ENGINEERS &
GEOSCIENTISTS
BRITISH COLUMBIA

PRACTICE ADVISORY

EMBODIED CARBON CONSIDERATIONS FOR STRUCTURAL ENGINEERS

Version 1.0, Published September 25, 2023

This practice advisory has been issued for registrants of Engineers and Geoscientists British Columbia (BC), who provide structural engineering services for new and existing building projects in BC. This practice advisory provides guidance on understanding embodied carbon in building design, calculating embodied carbon, and minimizing embodied carbon in the primary structural system through the design and decision-making processes.

The intent of this advisory is to complement—not replace—existing industry guides and standards by describing expectations and obligations for practice specifically in BC. This advisory does not summarize or refer to specific requirements of other documents; it is the responsibility of structural engineers of record (SERs) to familiarize themselves with those documents (see the Related Documents and Resources section below) and apply the guidance and requirements as appropriate. Key documents that SERs should be familiar with as it relates to structural embodied carbon are:

- *Embodied Carbon Guidelines* (City of Vancouver 2023)
- *How to calculate embodied carbon* (Second edition) (The Institution of Structural Engineers 2022)
- *National guidelines for whole-building life cycle assessment* (National Research Council of Canada 2022)

This advisory applies to SERs practicing or delivering projects in BC. However, the guidance may also be of interest to clients, authorities having jurisdiction (AHJs), industry stakeholders, contractors, architects, and other consultants, and could be adapted for use outside of BC. Similarly, some concepts presented may be applicable to structural engineering services for non-building projects.

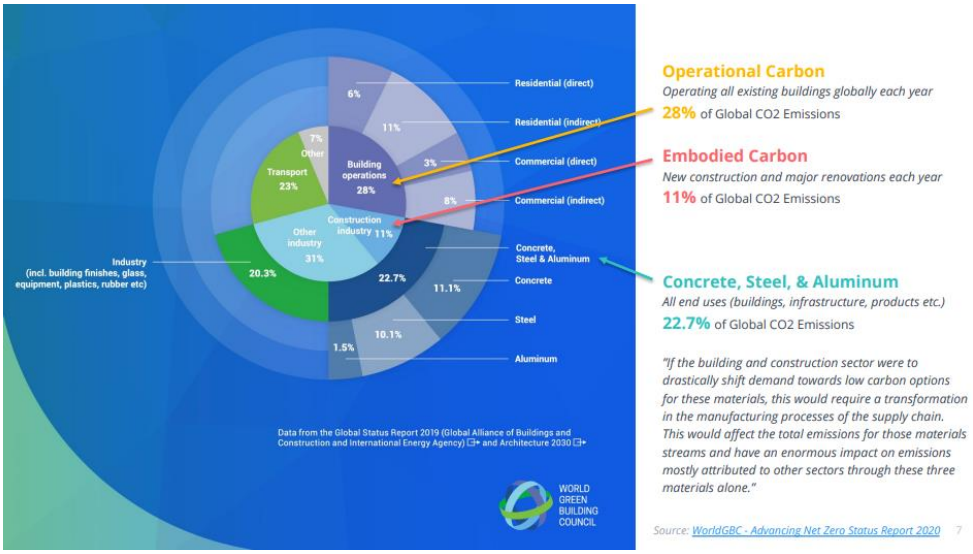
BACKGROUND

Per the *Canadian Net-Zero Emissions Accountability Act* (Statutes of Canada 2021), Canada has committed to achieving net-zero greenhouse gas emissions by 2050, with a 40 percent reduction from 2005 levels by 2030. Carbon dioxide (CO_2) is the primary greenhouse gas emitted in the world today and reducing carbon emissions is one strategy in reducing the overall global greenhouse gas emissions. Carbon emissions, as they relate to buildings, can be reduced through operational carbon reduction and embodied carbon reduction. Operational carbon reduction focuses on reducing carbon emissions through building operation, whereas embodied carbon reduction focuses on reducing carbon emissions within the materials and construction processes throughout the lifecycle of a building.

Figure 1 shows the breakdown and relative impact of carbon emissions due to construction and major renovation of buildings (construction industry) compared with carbon emissions in building operations, transportation, and other industries.

The City of Vancouver introduced a requirement to report and limit embodied carbon in new Part 3 buildings starting October 2023. Starting January 2025, the City of Vancouver will require 10 percent embodied carbon reductions for all new residential and commercial Part 3 buildings and 20 percent reductions for new low-rise Part 3 buildings that can be built with wood or mass timber. Several other jurisdictions in BC have introduced similar embodied carbon reduction requirements and it is expected that more will follow in the coming months and years. It is anticipated that the *National Building Code 2030* (NBC 2030) and subsequently published British Columbia Building Codes will also include requirements for the reduction of carbon emissions.

Minimizing carbon emissions is one component of overall sustainability strategies that engineering professionals should be aware of. This advisory focuses on reducing the embodied carbon of structural building materials, because that is the area where SERs have the greatest decision-making ability. Figure 2 shows the relative impact of the structure on embodied carbon compared with other components in a typical office building.



Data from the Global Status Report 2019 (Global Alliance of Buildings and Construction and International Energy Agency) and Architecture 2030

Operational Carbon
Operating all existing buildings globally each year
28% of Global CO2 Emissions

Embodied Carbon
New construction and major renovations each year
11% of Global CO2 Emissions

Concrete, Steel, & Aluminum
All end uses (buildings, infrastructure, products etc.)
22.7% of Global CO2 Emissions

"If the building and construction sector were to drastically shift demand towards low carbon options for these materials, this would require a transformation in the manufacturing processes of the supply chain. This would affect the total emissions for those materials streams and have an enormous impact on emissions mostly attributed to other sectors through these three materials alone."

