation, membranes, and openings included, allowing for faster installation and reduced trade coordination on site.

In comparable projects, prefabricated timber systems have achieved significantly higher installation rates than conventional framing. On typical firehall sites, this can translate into measurable time savings and reduced weather exposure, with positive implications for labour cost and scheduling.

To further capitalize on these benefits, the design team should collaborate with a timber manufacturer early in the project. This allows the structural and envelope systems to be developed around standardized panel sizes, factory capabilities, and crane logistics. When design decisions are aligned with manufacturing realities, the result is a more efficient building system with less waste, stronger integration, and lower complexity. These optimizations have the potential to significantly reduce both construction costs and embodied carbon, two key variables explored in this study.

By contrast, when mass timber is treated as a late-stage substitution or secondary feature, the design often lacks the coordination needed to unlock real value. Even small decisions, such as beam spacing or service routing, can significantly affect material use and construction sequencing.

06 Considerations for Nelson's Planned Firehall

The analysis of the Creston Emergency Services Building offers Nelson a valuable opportunity to apply lessons learned before key design decisions are made. The comparison between the timber and concrete designs illustrates how early coordination, system integration, and material strategy can shape both environmental performance and construction outcomes. These lessons are particularly relevant for Nelson as it moves forward with its own firehall project.

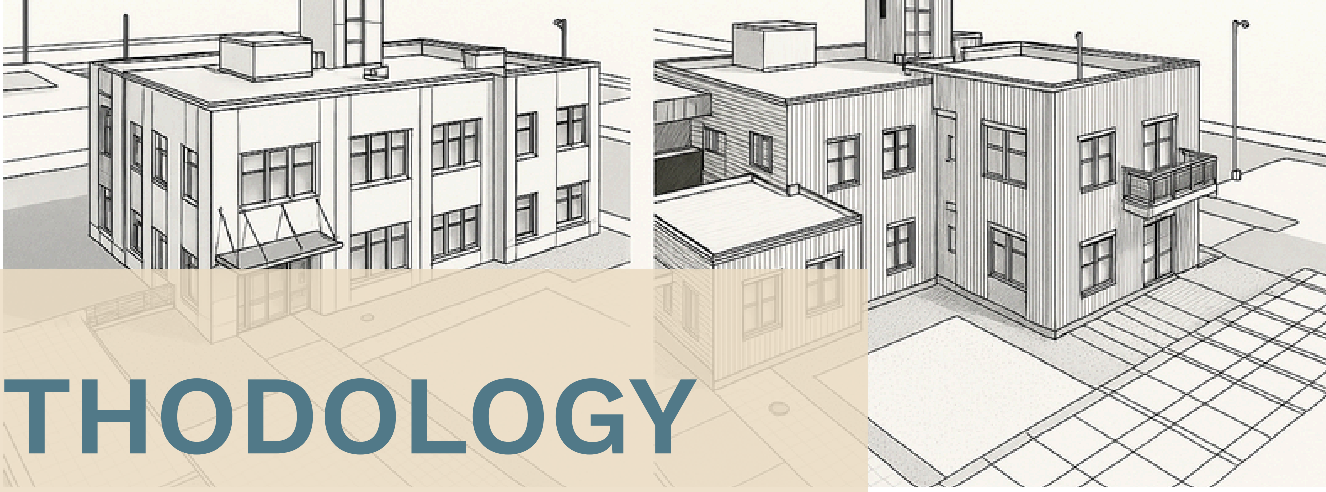
One of the clearest takeaways is that timber's success depends not just on the choice of material, but on how it is incorporated into the overall building concept. In the Creston case, timber was introduced without full integration into the structure or envelope, which limited its effectiveness and ultimately contributed to the selection of a concrete alternative. For Nelson, committing to a mass timber-forward approach early in the design process could help unlock the full benefits of prefabrication, sequencing efficiency, and reduced material redundancy.

To support this, collaboration with mass timber manufacturers should begin at schematic design. Structural grids, panel dimensions, and crane logistics can all be optimized through early input, avoiding costly adjustments later in the process. Prefabricated assemblies such as CLT roof panels or wall systems with integrated insulation and service cavities could significantly reduce site labour, construction timelines, and complexity during delivery.

