# REGULATING EMBODIED EMISSIONS OF BUILDINGS

## Insights for Ontario's Municipal Governments

**POLICY PRIMER** / AUGUST 2022


**PROJECT TEAM**

TORONTO

MANTLE DEVELOPMENTS

UNIVERSITY OF TORONTO

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TAF

# BACKGROUND

This primer has been created for policymakers and other decision makers - including owners, designers, engineers, procurement officers, and other stakeholders who decide what we build as a society. The primer includes background information on embodied emissions (also called embodied carbon), benchmarks from 41 large buildings across Ontario, proposed reduction targets, and policy recommendations with sample language and reporting templates. It also notes several knowledge gaps and barriers the industry will need to overcome to effectively reduce embodied emissions in the years ahead - reductions needed to meet our climate targets. The topics covered can generally be applied to most buildings and/or infrastructure projects, however our specific focus here is related to large-scale "Part-3" buildings in Ontario.

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Thank you to all involved for supporting this important work!

**AUTHORS**

1 Ryan Zizzo, CEO & Founder, Mantle Developments

2 Kelly Alvarez Doran, Director of the Ha/f Research Studio at the University of Toronto

**PROJECT MANAGER**

Lisa King, Senior Policy Planner, City Planning Division, City of Toronto

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**PROJECT ADVISORY COMMITTEE MEMBERS**

| ORGANIZATION | NAME | POSITION |
|---|---|---|
| B+H Architects | Lisa Bate | Global Sustainability Lead + Advance Strategy |
| BDP Quadrangle | Michelle Xuereb | Director of Innovation |
| Blackwell | Christian Bellini | Principal |
| Canada Green Building Council | Fin MacDonald | Zero Carbon Manager |
| City of Vancouver | Patrick Enright | Senior Green Building Engineer |
| Clean Air Partnership | Gaby Kalapos | Executive Director |
| Concrete Ontario | Bart Kanters | Vice President |
| Deltrea / Tridel | Graeme Armster | Director Innovation and Sustainability |
| EllisDon | Christian Cianfrone | V.P. Sustainable Building Solutions |
| Endeavour Centre // Part 9 study | Chris Magwood | Director |
| Entuitive | Emily King | Sustainable Performance Lead |
| National Research Council | Matt Bowick | Research Officer, Life Cycle Assessment |
| TAS | Liza Stiff | VP Innovation and Design |
| University of Toronto - Mass Timber Institute | Anne Koven | Director |
| Waterfront Toronto | Aaron Barter | Director, Innovation and sustainability |

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# EXECUTIVE SUMMARY

1. **Embodied emissions (also called embodied carbon) are a significant and growing source of greenhouse gas emissions in Ontario.** These emissions are currently estimated at more than 5 Mt $CO_2$e annually.

2. **Embodied emissions are largely unregulated in Ontario.** However, there is strong precedent emerging from leading regions that can serve as a model for policy makers wishing to set thoughtful limits and a reduction pathway. Leading regions including Toronto, Vancouver, Edmonton, and the federal government have begun rolling out embodied emissions requirements on some new construction.

3. **The vast majority of embodied emissions from new construction typically comes from the procurement of a handful of key materials.** These typically are concrete, steel, insulation, and timber.

4. **There are many 'low-hanging fruit' solutions that can be implemented to significantly reduce embodied emissions, with limited to no impacts on costs and schedule.** Ontario firms are showing that ~30% reduction is possible when low carbon material is prioritized, without impacting project cost or schedule.

5 **Future policy should outline a consistent methodology** for calculating and reporting life cycle assessment (LCA) to develop high-quality data for comparison benchmarking, and to foster collaborative, innovative approaches for determining reduction strategies.

6 **Canadian whole building embodied emissions benchmarking has been done** in Ontario and Vancouver. The data can help inform the creation of thoughtful limits which could be part of future regulation and shows the difference between stronger and weaker performance.

7 **Start with requiring calculation and disclosure / reporting,** possibly beginning with the largest, most complex projects. This could be required as part of the approvals process, with rezoning applications or at building permit stage, for example. Starting with municipality-owned buildings is a common approach.

8 **Next, set limits/caps and a reduction pathway for future years.** Various approaches to reductions are being used globally. One approach is to require a percentage reduction against a "baseline building" of "standard construction". Another approach is to set specific intensity limits (i.e. kg $CO_2e/m^2$ must be below a certain limit value or cap).

9 **Benchmarking has shown that embodied emissions typically vary by building type, so different limits per building category may be appropriate.** That said, caps at or around 500 kg $CO_2e/m^2$ seem to be appropriate for large buildings, with smaller buildings (typically using stick frame wood construction) having lower caps closer to 200 kg $CO_2e/m^2$. These caps should be reduced over time, with future reduction values and timelines set well in advance so the industry can plan for the reductions.

10 **Over time, better data and tools will become available.** Assessments will shift from generic industry-average environmental product declaration (EPD) data towards material manufacture facility-specific EPDs.

11 **Material quantities are required for this type of assessment and can most easily be taken from cost estimates and/or BIM models.** Architects, structural engineers, cladding designers, and contractors can also be asked to provide material quantities. Early-stage embodied emissions estimates can rely on average industry data and proxies. Late design-stage and tender documentation should include more accurate quantities for the project and manufacture-specific EPDs where available.

12 **Embodied emissions assessments can be done throughout design**, at schematic ("Class D"), early design ("Class C"), late design / tender ("Class B"), and even as built ("Class A"). Different solutions can be modelled and carbon saving decisions made at the first three stages including:

- Class D (schematic): main structural material (concrete vs steel vs timber), massing, amount of underground parking, setbacks, reusing existing structures, minimizing transfer structures
- Class C (early design): cladding materials and window-to-wall ratio, types of insulation, floor plan, interior partitions, concrete types and strength classes
- Class B (late design / tender): local and low-carbon suppliers, transportation distances and electric vehicles, material properties including recycled content, concrete mix specifics and curing time requirements, steel supplier, certified wood

13 **Project teams should include the same life cycle scope of assessment** (for example, cradle-to-occupancy, also known as 'upfront embodied emissions', associated with phases A1-A5), and the same object of assessment (for example, including the building's structure and envelope but excluding mechanical, electrical, and plumbing – see Appendix C). This is critical for comparing results between projects, to a limit/cap, or to benchmark results.