Source: WorldGBC - Advancing Net Zero Status Report 2020 7

Figure 1: Breakdown of Emissions (Source: BC Embodied Carbon Modelling Study, Priopta/Anthony Pak, 2020)

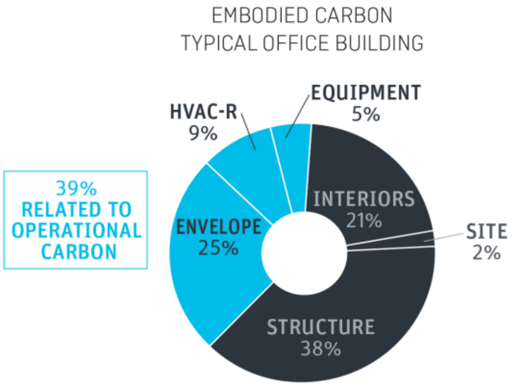


Figure 1: Breakdown of embodied carbon in a typical office building (Source: Whole Life Carbon: The Path to Desiloed Decarbonization, Stok 2021. Recreated by Engineers and Geoscientists BC.)

REDUCTION TARGETS

The overarching goal of net zero carbon emissions in 2050 and a 40 percent reduction by 2030 are clear (see the Background section); however, the steps to reach those goals and other interim goals may not be. What is clear is that the embodied carbon in buildings must be reduced and one of the most effective approaches for doing this successfully is to set clear targets. These targets are typically relative to a baseline but in some cases the target is absolute (e.g., maximum threshold for embodied carbon, similar to limits set for operational carbon emissions). Examples of absolute, intensity-based targets are identified by the International Living Future Institute (ILFI) and the Canadian Green Building Council (CAGBC).

A baseline target may come from parameters established by the AHJ (e.g., from a database of building archetypes), by the client or SER (e.g., from a building design per current industry practice before any embodied carbon minimization efforts are incorporated), or by a voluntary external program (e.g., CAGBC Zero Carbon Building Standard). The targets may be determined by the same parties and could be either voluntary or mandatory. In lieu of mandatory requirements from the AHJ, SERs should work with the client to determine the baseline and reduction targets that are reasonable and compatible with local objectives.

Resources to establish targets can be found through various organizations and programs that have adopted similar goals. See the Related Documents and Resources section below for examples.

PROFESSIONAL PRACTICE

REDUCING EMBODIED CARBON

Many strategies can be used to reduce embodied carbon in buildings. These include material reduction, material re-use, material specific strategies, and design decisions.

MATERIAL REDUCTION

One of the most impactful ways to reduce structural material is to utilize an efficient framing scheme that avoids unnecessary geometric complexity and transfer elements. The following section contains guidance on laying out and designing efficient structures. Due to architectural, constructability, and cost constraints, it is typically challenging to implement embodied carbon reduction strategies in all structural components. SERs should focus primarily on areas where structural decisions will lead to the highest embodied carbon reductions; typically, these are floor slabs and foundations, connections, and prefabrication.

A small reduction in the thickness of repeating floor slabs can result in a significant reduction of the overall embodied carbon. In mid-rise concrete buildings, floor slabs can account for 40 to 50 percent of the embodied carbon in a building structure and in low-rise concrete buildings, the foundations can account for 40 to 50 percent of the embodied carbon in a building structure. Optimizing floor slabs and foundations can therefore result in significant embodied carbon savings.

In steel construction specifically, connections can contribute as much as five to ten percent to the overall weight of the steel. Where appropriate, SERs should avoid designing connections based on element section properties, but rather, should design connections based on demands specific to a given connection. This approach can lead to noticeable material volume reductions and should be applied to other materials as well. Prefabrication allows for material waste reduction and more efficient use of energy. Most steel and wood structural systems are inherently suitable for off-site prefabrication. Similarly, precast concrete has the benefits of reduced sizes due to prestressing, decreased waste due to repurposed and reused factory formwork, and elimination of additional finishing materials on site due to high-quality in-shop finishing. When appropriate, SERs should embrace these prefabrication methods.

MATERIAL RE-USE

The embodied carbon footprint of a building project can be reduced by re-using existing buildings, assemblies, and materials. Long-term strategies include increasing the longevity of new materials and planning for re-use after deconstruction.

From an embodied carbon perspective, it is more efficient to preserve existing structures than it is to build new ones. The most embodied carbon efficient structure is the one that never gets built, the second is the one that is already in place, and the third is the one that is already in place and gets upgraded. When the removal of an existing structure is unavoidable, SERs should look for opportunities to re-use the detached existing elements for new construction. Existing steel and wood elements can be re-used directly or repurposed to form new structural elements. When material properties are not known, simple testing should be implemented.

The life span of the substructure and superstructure is typically significantly longer than the rest of the building components. While the lifespan of an overall building in BC is typically assumed to be 60 years, the foundation and other structural elements can last for significantly longer than that. Where appropriate, SERs should discuss the lifespan of the various building elements and the opportunities for future space re-purposing and building re-use with their client. Another impactful way to reduce the consumption of resources in construction is to design buildings with future dismantlement in mind. For example, by using mechanical rather than chemical connections, or encouraging the use of rigid insulation over spray foam.

MATERIAL-SPECIFIC STRATEGIES

To reduce the embodied carbon of structures, SERs should strive towards maximizing material utilizations, even if it means an increase in calculations and resources required during the design phase and number of different member types. Use of building information modelling (BIM) technologies and modern means of construction and procurement allow for improved efficiency when it comes to increased member typology. For example, using a greater number of steel beam section types designed with high utilization could lead to significant steel weight reduction of both primary elements and their connections.

