ZGF Fast+Epp EllisDon LAFARGE

CONCRETE

Get Started

A Pragmatic Approach to Lowering Embodied Carbon | 2023

Introduction

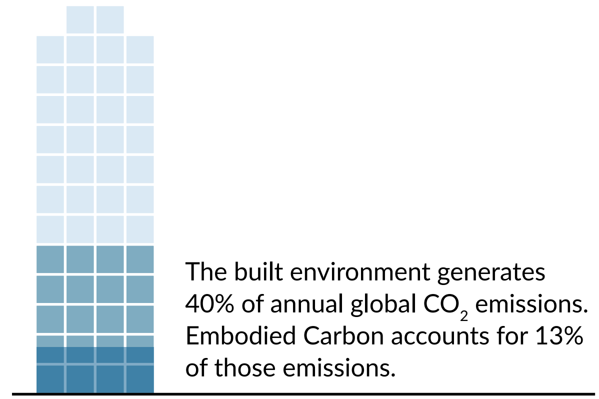
Decarbonizing buildings is a critical step in the transition to a low-carbon future and is necessary to meet global climate goals. Concrete, one of the most widely used structural materials, is typically the single largest contributor to a building's Embodied Carbon, requiring a significant amount of energy and emissions in its production. This interactive guide offers project teams strategies to reduce concrete's impact.

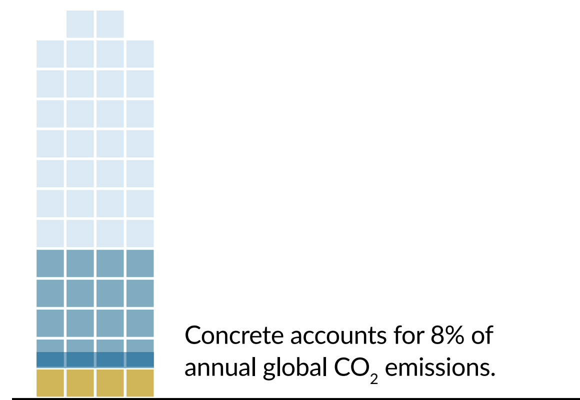
The built environment generates 40% of annual global CO_2 emissions. Of those total emissions, building operations are responsible for 27% annually, while Embodied Carbon is responsible for 13% annually. Embodied Carbon is the greenhouse gas emissions from the manufacturing, transportation, installation, maintenance, and disposal of building material. It is measured per m^2 of the building floor area in terms of carbon dioxide equivalent i.e. global warming caused by a kg of CO_2 ($kgCO_2e/m^2$).

Concrete is typically the largest contributor to a building's Embodied Carbon. Concrete consists of approximately 10% cement, which can account for as much as 90% of the overall Embodied Carbon impact for concrete. Concrete accounts for 8% of human-caused GHG emissions.

Until recently, efforts to reduce emissions in the building industry have focused on Operational Carbon reduction. However, to effectively reduce carbon emissions associated with buildings it is necessary to reduce *both* Embodied Carbon and Operational Carbon. This interactive guide offers pragmatic options at key project decision points to support stakeholders and consultants in the development of low-Embodied Carbon concrete solutions.

The technical guidance contained herein has been developed through the experience gained in the Lower Mainland of British Columbia, Canada by co-authors ZGF Architects, Fast+Epp, EllisDon, and Lafarge. This guide serves as a snapshot in time and will be updated by the authors as knowledge, products, and opportunities for low-Embodied Carbon concrete continues to advance.





Concrete is one of the biggest opportunities to reduce carbon in the built environment.

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Interactive Guide

Efficient and cost-effective low-Embodied Carbon concrete solutions are optimized when decision-makers and key consultants are included earlier in the project design process. The graphical table below is an interactive tool designed to identify opportunities to reduce Embodied Carbon through building project phases based on a typical concrete building project in the Lower Mainland of British Columbia.
Click on the "blue text" in the graphical table below to navigate to each section of the Interactive Guide.

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Client | Architect | Structural Engineer | Contractor | Concrete Supplier

Pre-Design	Schematic Design	Design Development	Construction Documents	Bidding	Construction Admin.

Baselines and Targets →
Set carbon reduction goals and targets with client. Review Embodied Carbon reduction goals and targets with structural engineer.
Team Members involved: Client, Architect, Structural Engineer, Contractor

Efficient Structure →
Invest in detailed geotechnical investigations and structural analysis; minimize concrete through use of Transportation Demand Management (TDMs) to reduce parkades; embrace efficient lay-out and minimize transfer slabs; optimize foundations; evaluate prefabrication and novel solutions.
Team Members involved: Structural Engineer, Architect

Optimize Mix Design →
Work with structural engineer, contractor and concrete supplier to develop low GWP concrete mix designs based on performance specifications.
Team Members involved: Architect, Contractor, Concrete Supplier, Structural Engineer

Specifications and Procurement →
Ensure Global Warming Potential (GWP) targets for low carbon concrete are included in specifications. Consider concrete GWP performance targets and Environmental Product Declaration (EPD) availability during concrete supplier bidding.
Team Members involved: Architect, Structural Engineer, Contractor

Early Embodied Carbon Calculations →
Perform preliminary baseline and Embodied Carbon calculations for concrete mixes and structural schemes during Schematic Design and early Design Development.
Team Members involved: Architect, Contractor, Concrete Supplier, Structural Engineer

Whole Building Life-Cycle Analysis (LCA) →
Perform whole building LCA from late Design Development through Construction Administration to understand relative impact.
Team Members involved: Architect, Contractor, Concrete Supplier, Structural Engineer

Baselines & Targets

Checklist

- ☑ Set carbon reduction goals and targets with the team no later than Schematic Design.
- ☑ Review opportunities to reduce concrete GWP and associated impact.

