Knowledge Brief
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Design Strategies for Lower Embodied Carbon State Buildings

COLLEGE OF BUILT ENVIRONMENTS
UNIVERSITY of WASHINGTON

CLF Carbon Leadership Forum

This knowledge brief provides an overview of (RCW 39.116.050):

> *(viii) Recommend approaches to designing lower embodied carbon state building projects*

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Introduction

A building's life cycle spans design, construction, use, and end-of-life, with each phase presenting an opportunity for embodied carbon reduction. The biggest leverage exists during early design, when decisions about the site, program, massing, and construction type are often made. This knowledge brief presents high-impact strategies intended to inform state agencies, project teams, and policymakers on how to reduce the embodied carbon of state building projects. While not exhaustive, this brief showcases proven approaches and includes Washington-based case studies to illustrate these strategies in practice. This brief does not provide specific guidance on how to conduct a robust whole building life cycle assessment (WBLCA), but general best practices for comparing WBLCAs are included in Appendix A.

Leveraging the design phase

Reducing embodied carbon in a building becomes more constrained as the project progresses. Early design offers the widest set of opportunities to achieve a low-carbon building, as any possible strategy can be evaluated with time to implement. Figure 1 provides an overview of project development stages and the relative potential for embodied carbon reduction.

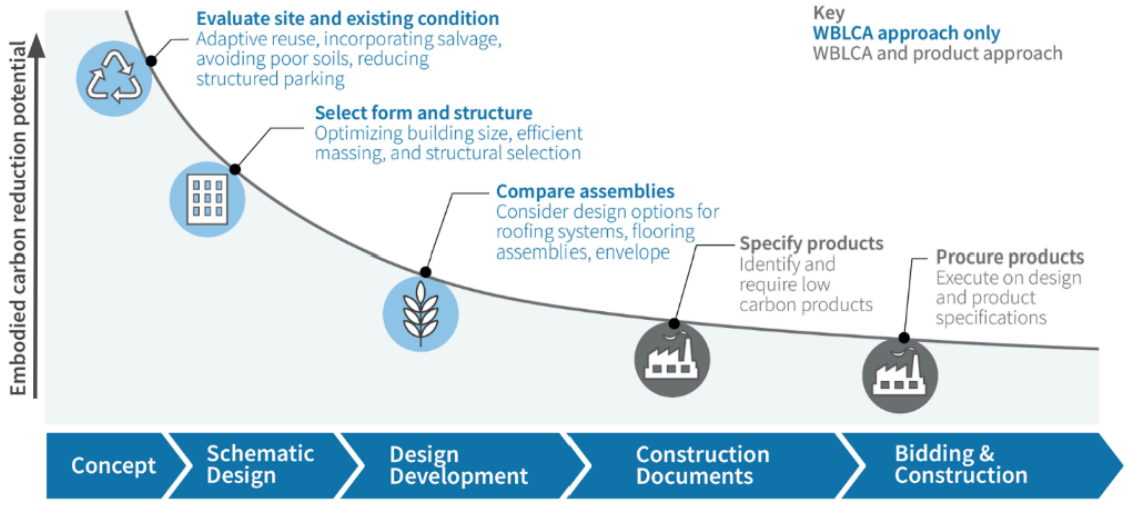


Figure 1. Project development stages and carbon reduction potential. The carbon reduction potential decreases as the project progresses from predesign, schematic design (SD), design development (DD), construction documents (CD), construction, and finally operations and maintenance. Adapted from CLF's Building-Scale Performance Requirements Factsheet.[1]

Measuring embodied carbon

A WBLCA quantifies the environmental impacts of a building across its life span. This includes the impact of all or a portion of materials used on the project, commonly the structure and

[1] Lambert, M., Lewis, M., Benke, B., and Carlisle, S. (2024). *Embodied Carbon Policy Toolkit Factsheets: Building-Scale Embodied Carbon Performance Requirements*. Carbon Leadership Forum, Seattle, WA.

envelope, as well as the emissions from activities like transportation, construction, renovations, repairs, and end-of-life. Typically, a WBLCA measures impact over a 60-year span with assumptions about what will happen in the future like product replacement or end-of-life waste processing. WBLCAs are best used to support decisions at multiple scales from holistic design and system selection, to material and product alternatives.

