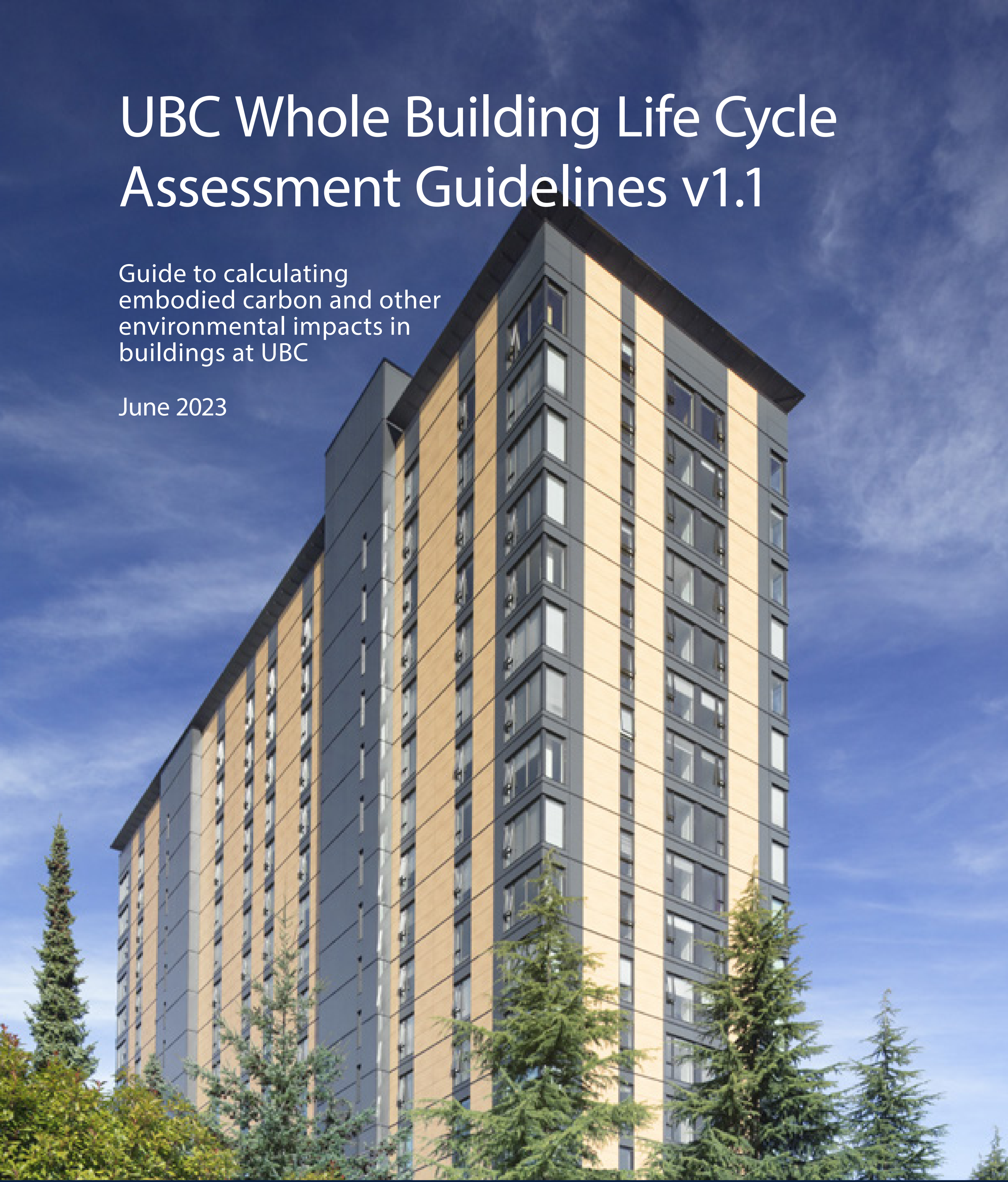
# UBC Whole Building Life Cycle Assessment Guidelines v1.1

Guide to calculating embodied carbon and other environmental impacts in buildings at UBC

June 2023



THE UNIVERSITY OF BRITISH COLUMBIA

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# 01 | EXECUTIVE SUMMARY

UBC's Climate Action Plan 2030 sets targets and actions toward zero operational emissions (scope 1 and 2) across UBC by 2035. The targets also include greenhouse gas emissions reductions for extended impact areas (scope 3), aligned with IPCC targets to keep human caused warming to 1.5°C. Each campus (Vancouver and Okanagan) has a unique emissions profile and tailored action plan to address emission reductions (see figures 1a and b below).

In UBC's Climate Action Plan for both campuses the specific target set for embodied carbon in buildings is "to establish a baseline and align new building and renewal designs with a 50% reduction target." In order to achieve this target incremental reductions in embodied carbon will be introduced over the years.