Whole building Embodied Carbon reduction targets are typically set by codes (City of Vancouver) and building certification bodies (LEED, CAGBC Zero Carbon Building design standard, and ILFI Zero Carbon). Typically, targets are set as a 5-20% reduction over a preset baseline or as an absolute Global Warming Potential ($kgCO_2e/m^2$) target.

Low-Embodied Carbon concrete solutions can play a significant role and can provide no-cost / low-cost solutions in achieving a project's whole building Embodied Carbon reduction target. Recent projects have achieved 10-20% of the whole building Embodied Carbon reductions through low-Embodied Carbon concrete solutions (section Optimize Mix Design Case Studies).

Setting the baseline and target early allows for an evaluation of a greater number of opportunities that can reduce the carbon impact of a project. This includes concrete volume reduction and optimizing the concrete mix design.

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Baselines

For each concrete mix design, develop a realistic baseline specific to the concrete strength, exposure class, and cure time requirements as defined by the structural engineer.

Use industry recognized guidelines in setting a baseline, such as:

- National Research Council Canada: Low Carbon Assets through Life Cycle Assessment (LCA[2])
- Upcoming City of Vancouver LCA guidelines for the Vancouver Building By-law

Common Global Warming Potential (GWP) baselines can be set using the following:

- CLF: Generic Pan-North America baseline, note that these are conservative
- Concrete BC Member Industry-Wide Environmental Product Declaration for Ready-Mixed Concrete: regionally specific concrete GWP numbers for BC

The guidelines listed above are constantly updating, users should look for the most recent versions. NOTE: Canadian regionally specific ready mix concrete EPDs are available (see Quick Links).

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Quick Links:

National guidelines for whole-building life cycle assessment - NRC Publications Archive - Canada.ca

CLF Material Baselines for North America

Concrete BC Industry-wide EPD

Standard on Embodied Carbon in Construction

Setting Targets

Specific targets for concrete GWP reductions should be set in collaboration with the project team and be in alignment with the Owner's project requirements, sustainability goals and budget.

Low-Embodied Carbon concrete solutions can play a significant role in a cost-effective achievement of a project's whole building reduction target. It is recommended to establish performance based concrete targets using the GWP of mix designs and analyze these as percentage reductions on the baseline. The Procurement section of this guide includes an example bid form that can be used to document the GWP baseline, targets and percentage reduction of concrete.

Use the Concrete BC Member Industry-Wide Environmental Product Declarations to determine each concrete mix designs GWP. These should be rolled up to an overall percentage reduction target for concrete. This allows the contractor and concrete supplier to develop mix designs based on the performance requirements of the concrete and providing GWP mix design innovations.

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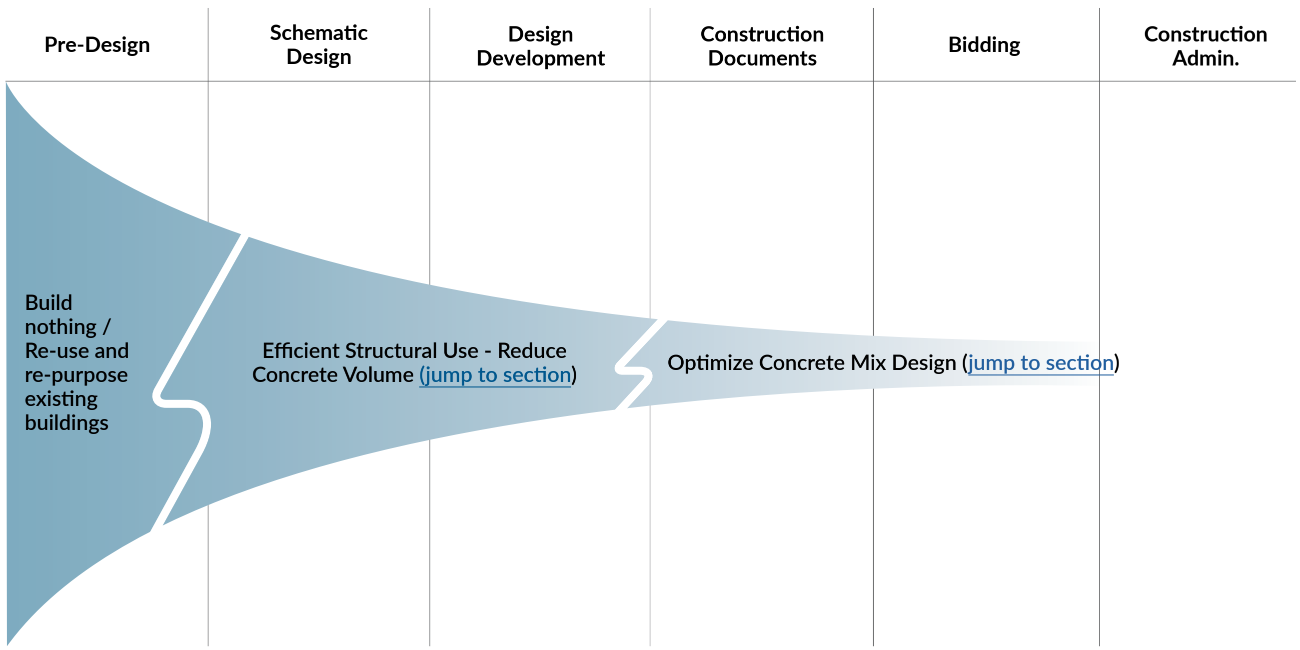
Opportunities & Scale of Impact

Setting the baseline and target early allows for the evaluation of a greater number of opportunities to reduce the Embodied Carbon of concrete.