14 **Results should be reported using a standard template** to allow for streamlined data collection and comparison between projects. See Appendix A.

The below figure shows the self-reported whole building LCA results from 41 Part 3 (large) building projects in Ontario and 503 Part 9 (small) buildings through the separate EMBARC study (see page 10). The authors of this report suggest policymakers consider new regulation that can be implemented as part of the building approvals process. The building type-specific proposed cap or limit is shown as the solid red line.

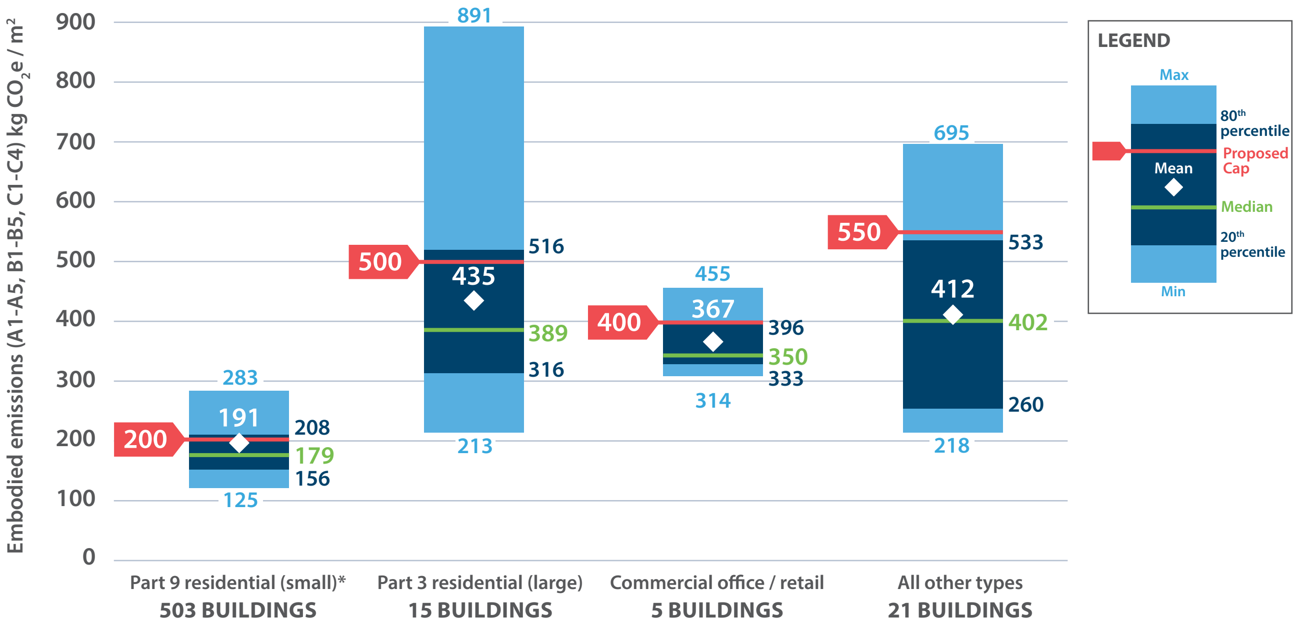


**Figure 1:** Proposed initial (2024) caps in red lines shown in relation to Ontario benchmarking

The caps could be reduced over time as follows such that the values are halved by 2030.

| YEAR | PART 9 RESIDENTIAL (SMALL) | PART 3 RESIDENTIAL (LARGE) | COMMERCIAL OFFICE / RETAIL | ALL OTHER TYPES |
|---|---|---|---|---|
| **2024** | 200 | 500 | 400 | 550 |
| **2026** | 166 | 415 | 335 | 460 |
| **2028** | 133 | 330 | 270 | 370 |
| **2030** | 100 | 250 | 200 | 275 |

* See footnote 4 on page 10

# PART 1

## Introduction to Embodied Emissions and Management Recommendations

# 1.1 / WHAT ARE EMBODIED EMISSIONS?

## The upfront, embodied emissions (also called embodied carbon) of Ontario's construction sector are a significant, overlooked, and mostly unmanaged source of greenhouse gas emissions. This needs to change.

Buildings are a major driver of the climate crisis. When asked how to reduce their carbon impact, what typically comes to mind is increasing energy efficiency and using more renewable energy to power our buildings. What's often overlooked is the large carbon impact associated with the construction of buildings, which is not addressed by energy efficiency or building-level green power.

The construction of buildings and infrastructure accounts for 11% of global greenhouse gas (GHG) emissions. These emissions are largely the result of upfront carbon emissions associated with the harvesting, transportation, manufacture, and installation of construction materials (termed "upfront embodied emissions", "embodied emissions" or "embodied carbon" for short). Additional embodied emissions are generated post-construction, including during the use, maintenance, refurbishment, and repair of a building, and additionally during the end-of-life of the building including deconstruction/demolition and waste processing/recycling. However, the bulk of embodied emissions (70-90%) happens "upfront" before the building is occupied.

The good news is that these emissions can be managed and minimized through smart design and procurement. Significant carbon reductions (around 30%) can be realized through simple material substitutions that can have next to no impact on project cost or schedule. All we need to do is start using lower carbon (or better yet, carbon-storing) materials!

With Ontario's projected growth over the coming decades fueling further construction, there is an imperative for municipal policy makers (and all construction stakeholders) to address embodied emissions in tandem with the policies that already exist for operational emissions. Preliminary calculations by TAF estimate that embodied emissions from construction of buildings in Ontario could account for at least 5 Mt CO2e annually. A leading Canadian construction firm shared in a recent workshop that they are achieving embodied emissions savings of around 30% without impacting overall project budget or schedule, when this is prioritized by the client and project team. If these strategies are applied across the province, at least 1.5 Mt CO2e per year could be avoided.

# 1.2 / NOW IS THE TIME TO REGULATE EMBODIED EMISSIONS

## There are three reasons why efforts to manage and reduce embodied emissions of new construction are accelerating:

1. **New buildings use less operating energy.** In Ontario, and globally, new buildings require much less energy to operate than older buildings. This is due to decades of increasing energy efficiency requirements for new buildings. Strong municipal action by the City of Toronto and others both in Ontario and in other provinces – most notably the City of Vancouver – have added more stringent regulations on top of provincial building code minimum energy efficiency requirements. In addition, other efforts to make buildings more energy efficient have been made by utilities, designers, owners, operators, governments, and building users. Voluntary green building systems like LEED and BOMA BEST have also helped to accelerate more efficient mechanical and electrical systems in new building design and drive down operating emissions.