Environmental Product Declarations (EPDs) provide standardized environmental data for individual products. WBLCAs use EPDs as one of multiple data sources to quantify environmental impacts across the full scope of the building and its life span.

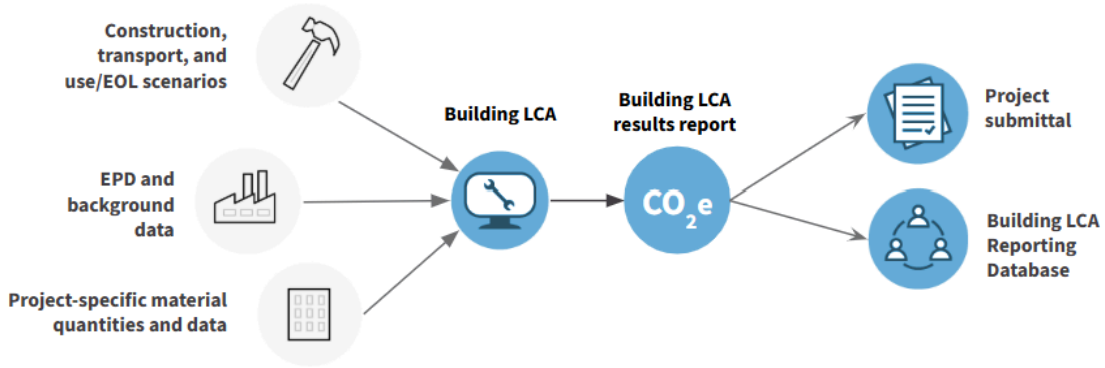


Figure 2. Data flow to create a WBLCA. Construction transport and use/ EOL scenarios; EPD and background data, and project-specific material quantities flow into a building LCA, which can be used for comparing to another WBLCA, or for summarizing a building's impact. Adapted from CLF's Building LCA 101 Factsheet.[2]

WBLCAs can be used to:

- quickly identify hot spots or major drivers of project impacts, and opportunities
- compare the impacts between building designs, systems, assemblies, materials, or products
- evaluate the potential embodied carbon reduction from building or system reuse
- evaluate the reduction potential at the building scale for nearly any reduction opportunity
- estimate the carbon footprint of a whole building

[2] Lewis, M., Benke, B., Carlisle, S., & Lambert, M. (2024). *Embodied Carbon Policy Toolkit Factsheets: Building LCA 101*. Carbon Leadership Forum, Seattle, WA. https://carbonleadershipforum.org/building-lca-101/

Process recommendations for projects

The following process can further support embodied carbon reduction by incorporating it directly into the design workflow[3]:

1. **Set an embodied carbon target or reduction goal**. Use embodied carbon as a design constraint to ensure it informs decisions from the beginning of the project. Establish a percent reduction target and/or an embodied carbon intensity threshold (kg CO_2e/m^2) for the project. Targets may be informed by CLF's North American Benchmark Report, local jurisdiction requirements, rating systems, or organizational commitments.
2. **Leverage a rating system.** Incorporate embodied carbon requirements to reinforce goals within the broader certification approach. Notable examples: LEED v5 includes a Reduce Embodied Carbon credit under the Materials and Resources category; Living Future's Zero Carbon Certification or Living Building Challenge; or Envision for infrastructure projects.
3. **Host an embodied carbon kickoff meeting.** Bring the full project team together early in the project to build a shared understanding of embodied carbon goals, agreed-upon strategies, and individual responsibilities. Create space to surface questions, clarify expectations, and address known challenges collaboratively. Use of early-stage carbon tools (i.e. c.scale or CARE tool) or WBLCA consultants can be helpful to frame the conversation.