The following provides a simplistic perspective of key decisions and their scale of impact. Reducing the volume of concrete is likely to have the largest impact in reducing a projects Embodied Carbon. It is never too late to reduce the Embodied Carbon of concrete with the optimization of concrete mix designs through Construction Documentation.



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Efficient Structural Use

Less concrete volume per floor area, leading to lower overall Embodied Carbon, can be accomplished through developing a more efficient structural system. To achieve this, it is critical for the design team to optimize the architectural concept with the help of the structural engineer early in the design process.

In the design of concrete structures, simple adjustments to the conventional approach can lead to significant Embodied Carbon reductions. Some of the most effective ways to reduce concrete volumes are:

- [x] Invest in detailed geotechnical investigations and structural analysis.
- [x] Minimize concrete through use of Transportation Demand Management (TDM) to reduce parkades.
- [x] Embrace efficient lay-out and minimize transfer slabs.
- [x] Optimize foundations.
- [x] Evaluate prefabrication and novel solutions.

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General Strategies

Less is more — in concrete buildings, most of the Embodied Carbon is located within the structure. Commitment to early concept optimization and lean detailed design is critical. In addition, a few fundamental yet simple strategies can lead to significant Embodied Carbon reductions.

Consider concrete with high compressive strength

- 40 MPa concrete is 60% stronger than 25 MPa concrete
- GWP increase is only 35%

Consider steel with high tensile strength

- 500 MPa steel is 25% stronger than 400 MPa steel
- Both have similar GWP

Minimize concrete volume by maximizing reinforcement ratio for flexural members

- Nearly 100% of steel used for producing reinforcing bars comes from recycled scrap, and more than 65% of all reinforcing bars are recycled
- Slab reinforced with 0.4% vs slab reinforced with 0.2% may be 40% thinner
- 32% GWP reduction

Maximize resistance utilization by maximizing number of element sizes

- Maximizing structural utilization (i.e. resistance/demand) of each element will minimize total material volumes
- GWP values are linearly dependent on material volumes

Round up sizing in concrete elements to nearest 25 mm vs higher increments

- Adapting 225mm thick slab vs 250mm thick slab
- 11% GWP reduction

Deeper beams are more efficient than wider beams

- 400 wide x 800 deep beam is as strong as 750 wide x 600 deep
- 40% GWP reduction

Embodied Carbon reductions listed above are examples of some specific cases, and may vary depending on actual conditions.

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Quick Links:

[Case Study Embodied Carbon Routes to Reduction](#)

Gravity System

Most of the structural Embodied Carbon is utilized in the gravity load resisting system. Well-organized column grid and elimination of vertical transfers are essential carbon reduction strategies. Use of more efficient slab systems and prefabricated elements will lead to additional reductions.

Embrace Regular Column Grid

- Columns account for 5-10% of structural carbon and slabs account for 40-50%
- Tighter column spacing will result in thinner slabs and lower overall material volume
- Equal column spacing in both directions is the most efficient solution
- Corner and end bays are the worst conditions increasing slab thickness - reduce spans by insetting columns from slab edges

Eliminate Vertical Transfers

- Continuity of vertical elements is the most efficient way to transfer loads down to foundations
- Avoid transfer beams, as they include large masses of concrete and are heavily reinforced

Use Efficient Slab Systems

- Post-tensioned slabs: Provides longer spans, thinner slabs and reduces building height which can result in a smaller envelope area
- Ribbed slabs: Lighter and stiffer system and effective for vibration-sensitive occupancies
- Voided slabs: Eliminates unnecessary concrete volume and reduces loads on foundations

Precast Concrete

Current EPDs for precast concrete are suggesting higher GWP than cast-in-place concrete. However, with factory setting and associated efficiencies precast concrete has the potential to improve the GWP performance of concrete and has other attributes to consider:

- Variety of efficient structural shapes such as double tee and hollow core are readily available, with the opportunity to pre-stress elements that can result in reduced concrete volume
- Factory formwork can be repurposed and reused
- High-quality concrete finishes can eliminate the need for additional finishing materials
- Precast concrete often leads to lower waste compared to cast-in-place

Embodied Carbon reductions listed above are examples of some specific cases, and may vary depending on actual conditions.

Slabs can account for 40-50% of the Embodied Carbon in a building structure.

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Lateral System

Effective layout of the lateral load resisting system results in leaner superstructure and foundations. It should be thoughtfully organized and locked-in early in the design. For high seismic regions, high ductility systems and base isolation systems will result in significant material savings and should be utilized more commonly.

Embrace Structurally Efficient Lay-out

- Embrace symmetry
- Avoid layouts with only a central core or a core located on one side. It is more efficient to distribute shear walls and cores uniformly throughout the floor plan and along building edges.
- Eliminate structural irregularities (vertical off-sets, out-of-plane off-sets, non-orthogonal systems, etc.)

Favour Shear Walls over Moment Frames

- Concrete moment frames are significantly less efficient in resisting lateral loads than concrete shear walls
- Moment frames are inherently more flexible and require a larger volume of concrete and rebars to satisfy strength and drift demands

Avoid Short Shear Walls

- Short shear walls are not efficient in resisting an overturning
- Results in thicker walls and high volumes of rebar steel
- Bigger foundations are required for shorter shear walls

Use High Ductility Systems

- Ductile seismic force resisting systems dissipate energy more efficiently and reduce design forces
- This results in noticeable member size and material volume reductions

Use Base Isolation

- Superstructure is separated from foundations with an energy dissipating system (elastomeric pads, sliding plates, etc.)
- Amount of energy that is transferred to the structure during an earthquake is significantly reduced, resulting in a lower volume of concrete and rebar steel in the superstructure and foundations

Embodied Carbon reductions listed above are examples of some specific cases, and may vary depending on actual conditions.