2. **Operating energy is decarbonizing.** There is an ongoing effort to "electrify everything" in Ontario since the province has low carbon electricity. As more systems "fuel switch" from gas to electricity, emissions are dropping. Ontario phased out coal-fired electricity generation in 2014, much of our baseload electricity is generated from extremely low-emitting hydroelectric and nuclear power, and we continue to build renewable generation including solar and wind. This means, Ontario's electricity continues to become lower carbon.[1] Natural gas is also becoming less carbon-intensive through the addition of renewable natural gas to the network (from landfill methane capture and organic waste programs). All of this means that a unit of operating energy requires less carbon than it used to.

3. **We need drastic emission reductions in the short term.** Operational emissions savings are fully realized only at the end of a project once the smaller year-over-year savings are aggregated. However, the vast majority of "upfront" embodied emission savings happen before and during construction and therefore have a significant and immediate impact on reducing climate impacts. It's not just the total amount of emissions being reduced that matters, it's the avoided time those emissions are in the atmosphere. A tonne of carbon avoided today is far better than a tonne of carbon avoided in ten (or fifty) years.[2]

**When these three realities are combined, the best approach to make drastic cuts to emissions from new construction is by focusing on lower-carbon materials through embodied emissions management.**

New buildings are already subject to stringent energy efficiency requirements and require the addition of low-embodied emissions requirements to make them truly sustainable.

A different strategy is required for existing buildings, especially buildings that are decades old which were designed prior to recent energy efficiency requirements in the approvals process. Increasing energy efficiency should be the primary focus for such older buildings since their embodied emissions have already been invested and can no longer be avoided or reduced, yet many opportunities exist to reduce their operational emissions.

Major renovations should target both low or zero carbon energy systems and low embodied emissions materials.

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1 For a real-time view of the carbon intensity of Ontario's electricity along with data on generation, comparisons to other regions, and historic trends, check out app.electricitymap.org

2 Due to the "time value of carbon savings": https://carbonleadershipforum.org/the-time-value-of-carbon

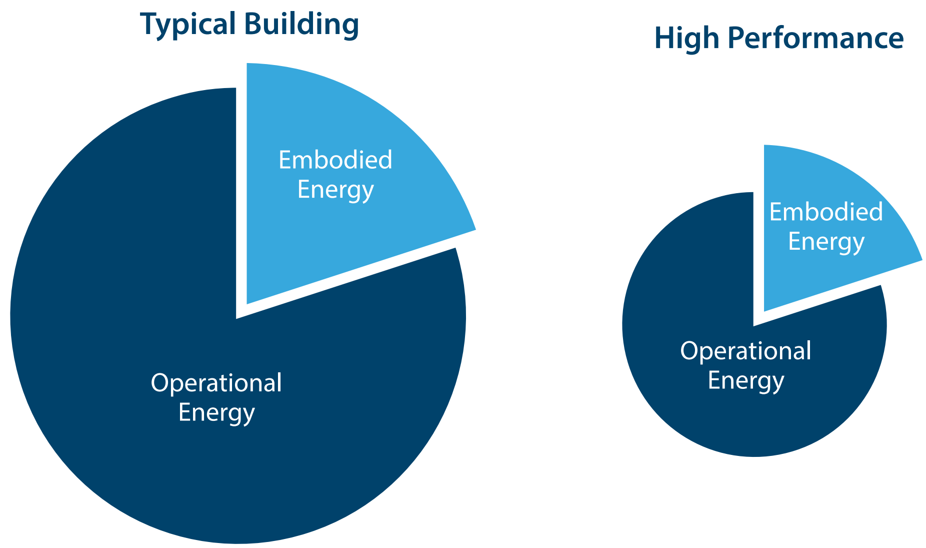


**Figure 1:** Embodied emissions can be the dominant source of emissions in high performance (energy efficient) buildings and in regions where buildings are operated with green energy (Carbon Leadership Forum: The Time Value of Carbon)

The Canada Green Building Council (CAGBC)'s Embodied Carbon Primer shows the outsized impact of embodied emissions over operational carbon in high efficiency new construction in Toronto (results would be similar across southern Ontario) when powered by electric geo-exchange systems (Figure 2).