The purpose of the UBC Whole Buidlng Life Cycle Assessment (WBLCA) Guidelines is to provide guidance and clarity on the methodology and approach to performing WBLCA's for UBC buildings on the Vancouver and Okanagan campuses in order to more accurately calculate building related embodied carbon reductions towards UBC's target and reduce other environmental impacts.

## UBC Vancouver Emissions Profile

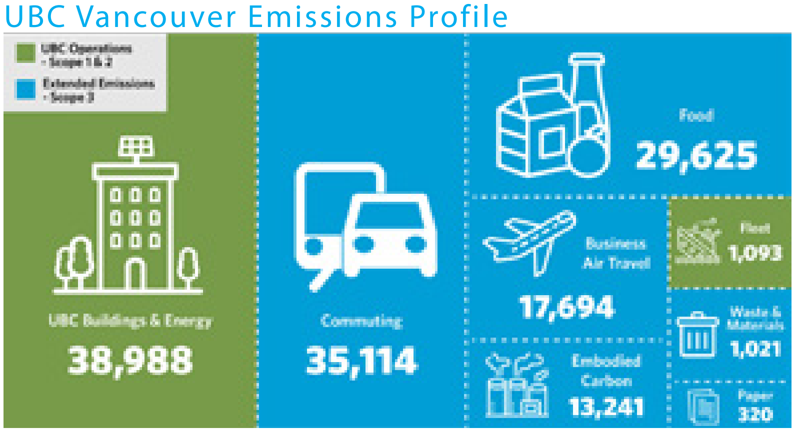


Figure 1a: Illustration from UBC Vancouver Campus emissions profile from the Climate Action Plan 2030 December 2021

## UBC Okanagan Emissions Profile

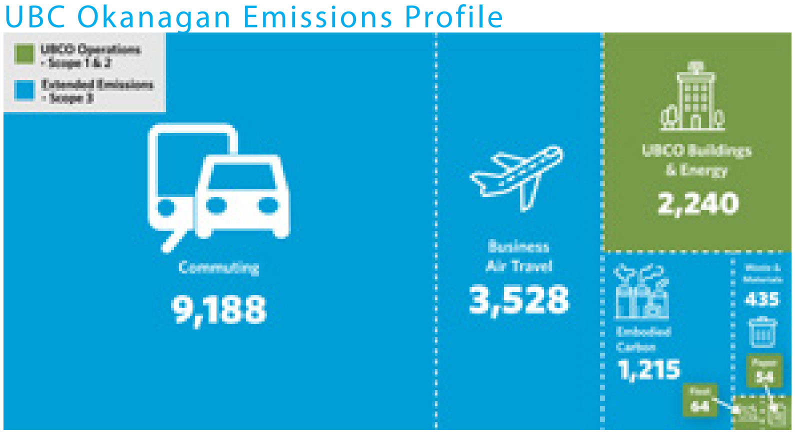


Figure 1b: Illustration from UBC Okanagan Campus emissions profile from the Climate Action Plan 2030 December 2021

# 02 | OVERALL PURPOSE OF THE GUIDELINES

Recognition of the importance of reducing embodied carbon in buildings is growing. At 11% of the world's carbon dioxide emissions, the impact of embodied carbon from buildings and infrastructure on the environment and the climate is significant[1]. In Canadian buildings designed for low operational carbon, embodied carbon can represent over 90% of total emissions over its service life[2]. As the operational emissions decrease due to increasing energy efficiency of buildings and use of low carbon systems, the embodied emissions become a larger portion of the total carbon and environmental footprint of the building sector. Transitioning to truly net zero buildings, therefore, requires increased attention to the reduction of the embodied environmental impacts of buildings.

Embodied carbon has an added urgency since emissions occur mostly at the up front phase of a building's life cycle and contribute to climate change immediately (see Fig. 1). Over a building's life cycle, multiple stages contribute to the environmental impact including: raw materials extraction, product manufacturing, transportation to plants and building sites, construction installation, maintenance and replacement, and end of life deconstruction or disposal. While operational carbon can be improved after construction through retrofits and demand-site management measures or fuel switching, little can be done to reduce embodied carbon once the building is constructed.