Base isolation significantly reduces the amount of energy transferred to the structure during an earthquake, minimizing concrete and rebar volumes.

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Foundations

Foundations are responsible for a significant portion of Embodied Carbon for any building. Complexities of soil properties and building load transfer often lead to a conservative design approach. More detailed investigations and analysis will provide more information and will help reduce the size of structural elements.

Invest in Investigations and Analysis

- More sophisticated geotechnical investigations can lead to higher soil bearing resistance, resulting in smaller footings
- Soil-structure interaction analysis evaluates the behaviour of soil and structure as a system and may reduce the predicted magnitude of seismic force resulting in a lighter lateral load resisting system including foundations

Maximize SCM

- Target to maximize cement substitution with SCMs for foundations
- High SCM content in massive elements helps control heat of hydration and minimizes cracking
- Most of the potential impacts of SCMs—including time strength gain, finishability, and adhesion—are rarely applicable to foundations

Foundation systems can account for 20% of the overall structural Embodied Carbon.

Minimize Slab-on-Grade (SOG)

- SOG thickness is often increased to minimize cracking caused by uneven settlements and concrete creep and shrinkage
- Uneven settlements can be mitigated by improving the quality of subgrade preparation
- Concrete creep and shrinkage cracking can be improved by placing rebars at tighter spacing
- It is often feasible to decrease SOG thickness by at least 25 mm (e.g. 125 mm vs 150 mm)

Release Hydrostatic Pressure

- High water table causes hydrostatic pressure, resulting in uplift forces underneath foundations
- 1 m of water table above the bottom of the foundations requires 0.7 m of concrete to balance the uplift
- Avoid using the self-weight of concrete to resist the uplift and eliminate it by releasing the hydrostatic pressure using alternative strategies (pumping system, storage tanks, bioswale, etc.)

Embodied Carbon reductions listed above are examples of some specific cases, and may vary depending on actual conditions.

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Optimize Mix Design

Checklist:

- ☑ Engage in early conversations with concrete suppliers to explore cement reduction opportunities.
- ☑ Engage contractor to understand construction schedule and potential to increase cure time.

Strategies to optimize mix design:

- **Aggregates**
  - Optimize combined aggregate gradations
  - Use water-reducing admixtures
  - Use recycled aggregates where possible
- **Air content**
  - Higher air content results in higher GWP. Air content depends on exposure class, but should be minimized where possible
  - Specify different mixes for different exposure classes
  - Avoid exterior design mixes for interior elements
- **Portland Limestone Cement (GUL)**
  - Consider specifying GUL as a direct substitution for GU cement
  - Up to 10% GWP reduction of the concrete mix design
  - Widely available in the Lower Mainland
- **Chemical admixtures:**
  - Use water-reducing and mix optimization admixtures
- **Supplementary Cementitious Materials (SCM)**
  - Increase SCM dosage with SCMs such as fly ash, slag, silica-fume to reduce cement content wherever possible
  - Investigate alternate SCMs, natural pozzolans (including metakaolin) and ground glass. These have regional availability and ready mix producers may not be familiar with their use
- **Carbon Capture, Utilization and Storage (CCUS)**
  - New and alternate cement production is being developed, but is a number of years from commercial availability. Embodied Carbon reduction should be evaluated through a third party validation

Quick Links:

Steps to Develop a Buy Clean Policy - Carbon Leadership Forum

EPD Requirements in Procurement Policies - Carbon Leadership Forum

Bid Document Examples from Building Transparency

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Case Study 1

As previously established, cement has the highest CO_2 emissions relative to mass among all concrete ingredients. ZGF worked with the concrete supplier during the early stages to optimize mix designs for all concrete mixes at no or negligible added cost for an institutional project in British Columbia. Below is an example of the findings.

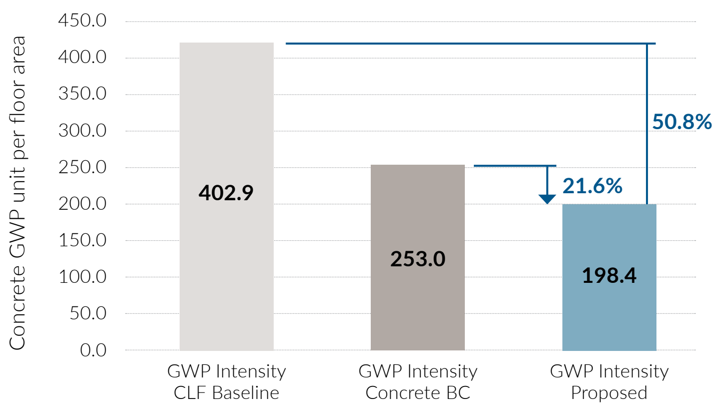
Project: 55,000 m^2 institutional project in British Columbia

Properties of Selected Concrete Elements*

	% Air Content	% SCM Dosage	% Cement Reduction	GWP Potential (kg CO_2 eq per m^3)
25 MPa Foundations	2.0	40	-67	230
30 MPa Beams and Slabs	2.0	15	-54	281
25 MPa Slab-on-grade	2.0	40	-61	235
45 MPa Columns	2.0	30	-43	365

*The table represents examples of concrete elements with their GWP. All concrete elements achieved reductions over the baseline GWP values.

Concrete GWP - Baseline vs Proposed



Additional Strategies:

- Setting Embodied Carbon reduction targets with key team members - architect / contractor / structural engineer
- Early stage Embodied Carbon analysis, evaluating elemental curing time
- Performance based concrete requirements
- Early engagement with concrete supplier

NOTE: GWP reductions expected to improve with project specific EPDs

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Case Study 2

In this commercial project in British Columbia, the structural engineer worked with the team during early design stages to generate performance requirements based on cure times for an expedited construction schedule. The supplier recommended products that reduced GWP at no added cost.