SERs should avoid favoring one specific material over another, but rather, should use materials in applications that utilize the materials' best properties to achieve efficient structural designs and the lowest embodied carbon footprint possible. For example, in a residential mid-rise: two-way cross-laminated timber (CLT) floor slabs could be used to minimize the structural weight of the floor, steel columns could be used to keep section sizes small, and a lateral concrete core could be used to allow flexibility in accommodating stair and elevator lay-out openings.

SERs should consider the manufacturing process itself, as not all are created equal. For example, not all sawmills, steel mills, and cement factories have the same process or use the same source of energy. Some locations may be connected to a higher carbon intensity power grid or run on coal. Additionally, SERs should consider the distance that a product needs to travel from the manufacturer to site. They should request environmental product declarations (EPDs) that account for the manufacturing process. EPDs include global warming potential (GWP)—another widely used term that encompasses embodied carbon—rates and targets. See the section Calculation Fundamentals below for more information on GWP rates and targets.

The following sections outline examples of ways to reduce embodied carbon while using concrete, steel, and wood.

Concrete

According to the *Chatham House Report* (2018), the production of concrete accounts for approximately eight percent of the total global carbon emissions. While cement typically accounts for only 10 to 15 percent of the concrete mass, it is responsible for 85 percent of concrete carbon emissions (Cement Association of Canada 2021). SERs should request EPD or life cycle assessment (LCA) reports for mix designs from suppliers, consider working with an LCA consultant to assess the quality of and interpret the information provided, and consider utilizing one or more of the following reduction strategies when it comes to specifying concrete mixes:

- Specify GWP targets and request values as part of mix design submittal. If GWP values are not available, specify higher supplementary cementitious material (SCM) content and/or Portland limestone cement (GUL), as it results in five to ten percent lower embodied carbon than Portland cement.
- Specify different mix designs for exterior and interior elements, as less entrained air may be appropriate for interior conditions and result in less embodied carbon.
- Specify and design for 56 day strength—rather than 28 day strength—and coordinate the constructability and construction schedule early in the design phase to accommodate longer strength gain.
- Specify high strength rebar—which has similar embodied carbon as regular strength rebar—to reduce the overall weight.

SERs should also refer to the *National guidelines for whole-building life cycle assessment* (National Research Council Canada 2022) and the *Concrete BC Member Industry-Wide EPD for Ready-Mixed Concrete* (Concrete BC 2022).

Steel

SERs should consider the different steel production processes. Most hot rolled sections are produced using an electric arc furnace, which uses 95 percent recycled steel, while most hollow structural sections (HSS) are produced using the basic oxygen furnace, which uses only 25 percent recycled steel. Consequently, embodied carbon can be reduced by specifying hot rolled sections rather than HSS.

When specifying steel members, SERs should consider:

- specifying embodied carbon or GWP targets, requesting values as part of shop drawing submittals, and requesting EPDs or LCA reports from suppliers;
- specifying steel that complies with the definition of low carbon steel per the SteelZero initiative (The Climate Group and Responsible Steel 2023);
- specifying high strength steel—which has similar embodied carbon as regular strength steel—and hot rolled sections over HSS, where appropriate; and
- avoiding galvanizing or other treatments that increase the embodied carbon of the section if not necessary.

Wood

Wood production is less carbon intensive than the production of other materials by volume, and properly managed forests have the potential to remove and store a significant amount of carbon. As such, wood products from certified forests are significantly more environmentally friendly than from un-certified forests. In Canada, the Sustainable Forestry Initiative, the Forest Stewardship Council, and the Canadian Standards Association are the internationally recognized forest certification organizations (Government of Canada 2022).

When specifying wood products, SERs should consider:

- requesting EPDs or LCA reports from suppliers;
- specifying wood be harvested from certified rather than un-certified forests; and
- using prefabrication solutions to minimize the volume of material waste and specifying engineered wood products that re-use wood products or waste.

DESIGN DECISIONS

Efficient structural layout is an impactful and direct way to reduce embodied carbon. The form of the building is normally designed by an architect, so most decisions regarding the surface-area to volume ratio of the building, the size of indoor spaces, and the placement of vertical structural members remain the domain of the architect. However, these parameters also affect the SERs design and, if discussed early in the project, the SER can influence the framing layout and assemblies to best suit the preferred, or appropriate, material. Successful alignment between structural and architectural layout priorities can lead to structural efficiencies and therefore reductions in embodied carbon.

Additionally, SERs should work closely with geotechnical engineers of record in the early design stages to explore possibilities for higher bearing pressures than those identified during initial investigations. For sites with complex soil profiles, more sophisticated geotechnical investigations can lead to more precise soil resistance properties, which can result in more efficient foundation designs. In addition, implementing a soil-structure interaction analysis may reduce the predicted magnitude of seismic force, which would result in lighter lateral load resisting systems, including foundations.

SERs should consider utilizing numerical results and graphics showing carbon benefits of more efficient structural concepts when communicating with their client, the architect, and other consultants.

The following sections discuss considerations for making design decisions on loading, serviceability criteria, and gravity and lateral systems.

Loading

The magnitude of loads used in the design directly affects the volume of structural materials. SERs should take care to accurately estimate the design loads. Examples of opportunities to reduce and/or more accurately estimate design loads include:

- utilizing loading plans to reflect specific loading conditions applied in the design;
- decreasing self-weight loads by increasing utilization, relaxing serviceability criteria (where applicable, see the Serviceability Criteria section below), and using cambering;
- reducing superimposed loads by calculating, rather than estimating, the floor assemblies;
- requesting and applying lighter green roof systems in lieu of conventional heavy green roof systems;
- requesting site-specific snow and wind load data from Environment Canada, or conducting a site-specific snow or wind study; and
- where applicable, reducing seismic impacts on buildings by utilizing more comprehensive analysis.