## Embodied carbon is urgent

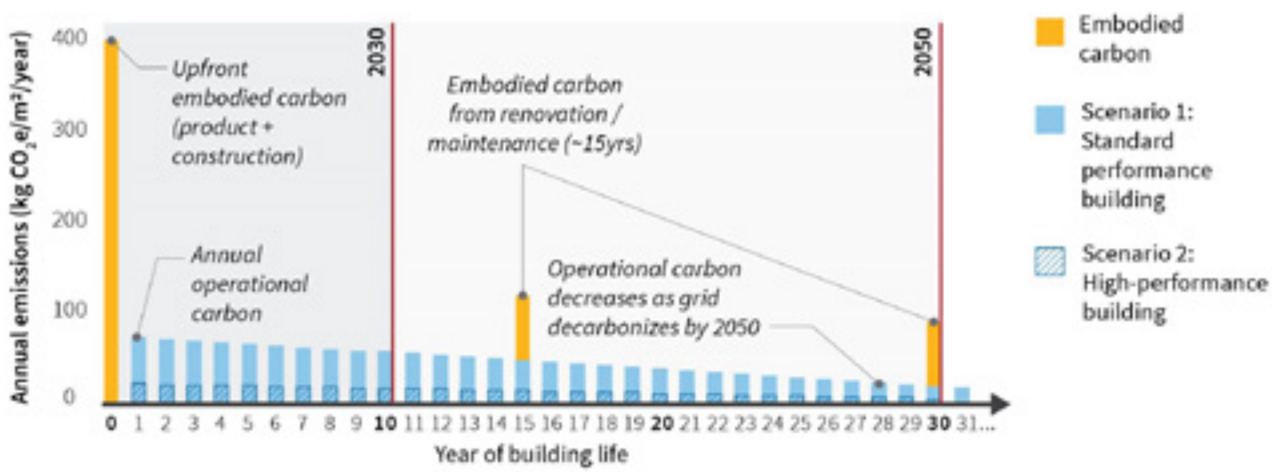


Figure 2: Graph from Carbon Leadership Forum - Embodied Carbon 101

[1] AIA website: https://architecture2030.org/2030_challenges/embodied/

[2] https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/ accessed 13th August 2021

Evaluation of embodied carbon at a building level is achieved by conducting a Whole Building Life Cycle Assessment (WBLCA). WBLCA is an accepted, scientifically based method used to calculate a building's environmental impacts – including embodied carbon – over its entire lifetime.

The methodology and the quality of the data gathered through WBLCA's are in development nationally and internationally, however the importance of assessing embodied carbon is leading to rapid change and continual improvement. This document is intended to provide greater consistency and clarity in the approach and methodology for calculating embodied carbon. This methodology will enable us to assess the impact of design approach in achieving UBC embodied carbon reduction targets.

> Design professionals should use these Guidelines to inform methodology and approach in performing WBLCA's for UBC buildings in order to more accurately calculate embodied carbon reductions and reduce other environmental impacts. The intent is to identify requirements for WBLCA scope, methodology, baseline, process, submittals and reporting. Reduction in embodied carbon is calculated by taking the percentage reduction of the proposed building over a

## UBC'S GOALS WITH RESPECT TO WBLCA'S ARE AS

1. Provide the university with analysis which can help inform design decisions and reduce the embodied carbon impact of the building without unduly increasing other environmental impacts.

2. Achieve incremental reductions in building embodied carbon to achieve CAP2030 targets at both campuses.

3. Provide data for future use to help benchmark embodied carbon in buildings on the campus and in the neighbourhoods and support continuous improvement of policy.

4. Demonstrate compliance to UBC's policy and LEED or REAP credit requirements (REAP only applies at the Vancouver campus).

# 03 | STRATEGIC DESIGN GUIDANCE

## POLICY PATHWAY

For individual materials and systems, guidance will be provided in the UBC Technical Guidelines for institutional projects and in REAP (Residential Environmental Assessment Program) for neighbourhood buildings on the Vancouver campus. These policies will encourage design teams to focus on efficient designs through the selection of low carbon structural systems and building materials. Consultants are further encouraged to develop adaptive and flexible designs which can be dissembled at the end of life and are both durable and easy to maintain.

## OVERALL STRATEGIES

The following strategies are of key importance for reducing emobdied carbon on campus[3.]

| | |
|---|---|
| Prevent | • Address embodied carbon emissions and reduction strategies from the outset, whether for a whole project or for a single product. Consider alternative strategies for delivering the desired function, such as increasing utilisation of existing assets through renovation or reuse or eliminating entirely. |
| Reduce and Optimise | • Apply design approaches that minimise the quantity of new material required to deliver the desired function, including reusing building elements or materials.<br>• Prioritise materials which are low or zero carbon, responsibly sourced, and which have low lifecycle impact in other areas, including the health of the occupant, as determined through a product specific environmental product declaration where available<br>• Choose low or zero carbon construction techniques having maximum efficiency and minimum waste on site. |
| Plan for the future | • Consider future use scenarios and end of life, maximising the potential for maintenance, repair and renovation, and ensure flexibility for future adaptation.<br>• Choose durable products that last for the service life and beyond. Design for disassembly and deconstruction to facilitate future reuse, selecting materials which can be recycled and which can be extracted and separated easily for processing. |

[3]Adapted from: "Bringing embodied carbon upfront", World Green 'Building Council [2019]

## FOCUS ON KEY BUILDING ELEMENTS

Most of a building's embodied carbon is attributable to structure, building envelope, MEP (mechanical, electrical and plumbing), and interiors, focusing on these elements can bring the best reductions. Structure and envelope are required elements in UBC's WBLCA's. MEP and interiors are an optional elements and although significant are not required to be included because the methodologies and data for these products are not well established.