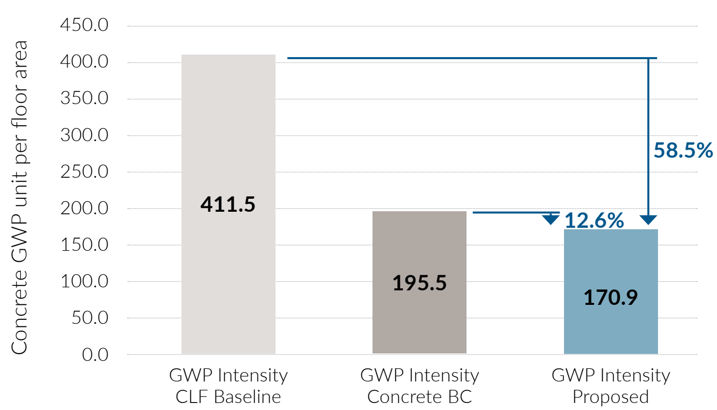
Project: 22,000 m² commercial project in British Columbia

Properties of Selected Concrete Elements*

	Exposure Class	Max Aggregate	GWP Potential (kg CO_2 eq per m³)
35 MPa Foundations	N	0.75"	252
35 MPa Slabs and Beams	C-1	0.75"	297
30 MPa Slab-on-grade	C4	0.75"	230
50 MPa Columns	L3	0.75"	275

*The table represents examples of concrete elements with their GWP.
All concrete elements achieved reductions over the baseline GWP values.

Concrete GWP - Baseline vs Proposed



Additional Strategies:

- Concrete volume reduction through elimination of transfer slabs and reduction in floor to floor height
- Developed performance requirements highlighted constraints on slabs curing time
- Performance based bidding form allowing concrete supplier to provide multiple mix design options.

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Case Study 3

112 multi-family residential project in downtown Vancouver, BC. The development of the low embodied concrete strategy forms part of the case study shown demonstrating how to meet the 2025 Vancouver Building By-law Embodied Carbon Requirements.

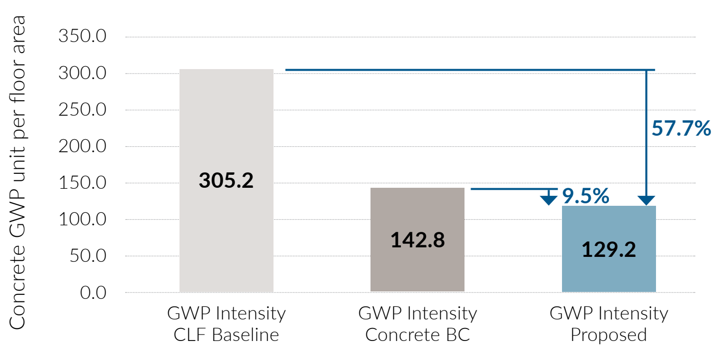
Project: 8,800 m² multi-family residential project in British Columbia

Properties of Selected Concrete Elements*

Elements	Exposure Class	Min. 56 Day Strength MPa (psi)	GWP Potential (kg CO_2 eq per m³)
Foundations and Footings	-	25 (3600)	182
Walls	F2	30 (4350)	215
Columns	F2	30 (4350)	215
Suspended slabs and beams	-	30 (4350)	248
Shear walls	F2	55 (7978)	314

*The table represents examples of concrete elements with their GWP.
All concrete elements achieved reductions over the baseline GWP values.

Concrete GWP - Baseline vs Proposed



Additional Strategies:

- Reducing parking levels
- Structural optimization (slab thicknesses reduced through aligning structural columns to avoid transfer slabs)
- Low GWP concrete specifications

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Specifications & Procurement

Specifications Checklist

- ☑ Develop performance based specifications that include concrete strength, exposure class and cure time required.
- ☑ Determine overall project Embodied Carbon reduction goal and define percentage reduction target for concrete as a whole (see Early Embodied Carbon Calculations).
- ☑ Specify provision of EPDs for each concrete mix design.

Procurement Checklist

- ☑ Contractor to issue bid form as part of tender package and communicate to concrete supplier the desire for lower carbon options.
- ☑ Concrete Supplier to complete bid form, with alternative low carbon mixes in support of GWP targets.
- ☑ Structural Engineer, Contractor and Concrete Supplier to review mixes and optimize for all performance expectations through Post Contract Award.
- ☑ Concrete Supplier and Contractor to track actual concrete volumes supplied, by mix and identify any change from early design agreements.

Performance based specifications allows the design and construction team to evaluate constraints (including schedule) through the bidding process to optimize low embodied concrete mix design. The bidding form allows carbon to be considered as a performance metric, with the team selecting a partner that shows a willingness to support in the Embodied Carbon reduction targets.

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Specifications

Performance-based specifications should be used allowing a level of flexibility in material selection by the contractor and concrete supplier, such as cement replacements (fly ash, slag, etc.) and aggregates. The performance based specifications should consider:

- Strength and Durability Requirements: Define minimum compressive strength, flexural strength, and durability parameters (e.g., freeze-thaw resistance, chloride ion penetration) that the concrete must meet.
- Workability and Placement: Specify acceptable workability characteristics, such as slump or flow.
- Curing and Setting Time: Define parameters related to curing methods and setting time to ensure proper hydration and development of concrete strength.
- Permeability and Porosity: Set limits on permeability and porosity to ensure that the concrete maintains appropriate resistance to moisture penetration and chemical attack.
- Reporting and Documentation: Require Environmental Product Declarations of the mix designs used.