Recommended strategies to reduce embodied carbon

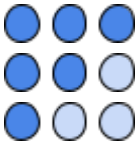
The following strategies offer the potential for significantly reducing embodied carbon when implemented during design. The strategies were developed through a limited literature review and the professional practice experience of the authors. Each strategy includes the following criteria:

- **Reduction Potential:** the low, medium, or high designations indicate the embodied carbon reduction potential of the design strategy evaluated over the building's lifespan (cradle-to-grave). A high reduction potential signals significant savings, while a low reduction potential suggests a more targeted impact. All strategies included are worthy of consideration—the rating is just indicative of their *relative* impact to one another.

High reduction potential:

Medium reduction potential:

Low reduction potential:



[3] All of these recommended process steps for projects are also highlighted in the model specifications available on the WA Commerce BCBF website: https://www.commerce.wa.gov/seep/bcbf/

- **Ease of Integration:** the low, medium, or high designations indicate how easy the strategy is to integrate into projects given traditional workflows and anticipated cost. A high ease of integration signals the strategy is relatively easy to implement, while a low ease of integration indicates some anticipated challenges. Again, all strategies are worth considering—the rating is just focused on their *relative* ease.

  Easiest to Integrate: 

  Moderate to Integrate: 

  Hardest to Integrate: 

- **Design Phase**: indicates the recommended implementation phase based on the scale and potential cascading impacts of the strategy.[4]
- **Action**: indicates if the strategy can be *directly incorporated* without the need to be further evaluated or if it requires *exploration through WBLCA* to assess its relative impact on a given project. For direct incorporation strategies, WBLCA can be used to understand the scale of reduction on a given project. However these strategies consistently offer savings so using WBLCA to confirm this scale is not always necessary.

Implementing reuse

Reusing existing buildings, incorporating salvaged materials, and/or planning for future material reuse can be among the most effective ways to avoid embodied carbon as it eliminates the need for new, carbon-intensive materials[5]. Table 1 presents a list of design strategies for implementing reuse.

Table 1. Design strategies for implementing reuse.

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Adaptive reuse. Retrofitting an existing building rather than demolishing and rebuilding largely eliminates embodied carbon of new structural and envelope materials and reduces environmental impacts from construction activities.			Predesign	Direct incorporation
Incorporate salvaged materials. Designing with reclaimed materials avoids the carbon associated with production. This strategy is most			SD/ DD	Direct incorporation

[4] Please note, "SD" is Schematic Design, "DD" is Design Development and "CD" is Construction Documents.
[5] *Building Material and the Climate: Constructing a New Future*. (2023). United Nations Environment Programme. Nairobi

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
effective when incorporating salvaged materials in structural applications, where code permits (e.g., steel or timber studs). Salvaged cladding, ceiling panels, and flooring materials can also be good options.				
Design for deconstruction. Designing connections, assemblies, details, processes, and documentation to support future successful disassembly enables material reuse on future projects, providing potential carbon savings beyond the current building's life.			SD/ DD	Direct incorporation

Site evaluation

Site design decisions such as hardscape, parking infrastructure, and site preparation can add significant embodied carbon to the project. Table 2 presents a list of design strategies to reduce impacts from site design decisions.

Table 2. Design strategies to reduce impacts from the site.

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Avoid building on poor soils. Sites with poor soil conditions require additional material and intensive systems, such as deep foundations or soil stabilization elements, to achieve the same structural performance. Where feasible, selecting sites with suitable soils avoids this additional embodied carbon.			Predesign	Direct incorporation
Minimize hardscape area. Reducing hardscaped surfaces limits the use of carbon-intensive materials such as concrete and asphalt and leaves more site area to carbon-storing vegetation.			SD	Direct incorporation

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Avoid or reduce parking. Below-grade or structured parking can be a significant contributor to embodied carbon because it can require extensive excavation and/or significant structural material. Surface parking is also carbon intensive due to the paving materials and eliminates opportunities for carbon-storing vegetation or other beneficial site uses.			Predesign /SD	Direct incorporation
Minimize excavation depth and volume. Earthwork operations can be highly carbon-intensive so limiting excavation depth and the volume of cut and fill can avoid these impacts. Balancing cut and fill to minimize the need to bring in or transport out earth can also reduce transportation emissions.			Predesign /SD	Direct incorporation

Structural system

The structural system is typically the largest contributor to a building's total embodied carbon. Optimizing system choices at this stage can deliver significant overall embodied carbon reductions. Table 3 presents a list of design strategies to reduce impacts from the structural system.