## COST EFFECTIVE STRATEGIES[4]

The most impactful and cost-effective measures for reducing embodied carbon in buidings are:

- Optimizing ready-mix concrete design: design lower carbon concrete mixes by replacing the cement and use lower-strength concrete where appropriate and schedule allows
- Choosing finish materials with low-embodied-carbon footprints and eliminate unnecessary materials entirely.
- Consider incorporating low-embodied-carbon or carbon-sequestering insulation options
- Salvage and reuse existing materials wherever possible.

Other considerations are:

- Sourcing lower carbon rebar and structural steel
- Choosing low-embodied-carbon glazing products
- Reducing high embodied carbon content when designing structural systems. For example, using hybrid steel and mass timber vs. all steel.

[4]Reducing Embodied Carbon in Buildings RMI Report July 2021

## SUMMARY OF BUILDING DESIGN STRATEGIES TO REDUCE EMBODIED CARBON

Consideration should be given to the following strategies that can contribute to significant reductions in embodied carbon in buildings:

1. Refurbish /renovate existing building rather than build new
2. Choose lower carbon structural system (for example: sustainably harvested wood structure)
3. Reduce resource use through design (for example: lightweight construction, simplified building form and layout, design for flexibility and adaptability, use materials that require lower maintenance, design for a longer service life)
4. Reuse materials, use recycled materials
5. Select materials with lower manufacturing emissions and substitute products with a lower carbon alternative (for example cellulose insulation instead of high density mineral wool)
6. Choose carbon sequestering materials that support carbonation (note: currently biogenic carbon and carbonation are not to be included in the percent reduction calculation)
7. Reduce construction installation impacts by using lower carbon operations
8. Reduce end-of life impacts by designing for disassembly and recyclability

Some of the major decisions which effect embodied carbon in buildings happen in early design phase (1,2 and 8 above) so reduction strategies should be considered at the project outset. During schematic design, decisions that are made can reduce impact (.3, .4 and .7 above). As the design becomes fully developed carbon reduction can be limited by specification of products (5-6 above).

# 04 | WHOLE BUILDING LIFE CYCLE ASSESSMENTS (WBCLA) PROCESS AND METHODOLOGY AT UBC

## 4.1 | SUBMITTAL REQUIREMENTS

For major projects and renewals, UBC Vancouver requires a WBLCA to be conducted during design development and submitted with the Building Permit submission to Campus and Community Planning - Sustainability and Engineering Department.

While at UBC Okanagan, since City of Kelowna issues the Building Permit, WBLCA should be submitted at CP Review #3 90% Construction Documentation which immediately precedes Building Permit application to the City.

Embodied carbon updates and discussion should be on the agenda for Sustainability Workshops 1,2 and 3. Ensure that consideration of WBLCA is put on the agenda for workshop 1 when structural systems could be explored.

## 4.2 | PROJECTS REQUIRED TO PERFORM WBLCA

The following projects are required to perform WBLCA and achieve reduction in embodied carbon:

### INSTITUTIONAL BUILDINGS (VANCOUVER AND OKANAGAN)

- Tier 1 and Tier 3a projects > 1,000 $m^2$: core and ancillary projects, student residences
- In some cases C+CP will confirm a specific embodied carbon target or pilot target in the project design brief with consideration given to the project context.

### NEIGHBOURHOOD BUILDINGS (VANCOUVER ONLY)

- Tier 1A: New multi-unit residential buildings or mixed-use/residential projects >1000$m^2$.
- Tier 1B: Institutional buildings >1000$m^2$.

Note: Potential future UBCO neighbourhood projects are expected to reference UBC Vancouver's requirement as a guideline.

## 4.3 | LEED PROJECTS

LEED gold projects at UBC Vancouver and Okanagan Campuses are required to achieve three points out of five for the Building Life-Cycle Impact Reduction credit and use UBC's WBLCA Guidelines. Further guidance is provided in UBC's LEED Implementation Guide.

## 4.4 | REAP PROJECTS (VANCOUVER CAMPUS ONLY)

New buildings are required to be REAP gold certified in UBC Vancouver's neighbourhoods. Currently REAP requires a project to report embodied carbon as a precondition using UBC's WBLCA Guidelines. Incentive credits are offered for reductions in embodied carbon.

## 4.5 | BASELINE CASE

### The baseline used for WBLCA studies is required to be the same scope, size, geometry, function and energy performance as the proposed project. The baseline building represents typical construction for the building type on each campus.