Serviceability Criteria

In certain situations, SERs can make conscious design decisions or adapt serviceability criteria to align with embodied carbon goals, while still meeting performance requirements. Some examples include:

- establishing appropriate deflection performance criteria for exposed roof structures;
- pre-cambering long-span structures to maximize strength utilization and minimize member size; and
- performing specific vibration analyses to determine more accurate stiffness requirements.

Gravity System

It is typically more efficient to use shorter spans than longer spans, and to use regular than irregular spacing of vertical elements. As corner and edge spans are typically the governing conditions for continuous structural systems, SERs should consider in-setting the columns to minimize the effects of the edge conditions. Transfer elements are inherently inefficient and should be avoided as much as possible; continuity of vertical elements is the most efficient way to transfer loads down to foundations.

When appropriate, the following examples of structurally efficient and/or low-weight floor systems should be considered:

- Post-tensioned, ribbed, or void concrete slabs
- Deeper metal deck and/or castellated and cellular steel beams with composite action
- Point-supported CLT slabs or mass timber panels on purlins and girder beams

Lateral System

To achieve an efficient design of lateral force resisting systems and a reduction in materials, SERs should consider implementing one of more of the following strategies:

- Embrace symmetry and distributing vertical elements uniformly throughout the floor plate. Layouts with only one or non-centralized cores and structural irregularities (e.g., vertical offsets, out-of-plane offsets, non-orthogonal systems) should be avoided.
- Avoid short and slender vertical elements (e.g., shear walls, braced frames, moment frames), as these are often less efficient in resisting overturning, and therefore result in increased thickness and volume of other components.
- Utilize higher ductility systems, which can lead to more material savings than lower ductility systems.
- Utilize energy dissipation systems to reduce the amount of energy transferred to the structure.

CALCULATING EMBODIED CARBON

To better understand which factors contribute to the embodied carbon volumes within a structure, SERs should be capable of performing embodied carbon calculations for the structural components within the product stage or within the product and construction process stages combined. The results of these calculations may be used to highlight differences between building schemes or materials and inform decisions by the architect, client, or contractor. This can be done using quantity take-offs multiplied by material and element embodied carbon impact factors found within environmental product declarations (EPDs), or by using proprietary life cycle assessment (LCA) tools.

The following sections describe the life cycle stages, calculation fundamentals, calculation tools, and reporting.

LIFE CYCLE STAGES

BS EN 15978:2011 Sustainability of construction works. Assessment of environmental performance of buildings. *Calculation method* and *ISO 21930:2017 Sustainability in buildings and civil engineering works—Core roles for environmental product declarations of construction products and services* split the environmental impact of a building into five life cycle stages and modules:

1. Product stage (modules A1-A3): considers the carbon dioxide equivalent released during extraction, processing, manufacturing, and transportation of materials between these processes.
2. Construction process stage (modules A4-A5): considers the carbon dioxide equivalent released during transport of materials and products to site, energy usage due to activities on site, and the carbon dioxide equivalent associated with the production, transportation, and use of materials wasted on site.
3. Use stage (modules B1-B7): considers the carbon dioxide equivalent released due to use, maintenance, repair, replacement, refurbishment, and operational energy and water while the building is in use.
4. End of life stage (modules C1-C4): considers the carbon dioxide equivalent released during decommissioning, demolition, deconstruction, transportation of materials away from the site, waste processing, and disposal of materials.
5. Benefits and loads beyond the building life cycle (module D): estimates any net carbon dioxide equivalent benefits or loads beyond the project's life cycle associated with recycling of materials, energy recovered from materials, and full reuse of materials or products.

Figure 3 depicts the five life cycle stages and modules of a building. There are three general scope approaches for calculating structural embodied carbon:

- Product stage (modules A1-A3) only
- Product and construction process stages combined (modules A1-A5) only
- Whole building life cycle assessment (WBLCA) including product stage through end-of-life stages (modules A1-C4)