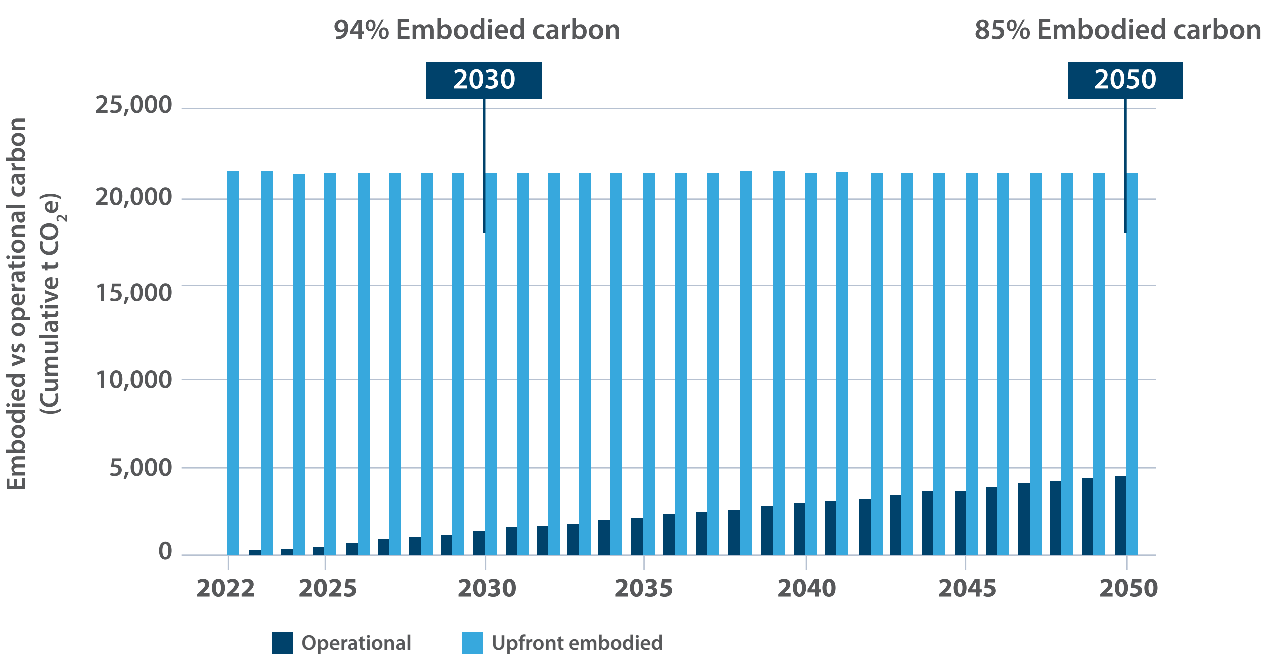


**Figure 2:** Embodied vs operational carbon split for high-efficient new construction with electrically powered geo-exchange heating systems in Toronto (results would be similar across southern Ontario).
A value of 400 kg $CO_2$ e/m$^2$ has been used as an average benchmark for upfront embodied emissions, which results in a total upfront embodied emissions of 21,451 t $CO_2$e for the archetypes studied (CAGBC Embodied Carbon: A Primer for Buildings in Canada).

# Regulatory Developments on Embodied Emissions

Leading jurisdictions are acting to manage and reduce embodied emissions. The Government of Canada's Greening Government Strategy requires a 30% reduction in the embodied emissions of structural materials in government projects by 2025. The City of Vancouver will require new construction to report embodied emissions which – as of 2023 – must be less than twice a baseline value. In 2025, projects will be required to demonstrate a 10% reduction (20% for wood or mass timber projects) in embodied emissions, when compared against a baseline building, to achieve a building permit (see report 1a, page 5-6). Edmonton will also require City-owned buildings to report embodied emissions as of 2025.

Many other examples exist in the USA (Buy Clean California), and in Europe including in London, UK. Clean Energy Canada summarized key lessons on Buy Clean policy from the USA, specifically for a Canadian audience. The Carbon Leadership Forum (CLF) keeps an updated list of jurisdictions with in-progress and active embodied emissions policies, and a policy toolkit to help drive further action.

To improve consistency in approach and methodology, Canada's National Research Council published the National Guidelines for Whole Building Life Cycle Assessment in June 2022. Future policy in Canada should refer to and require the use of this guidance or sections of it.

**With all these resources and examples to draw from, the time has come for embodied emissions management in Ontario to evolve from a voluntary best practice to a requirement.**

The Toronto Green Standard Version 4 came into effect in May 2022 and includes requirements for all City-owned construction to calculate and report embodied emissions. Mid to high-rise residential and non-residential construction in the city can do the same as part of a voluntary Tier 2 level of performance, with a higher Tier 3 level requiring a 20% reduction against a baseline building. Low-rise construction (of at least five units) has a voluntary Tier 2 limit on material-based carbon intensity in buildings (life cycle stages A1-A3 – see Figure 6 on page 23) of 250 kg $CO_2e/m^2$. These are good first steps, but Toronto recognizes that more needs to be done and is looking for ways to strengthen and accelerate these efforts.

Similar action can be taken by other municipalities from Windsor to Ottawa to North Bay and everywhere in between.

# 1.3 / SUMMARY OF PART 3 EMBODIED EMISSIONS BENCHMARKING

## A new study funded by The Atmospheric Fund (TAF) – *Benchmarking Embodied Carbon Emissions for Part 3 Buildings in the GTHA* – provides the first dataset for Ontario municipalities to use to inform future embodied emissions policies

The study – this Primer being its final output – sought to collect and compare whole building embodied emissions results – as calculated through life cycle assessments (LCAs) – voluntarily conducted for large (Part 3) buildings in Ontario. Designers, owners, and builders across the province answered the call and shared their data.

Almost none of the 41 projects in the dataset actively tried to reduce their embodied emissions in any significant or systematic way. Instead, their assessments were about understanding their standard designs and materials (Figure 3).[3]

See Appendix B for additional details about this benchmarking and the resulting findings.

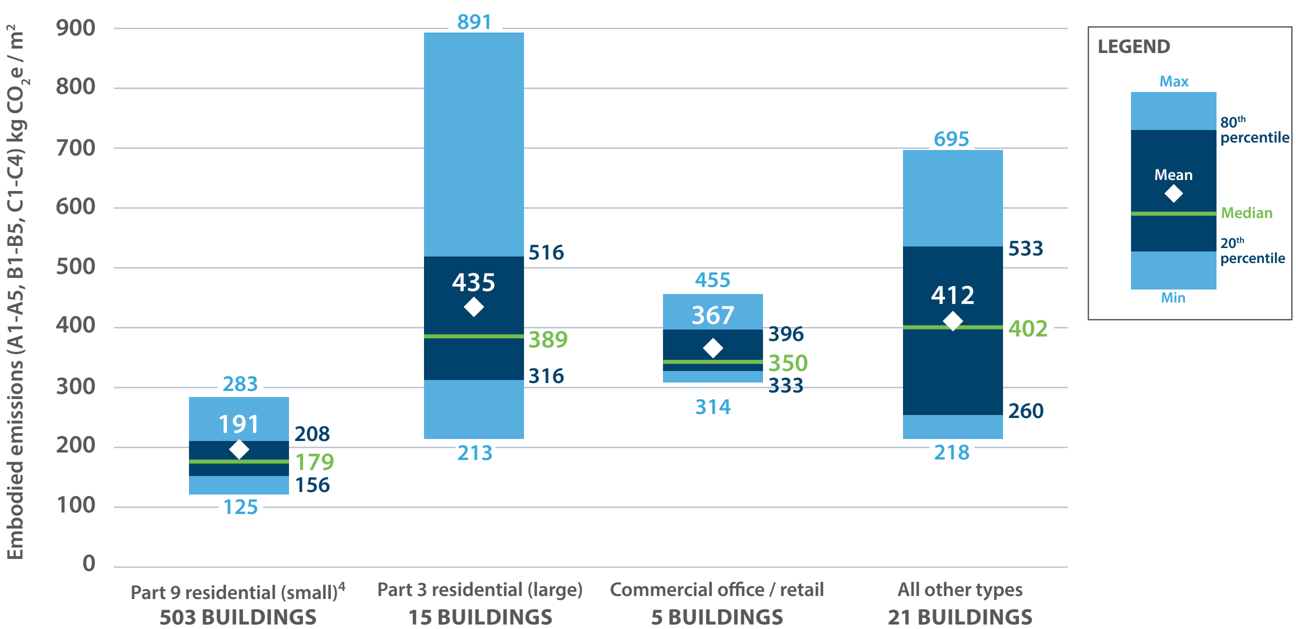


**Figure 3:** Ontario's first embodied emissions benchmarking; self-reported data from 41 separate large (Part 3) buildings, and results from separate EMBARC study[4] (see page 11) on small (Part 9) buildings.