Figure 5. gives examples of allowable approaches to help in the development of the baseline case. Materials assembly assumptions to be used for the baseline case are shown in figure 6. The baseline assumptions are provided as initial guidance to be used as a starting point for LCA practitioners, exceptions are permitted with justification. It is recommnded that the baseline is created from the proposed model and must have functional equivalence (geometry, thermal, structural etc.). If there are deviations, especially when comparing different structural systems, guidance should be provided by the structural consultant (e.g. what would typical floor slab thicknesses be for a concrete version of this mass timber building, or what is the change in foundation concrete volume for concrete baseline vs mass timber version, given soil conditions for this project).

| YOU ARE ALLOWED TO: | YOU ARE NOT ALLOWED TO: |
|---|---|
| Use materials and construction practices typical to the building archetype. | Use materials and construction practice that are not typical of the particular archetype e.g. concrete roof structure for gymnasium. |
| Optimize and reduce the mass of of the proposed design compared to the baseline while maintaining functional equivalency with baseline. | Unnecessarily increase baseline building mass using thicker walls or insulation or unusually large spans to show dematerialization. |
| Make better use of design and structural alternatives in the proposed design including stud spacing, floor-to-ceiling heights, changes in the use of beams and pillars. | Use a different GFA for the baseline building and proposed design. |
| Make use of lower carbon materials and/or products with known environmental impacts in the proposed building. | Omit required parts of the envelope and structure in the proposed design : footings and foundations, structural wall assembly (from cladding to interior finishes), structural floors and ceilings and roof assemblies. |
| Include construction elements that are listed as optional, such as MEP (see 4.7) | Include elements that are not part of construction element requirements indicated in the baseline but exclude it from the proposed design. |
| Use industry average values for materials. | Use a product-specific EPD with high embodied carbon values which are banned in Canada for the baseline and replace it with industry average values. |
| Include green roofs in both baseline and proposed design. | Change the effective R or U value of the building envelope elements. |
| Use the same strength concrete in baseline and proposed design. | |

Figure 5: Table showing baseline approaches that are allowed vs not allowed

| BUILDING TYPE | ABOVE GRADE STRUCTURE | ROOF | GLAZING | EXTERIOR WALL ASSEMBLY | INTERIOR PARTITIONS |
|---|---|---|---|---|---|
| Office/ classroom | Reinforced concrete | SBS/ polyiso insulation | Aluminum Windows/ Curtain wall | Steel stud with mineral wool insulation | Steel stud with drywall and acoustic insulation |
| Laboratory/ Science Building | Reinforced concrete | SBS/ polyiso insulation | Aluminum Windows/ Curtain wall | Steel stud with mineral wool insulation | Steel stud with drywall and acoustic insulation |
| Recreational Building | Reinforced concrete/steel roof | SBS/ polyiso insulation | Aluminum Windows/ Curtain Wall | Steel stud with mineral wool insulation | Steel stud with drywall and acoustic insulation |
| High-Rise Residence/ Residential | Reinforced concrete | SBS/ polyiso insulation | Aluminum Windows/ Curtain Wall | Steel stud with mineral wool insulation | Steel stud with drywall and acoustic insulation |
| Low rise/ Residential (Upto 6 storeys) | Light Wood Frame | SBS/ polyiso insulation | Vinyl Window Frame/ Aluminum Curtain Wall entrance | Wood stud with mineral wool insulation | Wood stud with drywall and acoustic insulation |

Figure 6 : Building design assembly baseline assumptionsf or each builing archetype

The baseline assumptions for materials are shown in figure 7.

| MATERIAL | ASSUMPTIONS AND GUIDANCE |
|---|---|
| Concrete | UBC Vancouver: All concrete in the baseline for UBC Vancouver Campus shall assume baseline mix with 20 SCM as specified in the New BC Provincial 2022 Industry Average Baseline.<br>UBC Okanagan: All concrete in the baseline for UBC Okanagan Campus shall assume baseline mix as concrete without any SCM material specified in the New BC Provincial 2022 Industry Average Baseline.<br>For both the campuses, all baselines should be of equivalent strength to the building design, unless lower strengths are enabled by structural design efficiencies. |
| Insulation | All insulation in the baseline shall have equivalent R-value if comparing different types of insulation, accounting for differences in R-value per inch of different insulation (Board, Blanket, Foamed in-place and Blown type) and associated changes in thicknesses. |
| Glazing | All glazing assemblies (curtain wall & windows) shall be in the same location and have the same number of panes of glazing as the building design. The window to wall ratio of |
| Steel Reinforcement (Rebar) | The baseline shall reference the rebar EPD published by Concrete Reinforcing Steel Institute (CRSI), however the building design may reference product specific EPDs. If purposeful design decisions are made to reduce rebar quantities in concrete elements on a project, those needs be reflected in the embodied carbon calculations and reporting of the building design consistently and accurately. |
| Steel | The baseline shall reference AISC EPD, however the building design may reference product specific EPDs. |
| Aluminium | Baselines for aluminum products shall refer to the relevant industry-wide EPD. Where available, give preference to Canadian industry-wide EPDs (e.g. AluQuebec) over US industry-wide EPDs. |
| Wood | Baselines shall reference relevant industry-wide EPDs from the Canadian Wood Council (CWC) or other relevant organizations. |
| Other materials | Please refer to CLF Material Baseline Report 2023 (https://carbonleadershipforum.org/clf-material-baselines-2023/) for information on embodied carbon ($kgCO2^e$) for other materials. |

Figure 7 : Showing material baseline assumptions

## 4.6 | DATA SOURCE REQUIREMENTS- INPUT (ASSESMENT INPUTS)

Use the following project data souces:

1. Building permit project drawings (if design teams use Revit models, cross-reference with design drawings and include any materials that may not be included in the BIM model e.g. rebar).