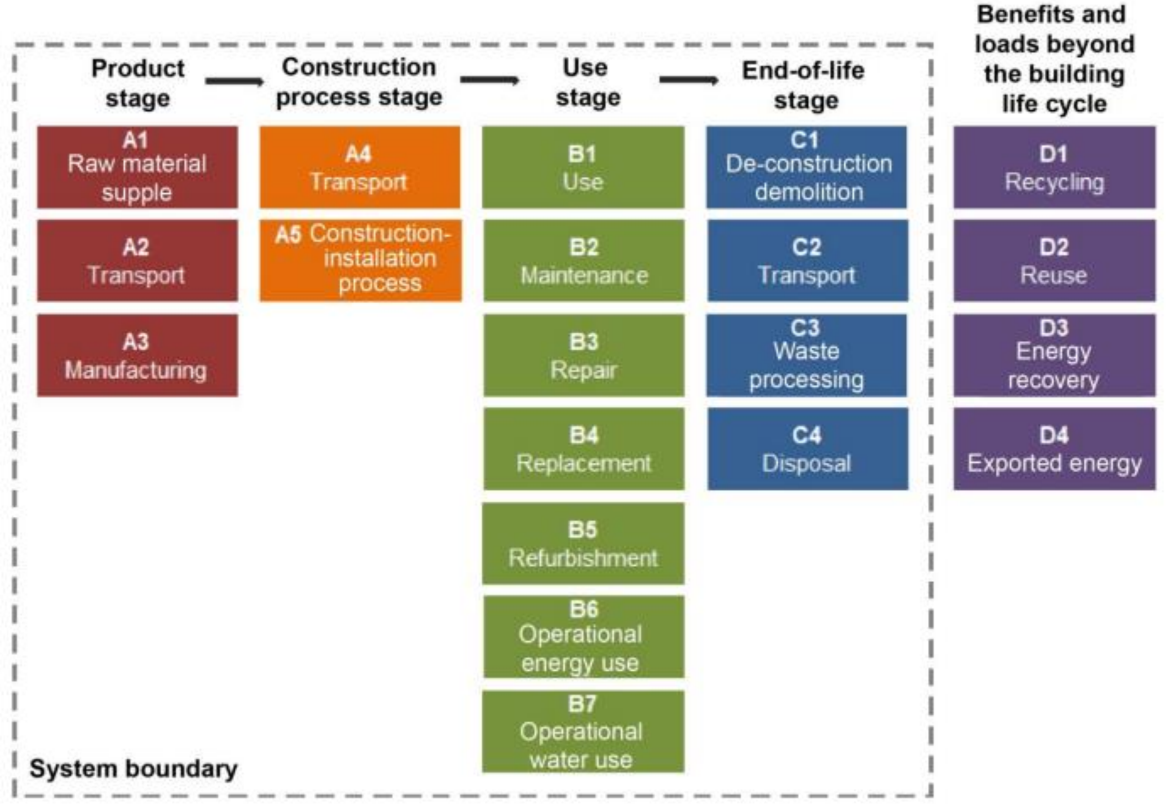


Figure 3: Life cycle stages, per EN 15978 and ISO 21930 (Source: Bowick et al 2022)

Typically, the majority of the carbon footprint of structural components occurs within modules A1-A5, with modules A1-A3 accounting for 80 to 95 percent of A1-A5 carbon. As such, the focus of structural embodied carbon calculations should be on the product stage. When it is important for the project to account for the emissions during construction, modules A4-A5 should be added to calculations.

A WBLCA accounts for the entire building—including exterior envelope and architectural components—and considers the full building life from product stage through end-of-life stages (modules A1 through C4). WBLCA should align with EN 15978 and/or the *National guidelines for whole-building life cycle assessment* (National Research Council Canada 2022) and should be performed by an LCA consultant. It is not anticipated that SERs will perform WBLCA unless specifically trained. However, SERs should provide the material quantities for the structural design to the LCA consultant upon request.

Module D-benefits and loads beyond the system boundary is calculated and reported separately from modules A1-C4 and is outside the scope and responsibility of the SER.

CALCULATION FUNDAMENTALS

The total embodied carbon is given in kilograms of global warming potential (GWP) or carbon dioxide equivalent (kgCO_2e), which is primarily comprised of carbon dioxide and other contributing gases like methane and nitrous oxide. SERs should keep in mind that the primary objective is to identify to project stakeholders (i.e., the client, architect, other consultants) where savings in embodied carbon can be made. Relative values are generally adequate to inform and enable selection of the most viable alternatives during design. Reasonable assumptions should be made if certain quantities are not easily measurable.

When performing an embodied carbon calculation for the structure alone, at a minimum, the following structural elements should be included:

- Substructure:
  - Piles, pile caps, and grade beams
  - Raft slabs and slabs on grade
  - Footings and foundation walls
  - All other major elements (e.g., underground floor slabs, columns, and beams)
- Superstructure:
  - Decks, slabs, and beams
  - Columns, walls, and braces
  - Stairs and ramps
  - All other major elements (e.g., structural balconies)

The following sections provide stage-specific calculation considerations.

Product Stage (Modules A1-A3 Only)

When considering only the product phase (modules A1-A3), the process is relatively simple. Quantities of each element are multiplied by the relevant embodied carbon impact factors—GWP rates published by manufacturers and industry associations in the form of EPDs—to obtain the embodied carbon of individual materials or elements, expressed in terms of GWP (kgCO_2e). EPDs follow a common, regulated procedure outlined in *ISO 14025 Environmental Labels and Declarations* and are freely accessible. To get the total structural embodied carbon, the results of all elements considered are summed. These calculations can be conducted using an embodied carbon WBLCA software (see the Calculation Tools section below) or a simple in-house developed procedure.

For example, *How to Calculate Embodied Carbon* (Gibbons and Orr 2022), outlines an approach for manually calculating modules A1-A3.

Biogenic carbon is carbon that has been taken out of the atmosphere during the life of a plant and stored until it is released again at the end of its life. Biogenic carbon can be approximated in the same way as embodied carbon and is often identified in wood product EPDs as a negative value for Modules A1-A3. Since this value is only negative during the product service life and can be released back into the atmosphere at the end of product's life, it is not accurate to use a reported negative value without addressing the nuances behind it. SERs should not include biogenic carbon in structural embodied carbon calculations. If it is estimated, it should be done using WBLCA or other specifically designed tools and reported separately.

Construction Process Stage (Modules A4-A5)

When information on construction processes and travel distance of materials are known, A4-A5 embodied carbon can be estimated using one of the following methodologies:

- *How to Calculate Embodied Carbon* (Gibbons & Orr 2022), which outlines the approach for modules A4 and A5 based on material quantities, assumed distances from site, and construction size/cost.
- *Embodied Carbon Guidelines* (COV 2023), which outlines a methodology for estimating A4-A5 as a percentage of calculated A1-A3 values.
- Proprietary WBLCA software tools that include A4-A5 as part of the calculations.

Use and End-of-Life Stages (Modules B1-C4)

This type of calculation should be completed using a WBLCA software that accounts for all modules. This scope often requires inputs on various elements beyond the expertise of most SERs and should be performed by an LCA consultant.

CALCULATION TOOLS

Table 1 lists several calculation tools available and includes information on the scope, applicable geographic regions, and BIM plug-in compatibility of each. When using embodied carbon calculation tools, even those noted as applicable in Canada, SERs should:

- make sure calculation assumptions (e.g., codes, standards) and material data (e.g., properties, units) are appropriate for use in BC;
- consider doing the calculation in at least two different ways to compare and verify results;
- consider experimenting with the assumptions and input values to understand the impact each has on the overall calculation and the direction of conservatism; and
- be aware of black box effects of software, understand the inputs and outputs, validate it periodically as per the *Guide to the Standard for Documented Checks of Engineering and Geoscience Work* (Engineers and Geoscientists BC 2023), and apply professional judgement to ensure the results make sense.