The fact that 41 projects in Ontario had this data to share means that likely many more have done this sort of voluntary analysis. This is evidence that industry can and already is calculating embodied emissions for large buildings in Ontario. The introduction of regulatory requirements on this topic will be an expansion of current best practice already being done and is not a totally new concept or approach unknown to the market.

The study included a Project Advisory Committee of 16 experts. Four workshops were held to share findings and hear the perspective of industry players, with 310 participants in total (see Appendix C for more from the workshops; recording available here).

Through this outreach it is evident that embodied emissions policy is not considered radical or too burdensome. Of the hundreds of professionals we

3 In previous years both LEED and the CAGBC's Zero Carbon Building Standard awarded embodied emissions reporting without demonstrated reductions, which led to many of these assessments. That approach is evolving, with limits and minimum reductions being phased in.

4 The EMBARC study looked at life cycle phases A1-A3 only. The material carbon intensity values based on total floor area shown in Figure 7 in that study have been increased by 20% in this study to account for the addition of the other life cycle phases (A4-A5, B1-B5, C1-C4)

engaged with, none argued against management of embodied emissions. In fact, the opposite was heard with many voicing the position along the lines of "move faster" and "be bolder". Some cautioned against incrementalism, asking for requirements at the level of ambition required by climate science, including to half emissions by 2030. Workshop participants noted that the current climate emergency does not allow for the luxury of time to pilot and phase in new requirements over many years or decades as may have been done in the past.

However, workshop participants also noted that the reality of our climate risks must be balanced with the very real social risks of affordability and equity. Thankfully, embodied emissions can be managed and greatly reduced without increasing construction costs. Greener materials don't have to cost more if one knows what to ask for!

## Embodied Emissions are a Scope 3 Emissions

Many organizations including municipal governments prepare emissions inventories that categorize emissions as scope 1 (from combusted fuels), scope 2 (from purchased energy), and scope 3 (from other upstream and downstream sources). Embodied emissions of construction projects fall into the scope 3 bucket.

Increasingly, scope 3 emissions are being prioritized with more organizations including them in corporate emission inventories. Organizations that have started to measure and manage their scope 3 emissions may wish to include embodied emissions in their next emissions inventory boundary and begin calculating and disclosing them.

# Ontario Small Building (Part 9 Building) Benchmarking Study: EMBARC Study

In 2021, the EMBARC (Emissions of Materials Benchmark Assessment for Residential Construction) calculated the emissions arising from the production of building materials for 503 homes in the GTHA. This is the largest study of its kind in the world and provides many insights for regulators in the region. The full report can be found here.

## RESULTS:

- An **average low-rise house** in the GTHA is responsible for **40 tonnes** of emissions from production of its structure, enclosure, and partition materials.
- Extrapolated to all new low-rise construction in the region, **annual emissions** from materials are approximately **840,000 tonnes**. This is the equivalent of annual tailpipe emissions from 183,000 automobiles.
- **Average emissions** intensity for houses in the GTHA is **191 kg $CO_2e/m^2$** of heated floor area.
- **Highest intensity is 561** (293% higher) and **lowest intensity is 116 kg $CO_2e/m^2$** (39% lower).
- Substituting the **best available** materials in just five categories could achieve **reductions of 50-75%**, at little to no additional cost.
- Substituting the **best possible** (but not readily available at scale) materials in just five categories could make new homes net carbon positive, **storing up to 50 tonnes** of $CO_2$ per home.

## TAKEAWAYS:

- Some developers' business-as-usual scenario is achieving nearly 40% less emissions than the average, indicating that affordable and practical solutions exist to meet current climate targets. It is within the industry's ability to meet regulations for dramatically reducing material-related emissions.
- Free tools enable the industry to easily measure and report on material emissions.
- Cities including Vancouver, Austin, and San Francisco have set targets to reduce material emissions by 40% by 2030.
- Benefits of reducing material-related emissions include creating new green jobs and promoting circular economy, improving building health for occupants, and reducing construction waste.
- Improving energy efficiency and reducing material emissions can be complementary strategies and should both be pursued.

**LEARN MORE:** Builders for Climate Action

# 1.4 / RECOMMENDATION: TIERED EMBODIED EMISSIONS INTENSITY CAPS REDUCING OVER TIME

## How best to address the issue? Tiered embodied emissions intensity caps, specific to building typology, which reduce over time and are halved by 2030 – with links to the building approvals process.

Leading jurisdictions have been regulating embodied emissions for the past number of years. A tried and tested method is emerging and is recommended here. Start with quantification and benchmarking (perhaps for two years, starting in 2022 or 2023), then bring in limits or caps on embodied emissions intensity (embodied emissions per square meter). The caps should lower over time (again, every two years), with the future caps and effective dates being published years in advance to signal industry and provide a clear roadmap.

Based on the new Ontario benchmarking data (Figure 3) and global best practice precedents, we recommend embodied emissions caps be introduced for new buildings in Ontario, linked to the building approval process, as shown in Table 1, Figure 4, and Figure 5. These values represent potential initial (2024) caps that are easily achievable using current technology, materials, supply chains, and construction processes, and will only have a marginal (if any) impact on cost, mainly in the form of minimal additional design, consultant, and/or procurement efforts.

The 2030 caps represent a 50% reduction by the end of the decade, which is the current climate science requirement. These caps are an initial step, and they should be revisited for updates once more data becomes available and manufacturers and designers start prioritizing lower carbon materials more fully. For example, it may become clear that the initial caps are too easy to achieve and may need to be further lowered.

Future year targets could be used as 'stretch targets' prior to their implementation, achievement of which could be linked to incentives. For example, if the 2026 target is achieved by a project registered before that year it could unlock an incentive.