Table 3. Design strategies to reduce the impact of the structural system.

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Evaluate structural system alternatives. Compare conventional structural systems against functionally equivalent alternatives that are materially efficient, make the structure lighter, and/or use lower-carbon materials to offer embodied carbon reductions.			SD	Exploration through WBLCA

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Optimize structural element sizing and spacing. Iterate on member size and bay spacing to achieve the required function and performance with less material and associated embodied carbon. Avoid transfer beams, transfer slabs, and other complex structural conditions by optimizing the structural grid.			SD	Exploration through WBLCA
Use efficient structural steel elements. Composite members, cambered beams, and cellular beams are lighter than standard steel sections, reducing total steel tonnage and corresponding embodied carbon.			SD/ DD	Exploration through WBLCA
Assess floor system options. Compare floor systems to identify the lowest-carbon solution for the project. Concrete void slab systems and post-tensioned concrete slabs use less concrete compared to conventionally reinforced flat slabs. Alternatively, metal deck floor systems or CLT slabs can reduce embodied carbon if appropriate for the project's needs.			SD/ DD	Exploration through WBLCA
Use braced frames instead of moment frames. Braced frames provide lateral resistance more efficiently than moment frames, achieving equivalent performance with less steel and lowering the environmental impact.			SD/ DD	Direct incorporation
Incorporate higher-strength steel in the structural system. High-strength steel, when used to reduce the number and size of structural elements needed, can lower embodied carbon.			SD/ DD	Exploration through WBLCA
Incorporate higher-strength concrete in the structural system. High-strength			SD/ DD	Exploration through

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
concrete provides an opportunity to reduce the amount of concrete and steel needed for a building's structural system. Though high-strength concrete can have a higher embodied carbon impact – particularly for taller, heavily loaded buildings – the reduction in material can outweigh the increase in embodied carbon per functional unit.				WBLCA
Evaluate low-carbon product options. Within all structural assemblies, assess lower-carbon product alternatives to determine feasibility and any additional design considerations.			SD/ DD	Exploration through WBLCA

Architectural considerations

Early programmatic massing and system-level material decisions can greatly influence a building's embodied carbon impact. Making these choices early in the design process when structural approach, envelope assembly, and building-wide systems are being considered can reduce material demand and ensure successful integration. Table 4 presents a list of design strategies to reduce impacts from architectural considerations.

Table 4. Design strategies to incorporate into architectural considerations.

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Reduce building size. A smaller fit-for-purpose building requires fewer materials, directly lowering total embodied carbon.			Predesign /SD	Direct incorporation
Efficient massing. Optimizing the building's shape, height, and orientation can minimize material use and reduce embodied carbon outcomes. This could include designing for a standard grid or reducing envelope area relative to floor area. A building can be similarly optimized to reduce operational energy			Predesign /SD	Exploration through WBLCA

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
demand through passive heating or cooling and daylighting.				
Right-size window-to-wall ratio. Windows have a higher embodied carbon intensity per square foot than typical framed wall assemblies. A lower window-to-wall ratio, when appropriate for the space, limits the embodied carbon impact and can also reduce operational energy demand.			SD	Exploration through WBLCA
Assess envelope assembly options. Comparing envelope options highlights differences in total upfront carbon and overall durability of the multiple products in the assembly like cladding, sheathing, insulation, and interior finishes. Additionally, evaluating envelope assembly options identifies opportunities to limit thermal bridging and further reduce operational energy loads.			SD/DD	Exploration through WBLCA
Consider bio-based material systems. Bio-based systems, especially those that include short-cycle plants (10 years or less), may have substantially lower embodied carbon than conventional alternatives. Because these choices can affect other building components, they should be explored in the context of the specific project, local code requirements, and land use implications.			SD	Exploration through WBLCA
Design-out high-carbon products. Eliminating known high-carbon products, particularly HFC-based XPS and spray foam insulation, can yield significant reductions in total building embodied carbon.			SD/DD	Exploration through WBLCA