Table 1: Embodied carbon calculation tools

Type	Name	Creator	Scope	Applicable Geographical Regions	BIM plug-in Compatibility
Free at point of use	The Structural Carbon Tool	The Institution of Structural Engineers	A1-A3	Global	No
	Beacon	Thornton Tomasetti, Inc.	A1-A3	USA	Yes
	EC3	Building Transparency	A1-A3	USA	No
	OneClick LCA Planetary	Cerclos	A1-A3	Many (incl. UK)	No
	eTool (open use subscription)	Cerclos	A-D	Global	No
	Impact Estimator for Buildings	Athena Sustainable Materials Institute	A1-A5, B4, B6, C1, C2, C4, D	USA and Canada	No
	Embodied Carbon Estimator (ECOM)	The Structural Engineering Institute	A1-A3	USA	No
Paid	OneClick LCA	One Click LCA Ltd.	A-D	Global	Yes
	eTool (paid version)	Cerclos	A-D	Global	Yes
	TallyLCA	Building Transparency	A-D	USA	Yes
	TallyCAT	Building Transparency	A-D	USA	Yes

REPORTING

The *National Guidelines for whole-building life cycle assessment* (National Research Council Canada 2022) defines and provides expectations for the following levels of embodied carbon calculation reporting:

- Informing design reporting: intended for informing and comparing designs. The SER should choose the depth of reporting to suit the communication needs of the client and project.
- Meeting requirements reporting: intended for submission to an AHJ or certification body, or as a supporting document for a larger scope study or assessment. The SER should use any reporting templates established by the AHJ or certification body.
- Performance declaration reporting: to determine conformance with the applicable guidelines and intended to be utilized in existing or future benchmark databases to collect data, to define current benchmarks, and to identify trends and embodied carbon reduction strategies. The SER should provide maximum detail in these declarations.

Reporting Format

At a minimum, the following information should be included in all levels of reporting described above:

- project location, typology (e.g., residential, commercial), and description (e.g., height above and below grade, materiality)
- purpose of the assessment and all significant assumptions
- modules included and methodology used (e.g., quantity take-offs, name of proprietary tool)
- material embodied carbon factors used (i.e., GWP material rates)
- GWP volumes per element type (e.g., footings, beams, columns)
- GWP per material type
- GWP total mass and total mass per gross floor area (including and excluding parking, if required)
- GWP of sequestered carbon (where applicable, reported separately)
- description of the GWP reduction strategies used and their impact, if applicable

This information can be presented on structural drawings or in a separate report. SERs should consider providing graphical representation of embodied carbon calculation results. Figure 4 shows a sample representation of GWP (embodied carbon) within a structure, grouped by elements as well as materials.

Similarly, when embodied carbon calculations are used to compare different structural schemes, SERs should consider providing a graphical comparison summary to help project stakeholders understand the impacts of the project and design decisions.

Figure 5 shows a comparison between GWP (embodied carbon) in a building with a mass timber gravity system and concrete lateral system and one with a concrete gravity system and concrete lateral system.

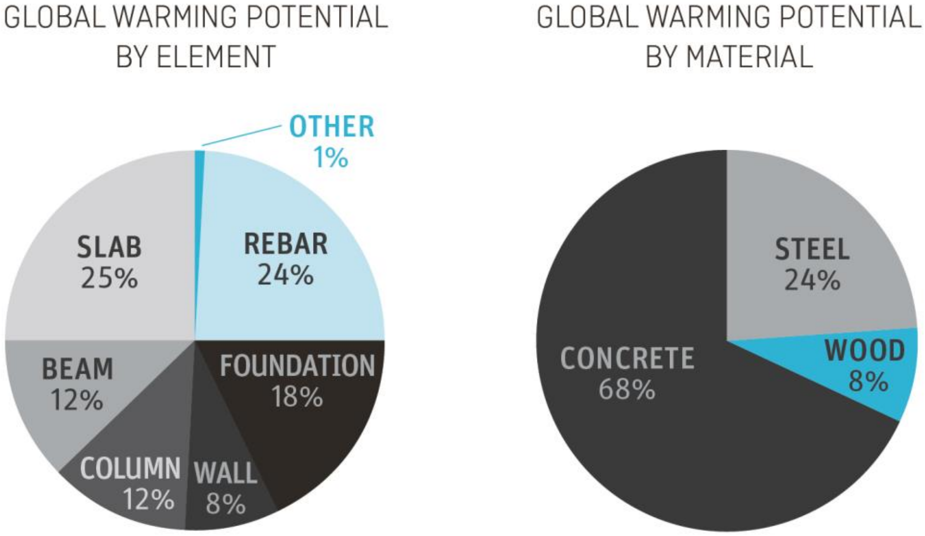
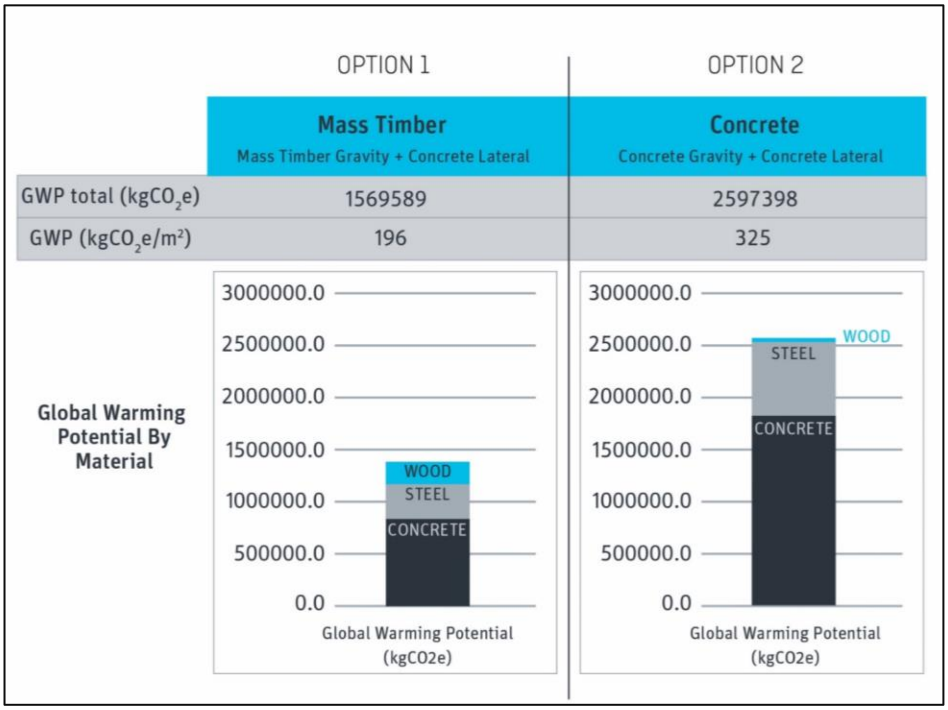