**Table 1:** Proposed upfront embodied emissions caps for buildings in Ontario in kg $CO_2e/m^2$ – Life cycle phases A1-A5

| YEAR | PART 9 RESIDENTIAL (SMALL) | PART 3 RESIDENTIAL (LARGE) | COMMERCIAL OFFICE / RETAIL | ALL OTHER TYPES |
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| **2024** | 200 | 500 | 400 | 550 |
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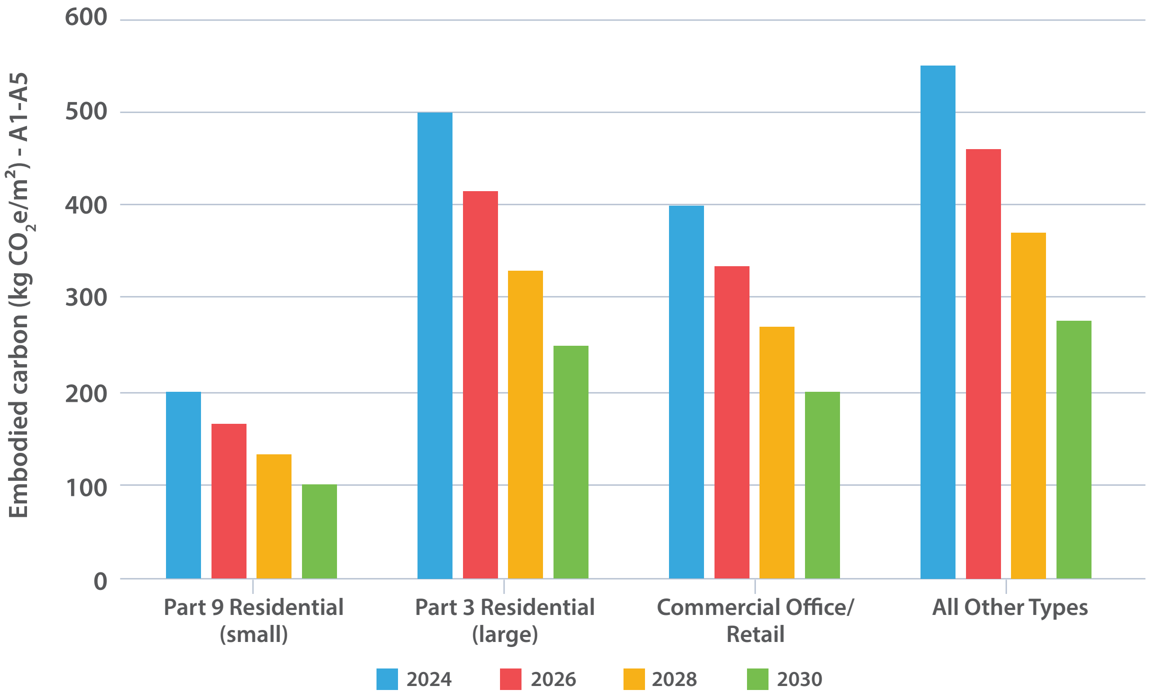



**Figure 4:** Proposed upfront embodied emissions caps for buildings in Ontario in kg $CO_2e/m^2$ – life cycle phases A1-A5

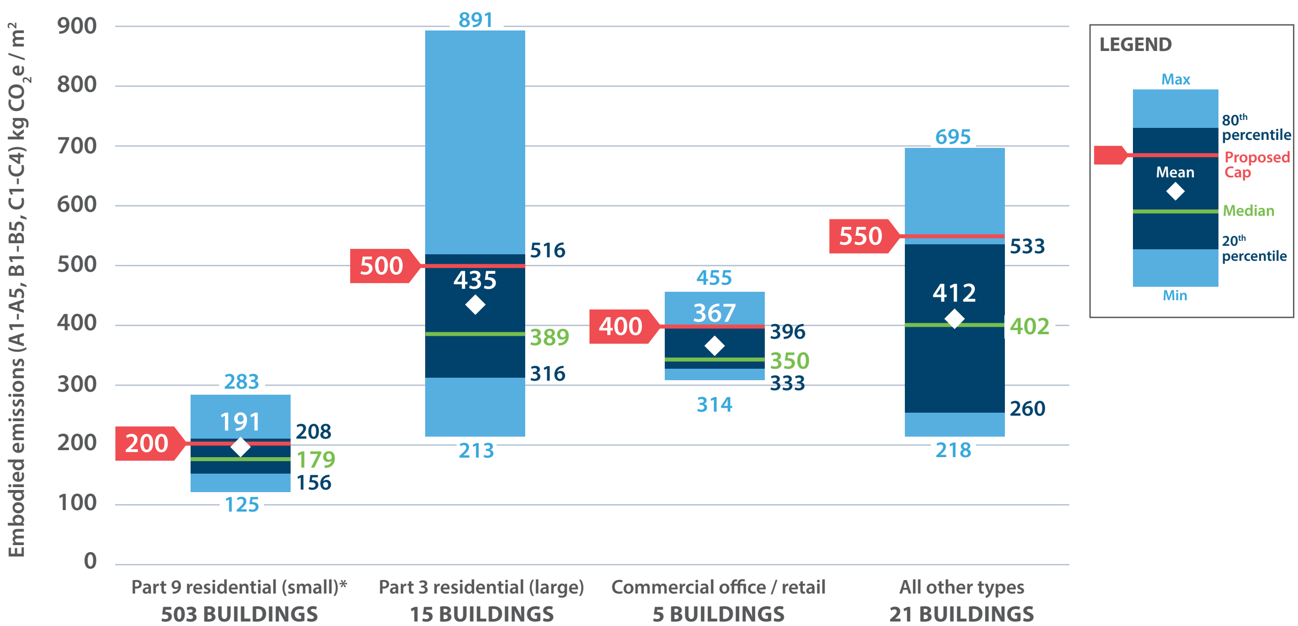



**Figure 5:** Proposed initial (2024) caps in red lines shown in relation to Ontario benchmarking

Although we believe all (or nearly all) buildings should be able to achieve these caps, it is prudent to allow for an optional compliance path that can be applied only in special circumstances which may be applicable to special construction projects that have uncommonly high embodied emissions impacts, for example high security locations like prisons or hospitals. Therefore, allowing a specific "reduction against a similar baseline building" approach for special circumstances may be appropriate, which puts the onus on the design team to show how they are lower carbon than a similar "typical" building. Vancouver is taking this approach requiring a 10% reduction against a baseline building (20% for wood-based buildings) by 2025.