From a carbon standpoint, the Creston case showed that while timber systems have strong long-term potential, their advantages can be diminished when assemblies are fragmented or over-layered. Nelson can avoid this by designing with whole-system efficiency in mind. A well-integrated timber design is more likely to outperform conventional systems both in total emissions and in lifecycle intensity, especially when paired with strategies that prioritize reuse, disassembly, and locally sourced materials. For example, in the timber design at Creston, drywall was used not only as the interior finish for vertical walls but also extensively as a fire barrier. This added material reduced the design's overall efficiency. In future projects, drywall use can be reduced or eliminated altogether by exposing the mass timber itself as a finished surface, simplifying construction and improving both carbon and material performance.

Public-facing projects like firehalls also carry an important symbolic role. Using regionally harvested timber, showcasing exposed structural elements, and aligning design with climate goals can help reinforce civic identity and public support. A well-integrated timber strategy can also support cost competitiveness, especially when factoring in faster installation and reduced finishing requirements. In this context, **mass timber offers more than technical benefits; it represents a commitment to resilience, sustainability, and local leadership.**

Nelson's upcoming firehall is well positioned to serve as a model of integrated low-carbon design. By applying the lessons from Creston, focusing on coordination from the outset, and treating timber as a system rather than a substitution, the city can deliver a high-performance building that reflects both its operational needs and its broader climate ambitions.



METHODOLOGY

01 Material Take-off

Material quantities for both the timber and concrete tilt-up designs of the Creston Emergency Services Building were extrapolated from the architectural and structural drawing sets provided by the original project teams. The mass timber design was based on architectural plans issued by Johnston Davidson Architecture on July 3, 2020, and structural plans by Herold Engineering dated July 8, 2020. The concrete tilt-up design was derived from architectural plans issued on July 29, 2021, and structural plans from Grubb Engineering dated June 30, 2021.

02 Life Cycle Assessments (LCAs)

Two whole-building Life Cycle Assessments (LCAs) were completed for this study: one for the initial mass timber design and one for the final tilt-up concrete design of the Creston Emergency Services Building. Both assessments followed a cradle-to-grave scope, capturing impacts from raw material extraction through manufacturing, transportation, construction, use-phase maintenance, and end-of-life disposal. A 60-year service life was assumed for both scenarios. Excluded from the analysis were interior divisions and non-structural components, interior finishes, mechanical systems, and other equipment.

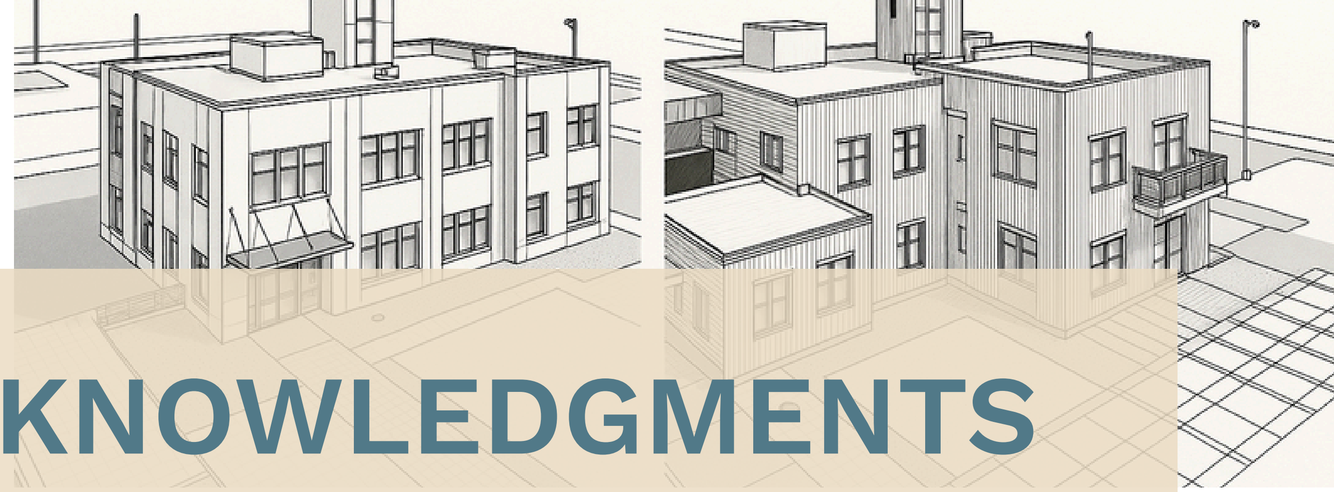
Material quantities were determined using manual takeoffs from the architectural and structural drawings provided, and augmented where possible with structural schedules. Takeoffs were initially completed using On Screen Takeoff, an industry standard cost estimating software. These were then corroborated and expanded for the WB LCA using Bluebeam, another industry standard software for interpreting PDF drawings.