Figure 4: Sample representation of GWP (embodied carbon) within a structure



	OPTION 1	OPTION 2
	Mass Timber Mass Timber Gravity + Concrete Lateral	**Concrete** Concrete Gravity + Concrete Lateral
GWP total ($kgCO_2e$)	1569589	2597398
GWP ($kgCO_2e/m^2$)	196	325

Figure 5: Example structural embodied carbon comparison of mass timber and concrete buildings

PROJECT DELIVERY

SERs should understand that the building code and referenced material standards do not always require, or necessarily foster, the minimization of embodied carbon in building projects. However, where appropriate, they should consider implementing the embodied carbon reduction design principles discussed above and encourage their clients and other consultants to do the same. SERs should also consider conducting embodied carbon calculations on as many of their projects as practicable, even if not mandated by the AHJ or by the client.

The following are the roles and responsibilities of the SER as it relates to embodied carbon in various design stages. These should complement, not replace, the list of roles and responsibilities provided in other applicable professional practice guidelines.

- Pre-Design Stage
  - understand embodied carbon reduction targets
  - understand how and to whom the results will be reported
- Conceptual or Schematic Design Stage
  - consider potential for re-use of building materials
  - provide schematic design options with preliminary embodied carbon calculations for the structural components
  - collaborate with clients, architects, and other consultants
- Design Development Stage
  - complete detailed embodied carbon calculations for the structural components
  - identify assemblies that have the highest contribution to embodied carbon and coordinate opportunities to reduce embodied carbon of the structure
  - consider discussing low-carbon material options with the client, suppliers, and contractor
- Contract Document Stage
  - clearly document all data, assumptions, calculations, and decisions related to embodied carbon
  - request EPDs from material suppliers
  - verify material quantities and GWP assumptions with the contractor and other consultants
  - finalize embodied carbon calculations and develop and authenticate final report on structural embodied carbon
  - consider requesting that the scope of independent review include comments on opportunities for embodied carbon savings
- Construction Stage
  - evaluate and communicate to the client and architect the consequences of material or member substitutions that have significant embodied carbon impacts and revise embodied carbon calculations accordingly

From the outset of a building project, the SER should be clear on embodied carbon targets and should revise their calculations throughout the design process to ensure they are meeting those targets. By beginning embodied carbon calculations early, there is greater opportunity to minimize the amount of embodied carbon in a building project. Figure 6 below depicts the opportunity for change and accuracy of calculations as a project progresses.

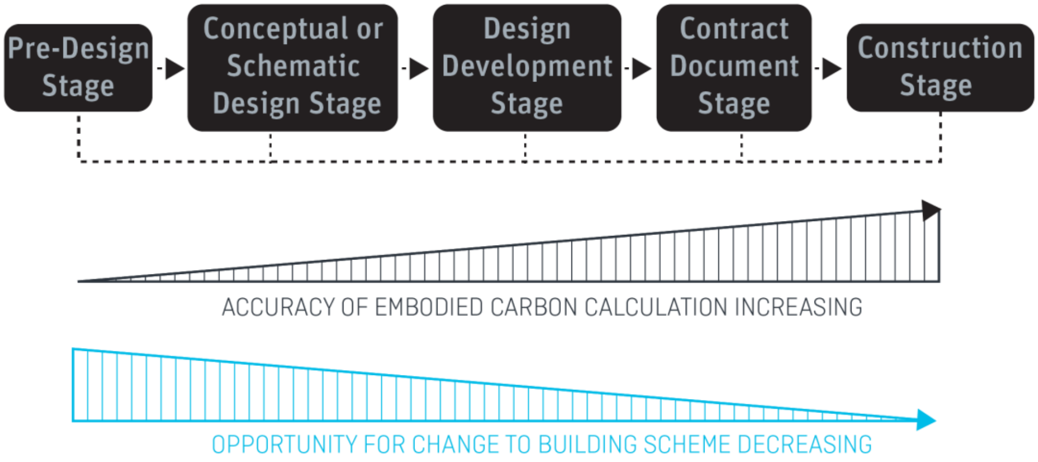


Figure 6: Flow chart depicting opportunity for change and accuracy of calculations as a project progresses

REFERENCES AND RELATED DOCUMENTS

REFERENCES

ACEC British Columbia. 2022. Budget Guidelines for Engineering Services Document 2- Buildings. EGBC. [accessed: 2023 June 6]. Egbc.ca

Akbarnezhad A and Xiao J. 2017. Estimation and Minimization of Embodied Carbon of Buildings: A Review. MDPI. [accessed: 2023 June 6]. Mdpi.com.