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Evaluate low-carbon product options. For all other envelope and roof assembly materials (cladding, insulation, sheathing, membranes, windows, roofing, etc), assess lower-carbon product alternatives (informed by EPDs, if available) to determine feasibility and any additional design considerations.			DD/CD	Exploration through WBLCA

Interior finishes

Though interiors are usually finalized later in design, designing for durability and specifying low-carbon product options within these systems present opportunities for embodied carbon savings. Table 5 presents a list of design strategies to reduce the impact from interior finishes.

Table 5. Design strategies to reduce impact from interior finishes.

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Design-out finishes. Eliminate finishes where possible. This might mean designing the building systems such as structure or MEP systems to be exposed as an interior design feature, which eliminates the need for finish materials and directly reduces embodied carbon.			SD/DD	Direct incorporation
Assess assembly options. Compare functionally equivalent assembly options for partitions, flooring, and ceilings to evaluate upfront carbon, maintenance, and other criteria.			DD	Exploration through WBLCA
Consider product durability. A product with higher cradle-to-gate (A1-A3) carbon but significantly greater durability may result in lower embodied carbon over the building's service life by avoiding replacement cycles.			DD/CD	Exploration through WBLCA

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Evaluate low-carbon product options. Assess lower-carbon product alternatives (flooring, drywall, ceilings, wall coverings, countertops, paints, etc.) informed by EPDs, if available, to determine feasibility and inform specification requirements.			DD/CD	Exploration through WBLCA

Mechanical, Electrical, Plumbing (MEP)

MEP systems, especially refrigerants, can be a significant source of embodied carbon. These strategies should be considered early in design to ensure they are appropriately incorporated into the larger building system. Table 6 presents a list of design strategies to reduce the impact from MEP systems.

Table 6. Design strategies to reduce the impact from MEP systems.

Strategy	Reduction Potential	Ease of Integration	Design Phase	Action
Use low-GWP refrigerants and reduce charge, piping extents, and leakage rates. Selecting equipment designed for lower-GWP refrigerants, and designing to minimize charge volume, piping runs, and leakage rates, can meaningfully reduce embodied carbon from mechanical systems. Tradeoffs with operational performance should be carefully evaluated.			SD/DD	Exploration through WBLCA
Optimize system sizing and reduce peak loads. Right-sizing mechanical systems to actual building loads and reducing peak loads through building and system design can result in smaller equipment that uses less material as well as less refrigerant and energy over its service life.			SD/DD	Exploration through WBLCA

Washington case studies

The following selected projects illustrate how the strategies described above have been successfully applied in Washington state to produce significant embodied carbon reductions.



Image Credit: Mithun

Washington Center for Deaf and Hard of Hearing Youth (CDHY) - Vancouver, WA
Early in the design process, the project team conducted an embodied carbon evaluation comparing a conventional steel-frame structure to a mass timber structure for a proposed wing expansion. The comparison revealed the potential to reduce embodied carbon by over 60% across the entire building scope (foundations, structure, roof, and floor). This result stemmed from the cascading benefits of mass timber's lower weight, which led to a smaller foundation. Enclosure assemblies were evaluated for low carbon insulation options, weighing the impact on wall cavity thickness and usable floor area. Additionally, the mass timber frame served as a finish material, eliminating the need for additional interior finishes. This project is a fantastic example of leveraging a WBLCA early in design to evaluate and optimize embodied carbon reduction strategies at the building-level.[6]
Key strategies: Evaluate structural system alternatives, Assess envelope assembly options, Design-out finishes