AND/OR

2. BIM Model – with Level of Development (LOD) 200 or higher https://bim-international.com/wp-content/uploads/2016/03/LOD-Specification-2015.pdf)[5].

## 4.7 | CONSTRUCTION ELEMENTS TO BE INCLUDED IN LIFE CYCLE ASSESSMENT (WBLCA) SCOPE

The structure and envelope are required to be included in the building's WBLCA scope since they represent the majority of a building's embodied carbon that can be easily determined. While MEP (mechanical, electrical and plumbing elements) and finishes may also be significant contributors there is currently not enough accurate data to include this as elements in the assessment.

The inclusions/ exclusions in the scope are as follows:

- Included: sub-structure (foundations), superstructure, enclosed parking, envelope, windows, exterior doors, interior finishes like partition walls, doors, windows, gypsum board for wall and ceilings and flooring
- Optional: landscape, excavation, temporary elements (e.g., formwork), finishes (e.g., tile, carpet, paint, etc.), electrical and mechanical services/equipment (e.g., elevators, lighting, ducting), stairs and handrails, door/window hardware, millwork, furnishings.

Some elements may be difficult to quantify based on unique or complex geometry or lack of available information (e.g., structural steel connections for columns). In these cases, inclusion or exclusion relies on the practitioner's discretion. Assumptions and significant exclusions should be consistent in the baseline and proposed designs, recorded and shared as part of the submission.

The level of detail (assembly detail) provided should include all major layers or components of an assembly. Finishes (eg paint) and smaller supplementary components (eg nails, screws and glue etc) are optional. For example, an exterior wall should include major elements like cladding, strapping, moisture/vapour/air barriers, insulation, wood framing, and gypsum wall board. Further calculations may need to be performed to account for top and bottom plates and blocking in the wood frame walls. Unique or one-off elements (e.g., flashing, ledges) should be included when possible, especially when composed of higher-impact materials like metal or concrete; ultimately, this determination is left to the practitioner's discretion but should be consistent in the baseline and proposed designs.

LEED : The construction elements to be included are consistent with LEED credit requirements but are more detailed in some cases. Some assemblies are optional in LEED but required by UBC (for example, interior non-structural partition walls)[6].

[5]Teams should ensure their model is developed to the appropriate level of detail LOD to ensure the best input (https://bim-international.com/wp-content/uploads/2016/03/LOD-Specification-2015.pdf).
[6]Inclusion of interior partitions capture a better picture of the building's major assemblies and reduce inconsistencies or misinterpretations of which walls to include.

## 4.8 | REFERENCE STUDY PERIOD (BUILDING SERVICE LIFE USED IN ASSESSMENT)

Use a 60 year building life. Note that: 60 years is consistent with LEED and REAP credit requirements.

## 4.9 | MULTIPLE BUILDINGS WBLCA GUIDANCE

Multiple buildings may be combined in one calculation of embodied carbon and other environemtnat categories if they have the same general designs and structural systems. If any of the buildings are likely to have significantly different embodied carbon intensities (e.g. greater than 10%), the calculation should be reported separately. For example, two low rise buildings of different heights that share a common parkade, could be included together because they use the same wood frame design and the same cladding system.

Where multiple buildings sharing a common parkade are to be separated into multiple LCA's, the parkade structure may be divided and allocated to each building according to the number of parking spots assigned to each building.

## 4.10 | RETROFIT AND RENEWAL PROJECTS WBLCA GUIDANCE

For retrofit and renewal projects above 1000 $m^2$, build a WBLCA model for all the new materials and compare against completely new building as per the baseline archetype to ensure consistency, fairness and accuracy in the results.

## 4.11 | ASSESEMENT TOOL REQUIREMENTS

- Whole Building Life-Cycle Assessment tools should be able to at least calculate all life-cycle stages (product, construction, use and end of life) and cover modules A-C.
- In addition to the primary WBLCA tool, alternative tools or calculators can be used at certain stages for specific line items to obtain a more accurate result.

## 4.12 | METHODOLOGY REQUIREMENTS

### Input Method

Use the Bill of materials input method or BIM-integrated input method.

It may be necessary to combine methods, for example, if the BIM model is missing a key element, it may need to be supplemented via quantity take-offs or modelled for the purpose of the LCA.