Architectural Institute of British Columbia and Engineers and Geoscientists BC. 2021. Encapsulated Mass Timber Construction up to 12 Storeys. EGBC. [accessed: 2023 June 6]. Egbc.ca

Bowick M et al. 2022. National guidelines for whole-building life cycle assessment. National Research Council Canada. [accessed: 2023 June 6]. Nrc-publications.canada.ca.

Canadian Net-Zero Emissions Accountability Act [Statutes of Canada 2021]. Chapter 22.

Engineers and Geoscientists BC. 2022. Structural Engineering Services for Tall Concrete Building Projects. EGBC. [accessed: 2023 June 6]. Egbc.ca

Engineers and Geoscientists BC. 2019. Structural Engineering Services for Part 3 Building Projects. Version 4.0. [accessed June 20, 2023]. https://www.egbc.ca/app/Practice-Resources/Individual-Practice/Guidelines-Advisories.

European Standards. 2012. BS EN 15978:2011 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method. [accessed: 2023 June 6]. https://www.en-standard.eu/bs-en-15978-2011-sustainability-of-construction-works-assessment-of-environmental-performance-of-buildings-calculation-method/.

Gibbons O.P. and Orr J.J. 2022. How to Calculate Embodied Carbon (Second Edition). The Institution of Structural Engineers. [accessed: 2023 June 6]. Istructe.org

Government of Canada. 2022. Standard on Embodied Carbon in Construction. Government of Canada. Canada.ca.

International Organization for Standardization. 2017. ISO 21930:2017 Sustainability in buildings and civil engineering works—Core roles for environmental product declarations of construction products and services. [accessed: 2023 June 6]. https://www.iso.org/standard/61694.html.

National Building Code 2030 [NBC 2030]. Canada.ca

Pak A. 2020. Embodied Carbon the Blindspot of the Buildings Industry. Priopta. [accessed: 2023 June 6]. Priopta.com

Pak A and Teshnizi Z. 2022. BC Embodied Carbon Modelling Study. Priopta. [accessed: 2023 June 6]. Priopta.com

Stok. 2021. Whole Life Carbon: The Path to Desiloed Decarbonization. [accessed: 2023 June 6] stok.com

Teshnizi Z. 2019. Policy Research on Reducing the Embodied Emissions of New Buildings in Vancouver. Zera Solutions. [accessed: 2023 June 6]. Vancouver.ca.

Yang F. 2018. Whole Building Life Cycle Assessment: Reference Building Structure and Strategies. ASCE. [accessed: 2023 June 6]. Ascelibrary.org

Zizzo R et al. 2021. Strategies for low carbon concrete: primer for federal government procurement: low carbon assets through life-cycle assessment (LCA)² initiative. National Research Council Canada. [accessed: 2023 June 6]. Canada.ca.

RELATED DOCUMENTS AND RESOURCES

Arnold et al. 2020. Setting carbon targets: an introduction to the proposed SCORS rating scheme. The Structural Engineer, Volume 98, Issue 10, 2020, Page 5. https://doi.org/10.56330/SQDI8782.

Athena Sustainable Materials Institute. calculatelca.com/software/

Athena Sustainable Materials Institute. Impact Estimator for Buildings. https://calculatelca.com/software/impact-estimator/.

Beacon. An Embodied Carbon feedback tool for Structural Engineers. https://core-studio.gitbook.io/beacon/.

Built Environment Carbon Database. https://www.becd.co.uk/

Building Transparency. EC3. https://www.buildingtransparency.org/.

Building Transparency. TallyCAT beta. https://www.buildingtransparency.org/tally/tallycat/

Building Transparency et al. Tally. https://choosetally.com/

Canada Green Building Council. Zero Carbon Building Standards. https://www.cagbc.org/our-work/certification/zero-carbon-building-standard/

Cement Association of Canada. 2021. Low carbon cement and concrete alternatives. https://cement.ca/expertise_center/cement-and-concrete-materials/low-carbon-cement-concrete-alternatives/

Cerclos. eTool. https://etool.app/.

Chatham House. 2018. Making Concrete Change: Innovation in Low-carbon Cement and Concrete. https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete

City of Vancouver. 2023. Embodied Carbon Strategy, Appendix K of Climate Emergency Action Plan Council Report. https://vancouver.ca/green-vancouver/zero-emissions-buildings.aspx.

Climate Group and Responsible Steel. SteelZero. https://www.theclimategroup.org/steelzero

Concrete BC. Concrete BC Member Industry-Wide EPD for Ready-Mixed Concrete. https://concretebc.ca/wp-content/uploads/2022/10/810.CRMCA_EPD_BC.pdf

Government of Canada. 2022. Forest management certification in Canada. https://natural-resources.canada.ca/our-natural-resources/forests/sustainable-forest-management/forest-management-certification-canada/17474

International Living Future Institute (ILFI). https://living-future.org/.

One Click LCA. One Click LCA Planetary. https://www.oneclicklca.com/planetary/.

Structural Engineering Institute. ECOM- Embodied Carbon Estimator. https://se2050.org/ecom-tool/.

Wood, Elliott. 2022. The Structural Carbon Tool Version 2. The Institution of Structural Engineers. https://www.istructe.org/resources/guidance/the-structural-carbon-tool/.

World Green Building Council. 2020. Advancing Net Zero Status Report 2020. https://worldgbc.org/advancing-net-zero/

ACKNOWLEDGEMENTS

The Structural Engineers Association of BC reviewed these guidelines and provided their endorsement.

VERSION HISTORY

VERSION NUMBER	PUBLISHED DATE	DESCRIPTION OF CHANGES
1.0	September 25, 2023	Initial version.