The Whole-Building lifecycle assessments were carried out using One Click LCA, and followed the recommendations of the National Whole-Building Life Cycle Assessment Practitioner's Guidelines (National Research Council Canada [NRC], 2024). Default assumptions were used in the software with localization applied only to industry average or generic material impact mapping. It should be noted that thermal performance, durability, and long-term maintenance were not modeled in detail beyond default values embedded in the tool.

Biogenic carbon was modeled in alignment with ISO 21930 and EN 15978 standards, which require separate accounting of biogenic flows from fossil emissions. Where applicable, biogenic carbon storage was included in the product stage (Modules A1-A3), representing the atmospheric carbon stored in organic materials. Subsequent life cycle stages (C and D) incorporate emissions and offsets associated with the release or recovery of this carbon at end-of-life. All biogenic results are reported distinctly from fossil GHG emissions, National Whole-Building Life Cycle Assessment Practitioner's Guide. Adherence across these standards implies the separation of biogenic and fossil carbon according to ISO/EN rules (ISO 21930:2017, EN 15804:2012+A2:2019), followed by application of TRACI (TRACI 2.1) factors to quantify GWP impacts for each category (Appendix 2).

03 Cost Analysis

The cost analysis was developed through a combination of industry-standard estimating practices and direct collaboration with local subcontractors familiar with regional construction conditions. Estimates were informed by current pricing data from suppliers and trades, ensuring locally relevant cost inputs. The analysis also benefited from insights provided by the original cost estimator involved in the Creston Fire Hall project, helping to validate assumptions and align the comparison with real-world project experience. This approach provided a high-confidence assessment of both the mass timber and tilt-up concrete designs (Appendix 1).



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We also thank the **Town of Creston** and the **Creston Fire Department**, whose previous design work and openness in sharing documentation allowed for a rare comparative analysis of timber and tilt-up concrete building strategies.

SUPPORTING RESOURCES

Appendix 1 - Cost Analysis

Detailed quantity takeoffs were prepared by Karen Ramsey of Building Wellness, with structural steel quantities for the concrete tilt-up version provided directly by Grubb Engineering.

All unit pricing was sourced in May 2025 from local suppliers and subcontractors to reflect up-to-date market conditions. These included:

- Concrete Materials: Nelson Ready Mix
- Concrete Labor & Equipment: Rokform Solutions
- Steel Fabrication: Zap Welding
- Mass Timber Materials: Kalesnikoff
- Mass Timber Labor & Equipment: Beam Craft
- Envelope, Insulation, Roofing, Siding, Windows/Doors, and Interior Finishes: North Mountain Construction

Appendix 2 - Standards and Guidelines

- **National Research Council Canada**. National Whole-Building Life Cycle Assessment Practitioner's Guide: Guidance for Compliance Reporting of Embodied Carbon in Canadian Building Construction. National Research Council Canada - Construction Research Centre, 1 Oct. 2024.

- **International Organization for Standardization**. Sustainability in Buildings and Civil Engineering Works: Core Rules for Environmental Product Declarations of Construction Products (ISO 21930:2017). ISO, 2017.

- **European Committee for Standardization.** Sustainability of Construction Works: Environmental Product Declarations - Core Rules for the Product Category of Construction Products (EN 15804:2012+A2:2019). CEN, 2019.

- **Bare, Jane C., and Gregory A. Norris.** Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) Version 2.1: User's Manual. U.S. Environmental Protection Agency, 2012.

QUESTIONS?

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