* See footnote 4 on page 10

# Embodied Emissions Intensity: Gross Floor Area, Parking, and Bedrooms

Both the total project embodied emissions and the area used when calculating embodied emissions intensity (kg $CO_2e/m^2$) should include all parking that is part of the structure.

Absolute embodied emissions, measured in kilograms of carbon dioxide equivalent (kg $CO_2e$) of buildings is typically divided by floor area to obtain an embodied emissions intensity value, normally kg $CO_2e/m^2$. This allows for results from buildings of different sizes to be compared if a consistent methodology is used including the selection of life cycle phases and object of assessment (building systems and materials). All of these should be aligned for high-quality comparisons between projects.

When using a floor area value, it's important to be specific about how it was calculated. For example, many operational energy models use gross heated floor area or inhabitable floor area, measured from interior wall surfaces. This corresponds to the space which must be heated, cooled, ventilated, and lit (and where most operational energy is invested). However, when looking at embodied emissions, its the total constructed floor area that matters (unheated storage areas or underground parking can have just as much or more embodied emissions than conditioned spaces, hence should be included).

Projects should calculate their gross floor area in accordance to the National Guidelines' Appendix A which notes the measurements should be taken from the outside face of the enclosing walls and include attached parking and/or garages above and/or below ground.

See Section 2.4 for more.

## Embodied Emissions Intensity per Bedroom?

Studies from The University of Toronto have normalized embodied emissions by other metrics such as the number of bedrooms in a home (see Capturing variability in material intensity of single-family dwellings: A case study of Toronto, Canada). These results demonstrate that the denominator matters and can greatly impact how we interpret and use such data. If a building's purpose is to house people, perhaps bedrooms is a useful denominator. Similar arguments could be made to normalize office building and school embodied emissions results by number of desks, and hospital or long-term care by number of beds, for example. Parking structures or levels might be optimized for embodied emissions per parking space.

# 1.5 / HOW TO MEET THESE GOALS

## Measuring embodied emissions is the first step to managing and reducing it. As the saying goes, what gets measured gets managed! Next, a few simple changes can dramatically reduce embodied emissions with minimal impact on project cost and schedule.

There are several strategies to reduce embodied emissions in buildings. Many strategies have minimal cost or schedule impacts. If project teams start including carbon in the metrics being valued to drive purchasing decisions there does not have to be a cost premium for lower carbon materials. See Table 2 for relevant design strategies that reduce embodied emissions and Table 3 for material-specific strategies.

**Table 2:** Design strategies to reduce embodied emissions in buildings

| | DESIGN STRATEGY | DETAILS |
|---|---|---|
| 1 | **Promote reuse and rehabilitation of existing buildings instead of demolition and new builds** | Most buildings that get demolished have perfectly safe and strong structure and foundations, which represent substantial embodied carbon investments, and carbon that has already been released into the atmosphere.<br>Seek ways to extend the life of these structures by promoting rehabilitation and reuse of existing structure, pared with new high efficiency envelopes and energy systems. |
| 2 | **Promote disassembly, salvage, and reuse of materials** | When a building must be taken down, do it thoughtfully through disassembly.<br>Materials should be salvaged for reuse where possible, and when salvage isn't possible, recycled. |
| 3 | **Minimize or remove high embodied carbon underground construction** | Underground construction typically has a larger embodied emissions footprint than above ground construction due to the use of high carbon retaining walls, concrete, XPS insulation, and shoring works typically required.<br>Look for ways to minimize the impact of this, including by limiting underground construction to only where needed, and including it in gross area calculations. |
| 4 | **Eliminate or reduce minimum parking requirements** | Instead of dictating a minimum amount of parking, let the developers and owners decide how much parking makes sense for a given project.<br>Consider setting a maximum on the amount of allowable parking to limit the embodied emissions associated with this additional construction. |
| 5 | **Ask for facility-specific EPDs from suppliers** | Although this doesn't directly reduce emissions, it will indirectly over time.<br>Once manufacturers start reporting publicly on their product's embodied emissions they will likely start taking actions to reduce it as market pressure for low carbon materials grows. |
| 6 | **Eliminate or reduce transfer structures** | When structural bay sizes change between building storeys as is often the case when a building transitions from residential storeys to parking storeys, a transfer structure is often required to shift the loads from one set of columns and walls to a separate set below in a different layout. These structures are often extremely thick and can be a major source of embodied emissions.<br>Transfer structures should be minimized through efficient and thoughtful design. |
| 7 | **Use performance-based design requirements, and ask for low carbon solutions** | Instead of prescribing specific approaches to be taken – which can often stifle innovation – set the desired performance while noting that low carbon solutions are preferred.<br>Let designers and suppliers innovate and find low carbon and cost efficient ways to deliver the required level of performance. |
| 8 | **Review how coverage regulations might incentivize sub-surface floor area** | An unintended driver of underground construction is how coverage is calculated and regulated through means like floor area ratio (FAR) or floor space index (FSI).<br>When these coverage calculations fail to include sub-grade floors area, they incentivize below grade construction, which is embodied emissions intensive (see point 3 above). |