Other considerations in developing the specification, include:

- Monitoring and Testing: Define protocols for quality control and testing throughout the construction process to ensure that the low embodied concrete consistently meets the specified performance standards.
- Incentives for Innovation: Provide incentives for contractors and suppliers to propose innovative approaches, materials, or technologies that can further reduce the carbon footprint while meeting performance goals.
- The National Master Specification (NMS) have been updated to include references that support low carbon concrete products and methods and can be used as a template.

Quick Links:

CLF Model LCA Specifications

CLF Guidance on Embodied Carbon Disclosure

Building Transparency Embodied Carbon Specification language template

Guide to Improving Specifications for Ready Mixed Concrete (nrmca.org)

National Master Specifications (NMS)

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Procurement

Utilize a concrete procurement form to allow concrete suppliers to propose low carbon concrete mix designs to meet the overall percentage reduction target.

Below is an example of a bidding form (template available here) that has been used to help determine the overall percentage reduction of concrete at 21% in Column H. This is based on developing the baseline using BC Concrete Industry EPDs, Column E and working with structural engineer to determine GWP targets using BC Concrete Industry EPDs, Column H. In a situation where the team does not have enough information to develop targets, an open bid process based on overall percentage reduction of the baseline can be set up with the different concrete suppliers.

It is recommended that the design and construction team evaluate the concrete bid submittals to determine best concrete mix design for project based constraints (schedule and cost), while maximizing GWP reductions through the concrete mix designs.

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Column A	*Column B*	*Column C*	*Column D*	*Column E*	*Column F*	*Column G*	*Column H*	*Column I*	*Column J*	
						Reference		**Alternate Bid Item #1**		**Alternate Bid Items continued...**
Elements	Exposure Class	Mix (MPa)	Vol (m^3)	Provisional Concrete BC Baseline Mix GWP from astm.org (Link)	Total Baseline GWP per mix ($kgCO_2e$)	Mix GWP Maximum Target ($kgCO_2e/m^3$)	Total GWP per mix ($kgCO_2e$)	Mix GWP	Total GWP per mix ($kgCO_2e$)	
Foundations and Footings		25	6,028.2	231	1,389,630	182.0	1,097,140			
Walls	F2	30	2,495.7	270	673,413	215.0	536,574			
Columns	F2	30	139.3	270	37,593	215.0	29,954			
Suspended slabs and beams		30	2.4	270	657	248.0	604			
Suspended slabs and beams (parking)	C1	35	7,102.1	311	2,205,268	248.0	1,761,317			
Architectural concrete, exterior	F2	30	1,938.2	270	522,987	215.0	416,715			
Architectural concrete, interior		30	3,120.2	270	841,913	198.0	617,792			
Slabs on grade, exterior	C2	32		285		319.0				
Slabs on grade, interior		32		285		277.0				
Topping concrete		32		285		277.0				
Masonry grout		20		194		189.0				
				Project GWP ($kgCO_2e$)	5,671,460	**Project GWP**	4,460,094	**Project GWP**		
				% Reduction	NA	**% Reduction**	21%	**% Reduction**		

Calculating Embodied Carbon & LCA

Checklist:

Early Design Embodied Carbon Calculations:

- ☑ Gain approximate concrete quantities from structural engineer or contractor (if available) during early design (schematic design and design development phases).
- ☑ Run baseline calculations using Environmental Product Declarations (EPDs) released by Concrete BC.
- ☑ Establish project Embodied Carbon reduction target from baseline.

Whole Building Life-Cycle Analysis:

- ☑ Gain updated concrete quantities from either structural engineer or contractor. It is recommended to work with the contractor estimators team as early as possible to attain more realistic concrete quantities.
- ☑ Update baseline GWP and targeted values using concrete supplier Environmental Product Declarations.
- ☑ Calculate Whole Building Life-Cycle Analysis for proposed building based on updated concrete information.

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Early Embodied Carbon Calculations

During the early stages of the project (SD or early DD), calculating projected Embodied Carbon of concrete is essential to establish a realistic baseline as well as the reduction targets. Requiring the following:

1. Gain approximate concrete quantities from structural engineer or contractor (if available) during early design (schematic design and design development phases).
2. Run baseline calculations using Environmental Product Declarations (EPDs) released by Concrete BC.
3. Establish project Embodied Carbon reduction target from baseline.

Embodied Carbon Calculations based on material quantities and related EPDs include impacts associated only with Transport and Manufacture (A1-A3) stages, which accounts for most of the total Embodied Carbon.

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Quick Links:

National guidelines for whole-building life cycle assessment - NRC Publications Archive - Canada.ca

CaGBC Zero-Carbon Design Standard

Concrete BC Industry-wide EPD

Life Cycle Assessment for Buildings – Why it matters and how to use it, Ebook by OneClick

Tally LCA Resources

Athena Impact Estimator for Buildings

WBLCA Classification System

Whole Building Life-Cycle Analysis

Whole Building Life-Cycle Analysis (LCA) evaluates the environmental impact of a product through its life cycle and typically covers Transport and Manufacture (A1-A3), Construction and Transport to site (A4-A5), Use (B2-B4), and End of Life (C1-C4). Beyond Life (D) is optional depending on the boundary scope of the project.

In relation to concrete, a Whole Building LCA primarily helps with 2 things:

1. Comparing the relative impact of concrete against overall building GWP.
2. Verifying and validating reductions for the purpose of achieving project targets.