Athena's 'assembly' input method (where the practitioner enters specific geometry for all assemblies to generate an approximate representation of the building) should only be used when other methodologies are not appropriate.

### Data sets (internal to tool)

Data sets must be compliant with ISO 14040, ISO 14044, ISO 21930, and EN 15804.

### Material replacement cycles (service life)

Best efforts should be made to align replacement cycles with UBC Technical Guidelines and make reasonable assumptions about replacements in an institutional setting. Replacements are not usually made until absolutely necessary at the university due to budget restraints. Some tools do not provide the option for the practitioner to specify material's lifespans; for example, in Athena Impact Estimator, this information is determined by the tool and replacement cycles are not readily disclosed to the practitioner. Other tools (e.g., Tally and One Click LCA) allow the user to select the materials' lifespans, and also offer a 'default' option based on material type. In case of lack of data availability with regards to the construction materials in LCA tool, an alternative material which is nearest to the actual material can be substituted.

## 4.13 | OUTPUTS/ RESULTS

System boundary (life cycle modules) required in WBLCA:

- System boundary: cradle to grave + Module D

- Modules: A1, A2, A3, A4, A5*, B1*, B2, B3*, B4, B5*, C1*, C2, C3, C4, D (reported separately)

  * = recommended but not required (availability depends on tool used for assessment)

- B6 and B7 should be excluded from the system boundary because they estimate operational impacts which are covered by building energy modelling.

- Module D should be reported separately (either as a GWP total or a more comprehensive breakdown) to give a picture of the estimated benefits/loads beyond the building life. Module D benefits/loads should not be included in the reporting of main results, and should not be added to the building's total GWP (kg CO2e/m2).

- Variation in tool modules is illustrated in the table below. The majority of impacts occur during the Product stage (A1-A3), meaning that inclusion/exclusion of other stages due to tool boundaries is less significant.

| Stage | Module | Athena IE4B | Tally | One Click LCA |
|---|---|---|---|---|
| Product | **A1 Raw material supply** | | | |
| | **A2 Transport** | | | |
| | **A3 Manufacturing** | | | |
| Transportation / Construction | **A4 Transport to building site** | | | |
| | A5 Construction-installation process | | | * |
| Use | B1 Use | | | |
| | **B2 Maintenance** | | | |
| | B3 Repair | | | |
| | **B4 Replacement** | | | |
| | B5 Refurbishment | | | |
| | B6 Operational energy use | - | - | - |
| | B7 Operational water use | - | - | - |
| End of Life | C1 De-construction demolition | | | |
| | **C2 Transport** | | | |
| | **C3 Waste processing** | | | |
| | **C4 Disposal** | | | |
| Beyond the System Boundary | D Reuse, recovery, and recycling potential | | | * |

Figure 8: Variation in Whole Building LCA tools module coverage

## Gross Floor Area calculation

Use the CIQS method for calculating gross floor area (GFA) as recommended by the Athena Sustainable Materials Institute:

- Method: Measure the outside face of enclosing walls for the area on each floor. When enclosing walls are broken up with a large number of small projections (e.g. columns), the measurements should be taken to the mean face of the enclosing walls.
- Areas included must be fully enclosed.
- No deductions to the area shall be made for walls, partitions, columns, beams, pilasters, shafts, openings in floors for stairwells, escalators, elevators, ducts, pits, trenches, or any other features within the confines of the perimeter walls.
- For open spaces that extend through two or more floors, include the largest area at one level only.
- Notable inclusions : mechanical and electrical rooms, service corridors, basement areas 2m or greater in height, duct shafts/etc. projecting beyond the general face of enclosing walls providing they extend the full floor height, dormers/bay windows providing they extend the full floor height, penthouses, elevator machine floors within penthouses, enclosed connecting links or walkways, enclosed staircases and fire escapes, balconies and mezzanines that are within the enclosing walls of the structure.
- Notable exclusions: enclosed underground or at-grade parking spaces[11] , exterior balconies, canopies and roof overhangs, unenclosed exterior staircases and fire escapes, interior open courtyards/lightwells, exterior steps/landings, exterior surfaces, projections beyond the face of enclosing walls that don't extend the full floor height.
- Include the area of enclosed underground parking separately.

### Environmental Impact Categories and Units

At a minimum include the following categories and use the unit listed:

- Global Warming Potential: kg $CO_2$ eq/$m^2$
- Ozone Depletion Potential: kg CFC-11 eq/$m^2$
- Acidification Potential: kg $SO_2$ eq/$m^2$
- Eutrophication Potential: kg N eq/$m^2$
- Smog Potential: kg $O_3$ eq/$m^2$
- Depletion of Fossil Fuels/Non-Renewable Energy Resources: MJ/$m^2$

Global Warming Potential (kg $CO_2$ eq) is the most important impact category for the assessment since it is directly connected to embodied carbon, but report on the liseted impact categories is required.