Image Credit: Boise Cascade

Hubbard's Corner - Seattle, WA
As part of a comprehensive adaptive reuse project to convert a 1912 unreinforced masonry building into a mixed-use commercial space, the project team tested innovative low-carbon materials and techniques. Utilizing novel concrete technology, the team installed five distinct low-carbon mixes across various applications including a loading dock, right of way, exterior steps, basement slab and shear walls. An analysis found these

[6] Jungclaus, M., Esau, R., & Huynh, T. (2026). *Using Cost and Carbon Data to Guide Design* (Case Studies in Cost-Effective Low Embodied Carbon Buildings). RMI. https://rmi.org/wp-content/uploads/dlm_uploads/2026/02/rmi-using-cost-and-carbon-data-to-guide-design.pdf

low-carbon concrete mixes alone achieved 40-60% embodied carbon savings compared to standard installations. The project team commented on the unique logistical and technical considerations essential for implementing low-carbon concrete at scale. This project leveraged product-level innovation within a broader design strategy to see significant building-scale embodied carbon reductions.[7]

Key strategies: Adaptive reuse, Evaluate low carbon product options



Image Credit: Mithun

Bush School - Seattle, WA

During the schematic design phase, the project team assessed the embodied carbon impact of a conventional concrete-over-metal-deck system supported by structural steel framing against mass plywood panels supported by glue-laminated timber. The team further optimized the timber design by selecting a beam width that maintained acceptable head clearance while maximizing the plywood panel span. This analysis demonstrated a 13% cradle-to-gate embodied carbon reduction for the timber structural system compared to the conventional alternative, making it an excellent example of early design strategies being evaluated and implemented to reduce embodied carbon.[8]

Key strategies: Evaluate structural system alternatives, Optimize structural element sizing and spacing

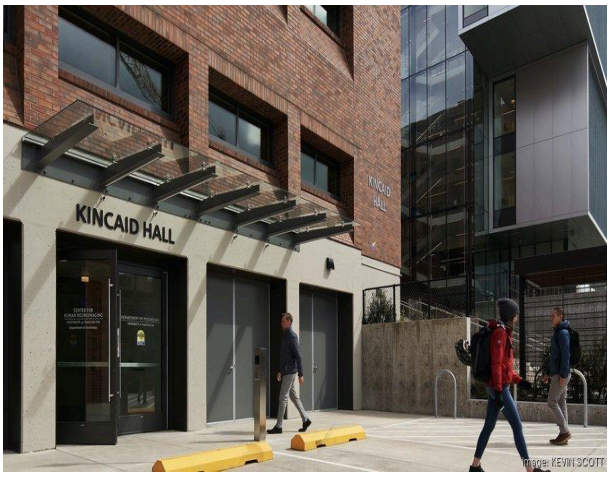


Image Credit: Puget Sound Business Journal

Kincaid Hall - Seattle, WA

The project team explored the embodied carbon impacts of renovation and adaptive reuse compared to demolition and new construction for an existing academic building at the University of Washington. To meet modern code and campus needs, the building required seismic improvements, a new roof, and MEP upgrades. The team evaluated both scenarios using a simplified embodied carbon assessment that included steel,

[7] Davis, D., Crooks, J. *Adaptive Reuse Footings and Slab on Grade* (Low Carbon Concrete Case Study: C-Crete Mixtures). Lower-Carbon Concrete Task Force. https://lowercarbonconcrete.org/c-crete-adaptive-reuse

[8] SE2050. (2024). *Case study: Bush School*. https://se2050.org/wp-content/uploads/2024/07/SE-2050-Embodied-Carbon-Reduction-Case-Study-EXAMPLE.pdf

concrete, aluminum, drywall, ceiling tiles, glazing, and insulation. The assessment estimated approximately 77% cradle-to-gate (A1-A3) embodied carbon savings for the renovation scenario, driven largely by the preservation of the existing structural concrete and steel in the building's shell. The renovation also yielded substantial cost savings compared to full demolition and new construction, demonstrating how early exploration of adaptive reuse strategies can deliver significant benefits across the project's goals.[9]