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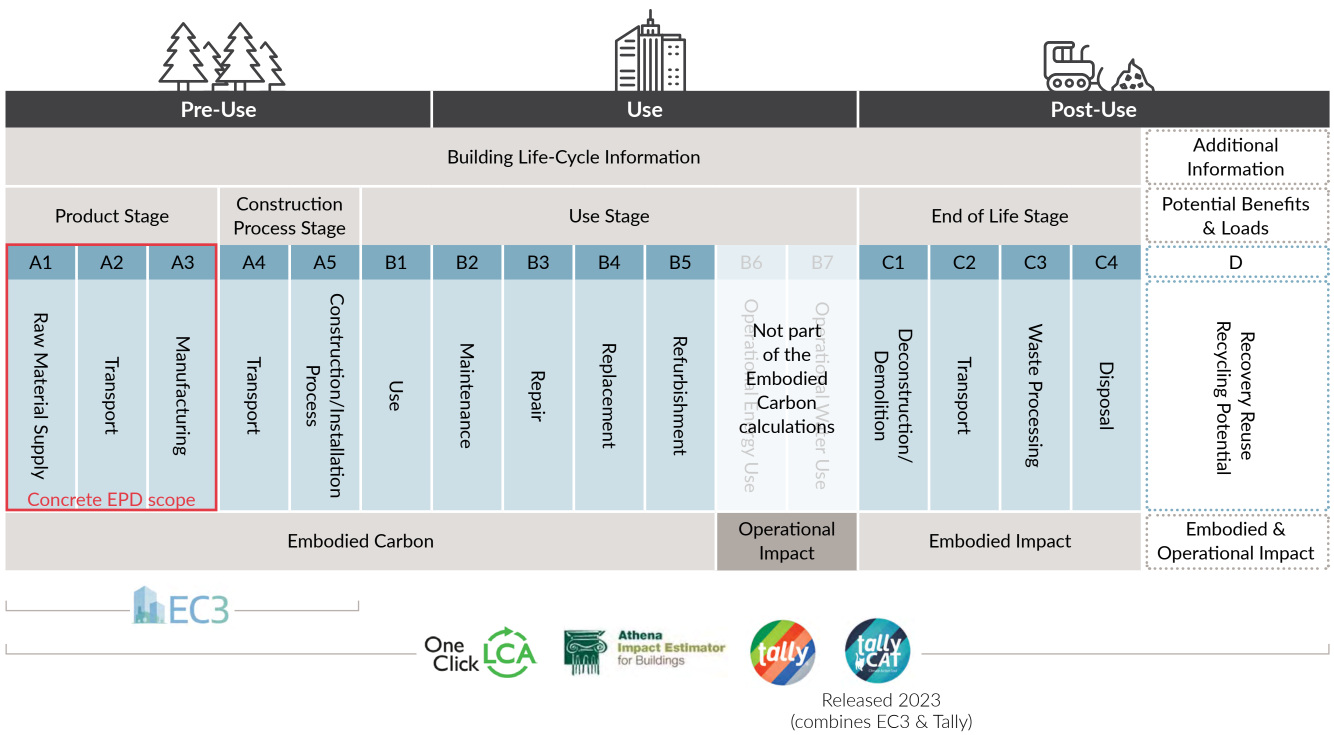

Key Terminology

Embodied Carbon: All the CO_2 emitted in the production of the building and is a result of distinct, rather than ongoing, processes that produce carbon. This includes the extraction and production of materials used during construction, and their transportation in addition to the carbon released by plants and machinery throughout the building process itself. In the case of rebuilds, demolition adds to the Embodied Carbon of a site.

Embodied Carbon Calculation: Method of quantifying the carbon environmental impact of a material or an element associated with its supply and manufacturing.

Environmental Product Declaration (EPD): According to the International EPD system, an EPD transparently reports objective, comparable, and third-party verified data about products and services' environmental performance from a life-cycle perspective. This includes estimated Embodied Carbon emissions data over a presumed life-cycle of the product through various life-cycle stages.

Global Warming Potential (GWP): According to the Government of Canada, the Global Warming Potential (GWP) metric examines each greenhouse gas's ability to trap heat in the atmosphere compared to carbon dioxide (CO_2). We measure this over a specified time horizon.

Life-Cycle Analysis or Assessment (LCA): Method of quantifying the environmental impacts associated with a material. Whole building LCA accounts for the sum of environmental impacts associated with all major contributing materials in a building.

Operational Carbon: The carbon released from the ongoing operation of a building. Sources will include lighting, power, heating, ventilation, air conditioning, and other infrastructure such as lifts and automatic doors.

Ordinary Portland Cement (GU or OPC): A finely powdered hydraulic binding material, which, when mixed with water, holds aggregates, sand, and other supplementary cementitious materials to form concrete.

Portland Limestone Cement (PLC or GUL): A blended cement with a higher limestone content (GU has 5%, while GUL has up to 15%). GUL performs similarly to Ordinary Portland Cement (GU) but can have up to 10% less GWP compared to GU.

Supplementary Cementitious Materials (SCM): Materials such as fly ash, slag, silica fume, pozzalon and white mud that work in conjunction with cement to form concrete and contribute to the properties of the concrete such as strength, durability, permeability, finish, and carbon impact.

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Quick Links

Baselines & Targets

Concrete BC Industry-wide EPD

CLF Material Baselines for North America

National guidelines for whole-building life cycle assessment - NRC Publications Archive - Canada.ca

Standard on Embodied Carbon in Construction

Efficient Structural Use

Case Study Embodied Carbon Routes to Reduction

Optimize Mix Design

Steps to Develop a Buy Clean Policy - Carbon Leadership Forum

EPD Requirements in Procurement Policies - Carbon Leadership Forum

Bid Document Examples from Building Transparency

Specs & Procurement

CLF Model LCA Specifications

CLF Guidance on Embodied Carbon Disclosure

Building Transparency Embodied Carbon Specification language template

Guide to Improving Specifications for Ready Mixed Concrete (nrmca.org)

National Master Specifications (NMS)

Bidding Form Template

Calculating Embodied Carbon & LCA

National guidelines for whole-building life cycle assessment - NRC Publications Archive - Canada.ca

CaGBC Zero-Carbon Design Standard

Concrete BC Industry-wide EPD

Life Cycle Assessment for Buildings – Why it matters and how to use it, Ebook by OneClick

Tally LCA Resources

Athena Impact Estimator for Buildings

WBLCA Classification System

Checklists

Baselines & Targets

- ☐ Set carbon reduction goals and targets with the team no later than Schematic Design.
- ☐ Review opportunities to reduce concrete GWP and associated impact.