## 05 | SUBMISSION REQUIREMENTS

Vancouver campus instructions:

Submit to the Green Building Manager UBC Sustainability & Engineering (S&E Vancouver) at time of Building Permit submission

Okanagan Campus instructions:

Submit to Associate Director, Sustainability Operations, Campus Planning (Okanagan) at 90% Construction Documentation submission to City of Kelowna

Submit the following:

1. UBC Whole Building Embodied Carbon and Environmental Impact Report including:
    1. Environmental impact results, emobodied carbon % reduction over baseline , interpretations and recommendations.
    2. Project data source noted (BIM model or project drawings) used to generate quantities for LCA
    3. Bill of materials (input list). This refers to an organized list of material quantities compiled prior to input into the tool and does not include quantities from construction waste factors and/or material replacements generally added by the tool. If material proxies or substitutions are used, note the original material type.
    4. Bill of materials (output list). This refers to the summary list of material quantities compiled by the tool and includes quantities from construction waste factors and/or material replacements added by the tool.
    5. Provide bill of materials input and output list for baseline and proposed design.
    6. Record of assumptions. This should include notable exclusions, approximations, and material substitutions.
    7. Module D should be reported separately from GWP total. Separate biogenic carbon from other module D items.

8. Suggested results breakdown: by building assembly (eg exterior walls), material type, life cycle stage, etc.

2. LCA file (if possible, given the tool)

3. Any other LEED documentation (e.g. write-up detailing impact reduction strategies)

## 06 | GLOSSARY

Bill of Materials: A summary of the estimated quantity of materials required to construct the building, not including waste material which are a by-product of construction.

Carbon Dioxide (CO2): A naturally occurring gas that is also a by-product of the combustion of fossil fuels and biomass, land-use changes, and other industrial processes. It is the principal anthropogenic greenhouse gas. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential (GWP) of 1.

Climate Action Plan (CAP): A framework that provides a pathway to net zero emissions for the Vancouver and Okanagan campuses. This was first initiated in 2010, and has been subsequently updated in 2020 (CAP 2030).

Embodied Carbon Emissions: The GHG emissions, measured in equivalence to CO2, associated with building materials and products (as opposed to emissions from operations).

Environmental Impact Category: Environmental impact issue being examined, eg. Global Warming.

Environmental Product Declaration: A third-party verified report providing environmental data (impacts) using predetermined parameters and, where relevant, additional environmental information for the product being studied.

Extended Impact Emissions: Emissions occurring from activities that are not always fully controlled by UBC, but that the institution impacts and influences through purchasing decisions, plans, policies, guidelines, behavioral change programs, and others. These emissions are generally referred to as scope 3 emissions and include sources such as commuting to and from campus, business air travel, food consumed on campus, waste, and the embodied carbon associated with the construction of new buildings and retrofits.

Global Warming Potential (GWP): GWPs are particularly important within the context of emissions reporting since international protocols require the reporting of both individual GHG's and their carbon dioxide equivalents (CO2e). For this reason, the calculation of GHG emissions generally involves multiplying the emission factor for a GHG by an appropriate measure of consumption (activity) to produce the corresponding emissions for that GHG and then multiplying those emissions by its GWP to produce the corresponding CO2e emissions.

Greenhouse Gas (GHG) Emissions: Gases emitted from fuel combustion and other sources, that contribute to the greenhouse effect and global warming including: carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbons.

Life Cycle: Consecutive and interlinked stages of a product from raw material acquisition or generation of natural resources to the final disposal.

Object of Assessment: Defines which materials and components are included in the scope of the LCA.

Operational Emissions: Emissions generated through campus operations are defined as emissions from sources directly controlled and operated by UBC, including combustion of natural gas on campus (scope 1), and from upstream emissions from electricity consumed on campus (scope 2).

System Boundary: Describes what is being assessed within the life cycle of the system studied.

Tonnes of Carbon Dioxide Equivalent (tCO2e): The universal unit of measurement to indicate the global warming potential (GWP) of each of the six greenhouse gases, expressed in terms of the GWP of one unit of carbon dioxide. Expressing all GHGs in terms of tonnes of CO2e allows the different gases to be aggregated. The GWP of CO2 equals one. Methane or CH4 has a GWP of 25, indicating that its radiative forcing is 25 times that of CO2. In other words, releasing one tonne of CH4 will have the same warming impact as releasing 25 tonnes of CO2. This impact is often expressed using the concept of carbon dioxide equivalent, or CO2e: that is, one tonne of CH4 can also be expressed as 25 tonnes of CO2e.

Whole Building Life Cycle Assessment (WBLCA): Compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product throughout its life cycle.

# 07 | ACKNOWLEDGEMENTS

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[7] https://sustain.ubc.ca/sites/default/files/ECP%20Final%20Report-Phase%201%20June%202021.pdf

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