Key strategies: Adaptive reuse



Image Credit: Weber Thompson

Northlake Commons - Seattle, WA

The project team evaluated several structural system solutions to minimize embodied carbon while meeting the demands of this laboratory-ready office building. By comparing a buckling-restrained brace frame (BRBF) lateral system to a traditional concrete core, the team found the BRBF not only reduced embodied carbon by over 80% but also offered greater layout flexibility for future tenant improvements. The project team also conducted an analysis of a mass timber system versus a standard concrete structure and found that using local timber products could deliver over 20% in embodied carbon savings. The final design of the building features a three- story concrete podium topped with a hybrid mass timber and structural steel frame for the upper four floors. Additional embodied carbon savings were achieved by optimizing the podium's ready-mix concrete to reduce cement content. This is a fantastic example of integrating design-led and product level strategies to produce a lower embodied carbon building.[10]

Key strategies: Evaluate low carbon product options, Evaluate structural system alternatives, Optimize structural element sizing and spacing, Use braced frames instead of moment frames

[9] Jungclaus, M., Esau, R., & Huynh, T. (2026). *Adaptive Reuse Effectively Cuts Cost and Carbon* (Case Studies in Cost-Effective Low Embodied Carbon Buildings). RMI. https://rmi.org/wp-content/uploads/dlm_uploads/2026/02/rmi-adaptive-reuse-effectively-cuts-cost-and-carbon.pdf

[10] Weber Thompson. (2024). *Carbon benefit and beyond: Sharing the life cycle assessment findings of Northlake Commons*. Weber Thompston. https://www.weberthompson.com/thought/carbon-benefits-northlake-commons/.

Appendix A: WBLCA best practices for comparison

A WBLCA can be a highly effective tool to support embodied carbon reduction by maintaining a whole project perspective complemented by product-specific considerations. Product decarbonization strategies typically provide a narrower set of reduction opportunities compared to the larger systems approach. Iterative WBLCA during design can enable the comparison of numerous design, system, and product options and evaluate embodied carbon alongside other metrics like cost, performance, or constructibility. Below is a summary of best practices when conducting a comparative assessment:

1. Establish **functional equivalence** between the design options by ensuring the total systems being compared have an equivalent function (e.g. size, program, occupancy) and are designed to meet the same codes (e.g.. thermal, structural, acoustic, fire performance) in a project, regardless of the materials or configuration.
2. Design the options to reflect a **consistent level of development** to avoid comparing an early concept design to a fully developed design, or other misleading case.
3. Use the **same system boundary** for all options compared. The life cycle stages and building elements modelled should be consistent across any options being evaluated against one another. Ideally, the most comprehensive system boundary including consideration of typical differences in transportation, construction, durability and end-of-life scenarios (A-C) will be the most informative to inform comparison.
4. Apply a **consistent assessment methodology** across any system LCAs being compared. This applies to the material quantity takeoff approach, data source types, and assessment assumptions. Several emerging standards provide direct guidance for WBLCAs. These include:
    a. ASHRAE 240P (draft): a comprehensive methodology to conduct cradle-to-grave LCAs.
    b. RESNET 1550: outlines LCA requirements specifically for residential buildings.
    c. ASTM E2921: provides minimum criteria to follow when comparing WBLCAs between a reference and final building design.
5. Report ***biogenic carbon***[11] ***and carbonation***[12] **separately** from fossil impacts to maintain consistency and transparency given methodological unknowns and complexity.
6. Start by using **industry average materials** data to make systems comparisons in early design (when suppliers are not yet known) and isolate the impact of system selection. Then layer in low-carbon products into the comparison to better contextualize the decarbonization opportunity available via procurement.

[11] *Biogenic carbon* is carbon that is absorbed from the atmosphere through photosynthesis and stored in plants, trees, and other living matter as part of the natural carbon cycle (Source: 2025 CLF North American Material Baselines).

[12] *Carbonation* is a mineralization pathway in which atmospheric CO_2 reacts with hydrated cement, permanently storing CO_2 within cementitious materials (Source: 2025 CLF North American Material Baselines).