Efficient Structural Use

- ☐ Invest in detailed geotechnical investigations and structural analysis.
- ☐ Minimize concrete through use of TDMs to reduce parkades.
- ☐ Embrace efficient lay-out and minimize transfer slabs.
- ☐ Optimize foundations.
- ☐ Evaluate prefabrication and novel solutions.

Optimize Mix Design

- ☐ Engage in early conversations with concrete suppliers to explore cement reduction opportunities.
- ☐ Engage contractor to understand construction schedule and potential to increase cure time.

Specifications & Procurement

Specifications:

- ☐ Develop performance based specifications that include concrete strength, exposure class and cure time required.
- ☐ Determine overall project Embodied Carbon reduction goal and define percentage reduction target for concrete as a whole (see Early Embodied Carbon Calculations).
- ☐ Specify provision of EPDs for each concrete mix design.

Procurement:

- ☐ Contractor to issue bid form as part of tender package and communicate to concrete supplier the desire for lower carbon options.
- ☐ Concrete Supplier to complete bid form, with alternative low carbon mixes in support of GWP targets.
- ☐ Structural Engineer, Contractor and Concrete Supplier to review mixes and optimize for all performance expectations through Post Contract Award.
- ☐ Concrete Supplier and Contractor to track actual concrete volumes supplied, by mix and identify any change from early design agreements.

Calculating Embodied Carbon & LCA

Early Design Embodied Carbon Calculations:

- ☐ Gain approximate concrete quantities from structural engineer or contractor (if available) during early design (schematic design and design development phases).
- ☐ Run baseline calculations using Environmental Product Declarations (EPDs) released by Concrete BC.
- ☐ Establish project Embodied Carbon reduction target from baseline.

Whole Building Life-Cycle Analysis:

- ☐ Gain updated concrete quantities from either structural engineer or contractor. It is recommended to work with the contractor estimators team as early as possible to attain more realistic concrete quantities.
- ☐ Update baseline GWP and targeted values using concrete supplier Environmental Product Declarations.
- ☐ Calculate Whole Building Life-Cycle Analysis for proposed building based on updated concrete information.

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Baselines & Targets

Baselines

Setting Targets

Opportunities & Scale of Impact

Efficient Structural Use

Optimize Mix Design

Specifications & Procurement

Calculating Embodied Carbon & Life-Cycle Analysis

Baselines & Targets

Pre-Design | Schematic Design | Design Development | Construction Documents | Bidding | Construction Admin.

Checklist

- ☑ Set carbon reduction goals and targets with the team no later than Schematic Design.
- ☑ Review opportunities to reduce concrete GWP and associated impact.

Whole building Embodied Carbon reduction targets are typically set by codes (City of Vancouver) and building certification bodies (LEED, CAGBC Zero Carbon Building design standard, and ILFI Zero Carbon). Typically, targets are set as a 5-20% reduction over a preset baseline or as an absolute Global Warming Potential ($kgCO_2e/m^2$) target.

Low-Embodied Carbon concrete solutions can play a significant role and can provide no-cost / low-cost solutions in achieving a project's whole building Embodied Carbon reduction target. Recent projects have achieved 10-20% of the whole building Embodied Carbon reductions through low-Embodied Carbon concrete solutions (section Optimize Mix Design Case Studies).

Setting the baseline and target early allows for an evaluation of a greater number of opportunities that can reduce the carbon impact of a project. This includes concrete volume reduction and optimizing the concrete mix design.

Case Study 1

As previously established, cement has the highest CO_2 emissions relative to mass among all concrete ingredients. ZGF worked with the concrete supplier during the early stages to optimize mix designs for all concrete mixes at no or negligible added cost for an institutional project in British Columbia. Below is an example of the findings.

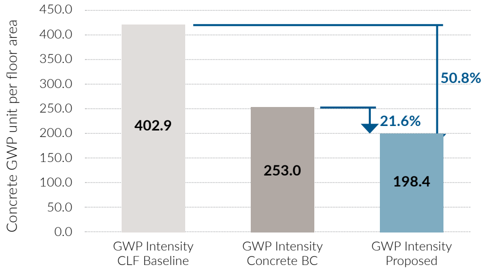
Project: 55,000 m^2 institutional project in British Columbia

Properties of Selected Concrete Elements*

	% Air Content	% SCM Dosage	% Cement Reduction	GWP Potential (kg CO_2 eq per m^3)
25 MPa Foundations	2.0	40	-67	230
30 MPa Beams and Slabs	2.0	15	-54	281
25 MPa Slab-on-grade	2.0	40	-61	235
45 MPa Columns	2.0	30	-43	365

*The table represents examples of concrete elements with their GWP. All concrete elements achieved reductions over the baseline GWP values.

Concrete GWP - Baseline vs Proposed



Key strategies:

- Setting Embodied Carbon reduction targets with key team members - architect / contractor / structural engineer
- Early stage Embodied Carbon analysis, evaluating elemental curing time
- Performance based concrete requirements
- Early engagement with concrete supplier

NOTE: GWP reductions expected to improve with project specific EPDs

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