**Table 3:** Material-specific strategies to reduce embodied emissions

| MATERIAL | STRATEGY |
|---|---|
| CONCRETE | **1.** Use Portland-limestone cement (PLC) – also called general use limestone (GUL) – instead of regular Portland cement. PLC is 10% lower embodied emissions, widely available, and cost and performance neutral. It has been approved for use by Canadian regulators and safety associations as a one-for-one substitute with Portland cement without needing to revise the design.<br>**2.** Allow structural elements that do not require early strength more time to achieve their rated performance, beyond the standard 28-day period. Candidate structural elements for 60-, 90-, or 120-day strength include most footings, sheer walls, columns, and slabs-on-grade. Longer curing times mean less cement and therefore lower embodied emissions. Speak about this with your structural engineer and concrete supplier.<br>**3.** Use a higher percentage of supplemental cementitious materials (SCMs). Most concrete mixes use nominal SCMs (5-10%), however mixes can use far more, up to 70% SCMs in some applications. Each 10% increase in SCMs leads to an approximate 7% reduction in concrete's embodied emissions. |
| STEEL | Order steel that is made from low-carbon mills utilizing high levels of recycled scrap. The carbon impact of steel manufacturing can vary widely depending on how the steel is made, in either typically higher emitting blast oxygen furnaces, or potentially lower emitting electric arc furnaces.<br>The details within those categories matter too, since blast oxygen furnaces can be fueled by coal (resulting in very high embodied emissions steel) or hydrogen produced from renewable energy (resulting in very low embodied emissions steel). Similarly, whether an electric arc furnace is powered by fossil vs renewable electricity makes a huge difference to the ultimate embodied emissions of the steel.<br>Facility-specific EPDs from your steel manufacturer candidates is the best source of information to request and compare to find the lowest carbon option. Also consider the A4-transportation impacts of shipping your steel to the construction site. This can be significant if shipping steel from far away jurisdictions, however may still be a net carbon saving strategy if the steel from a distant jurisdiction is ultra-low carbon. |
| WOOD | As with all other materials, how wood is grown and harvested matters to its final embodied emissions footprint. Wood has a few added complexities since it is a renewable resource and part of a larger forest carbon cycle. The best approach to ensure your wood is low embodied emissions is to ask for wood that is certified to one of the recognized standards for sustainable managed forests and harvested wood such as the Forest Stewardship Council (FSC) or Program for the Endorsement of Forest Certification (PEFC). This will ensure your wood was not from old growth forests and that responsible forest practices including replanting was used. |
| INSULATION | Many types of insulation exist, and their embodied emissions can vary widely. Extruded Polystyrene (XPS) insulation is typically the highest carbon option and should be avoided where possible. There are some bio-based insulations that are much lower carbon, including straw bale and wood fiber board. Bio-based insulation can even be net-negative if biogenic carbon is considered. See Figure 11 of the EMBARC report for a list of insulations and their relative embodied emissions. |

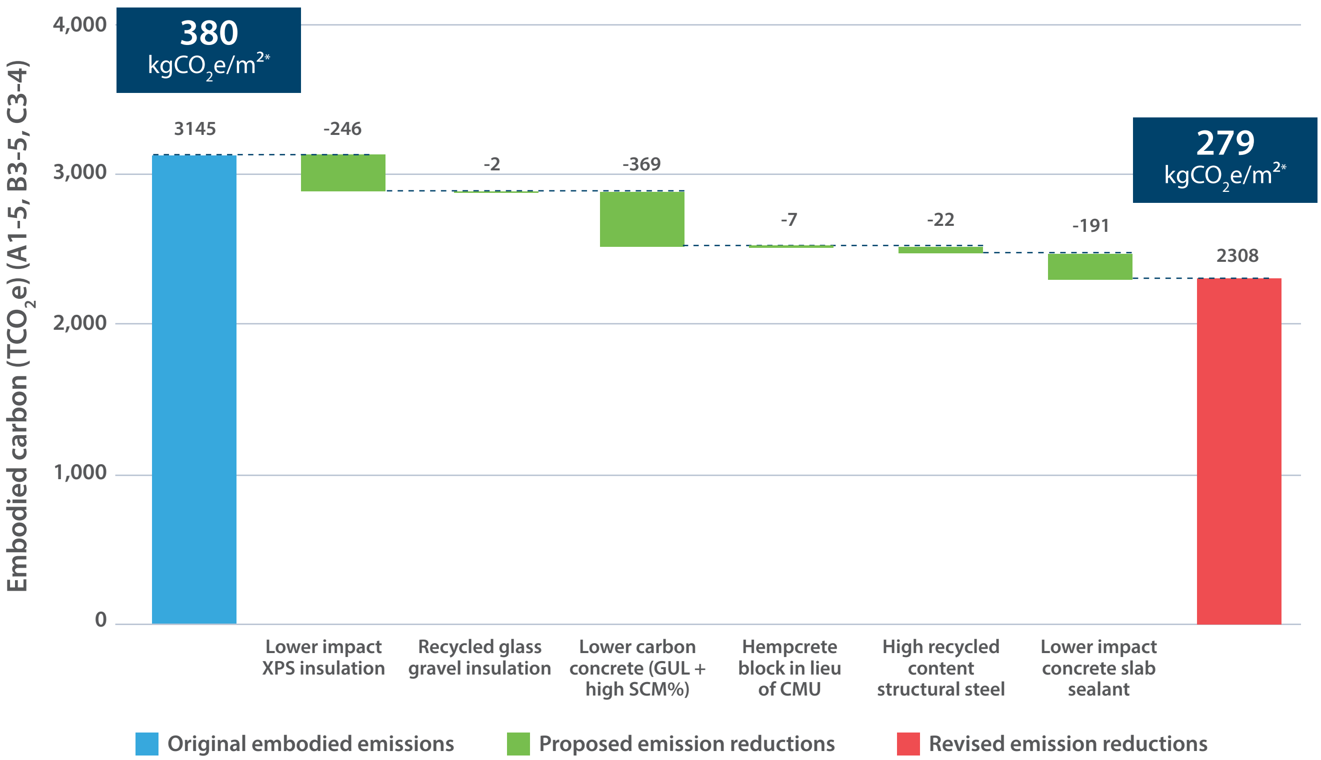
## Strategies for Low Carbon Concrete

Canada's National Research Council (NRC) published a free primer for federal government procurement agents – and applicable to anyone who orders concrete – with strategies that can be asked for of your concrete supplier to drive down its embodied emissions footprint, mostly at no cost or schedule impact.

The document can be freely accessed here.

## CASE STUDY | Toronto Emergency Medical Services Station

This new innovative mass timber building will be the future home of Toronto's paramedic training and ambulance storage facility. The design was already quite low embodied emissions due to the use of mass timber as the primary structural material. An examination of the final design uncovered six additional opportunities to reduce embodied emissions through material substitutions with little to no impact on cost and schedule. The result is a **30% reduction in embodied emissions, avoiding around 800 tonnes of $CO_2$e with no cost premium.**



# 1.6 / NEXT STEPS AND REQUIRED FUTURE WORK

## Ongoing dialog, education, and outreach is required with all stakeholders to increase embodied emissions literacy and management

As an emerging topic, embodied emissions management requires increased education and awareness. Key resources, case studies, and training events should be developed and shared with all construction stakeholders, including owners, constructors, designers, engineers, planners, tenants, policymakers, manufacturers, specification writers, funders, and more.

These discussions should be about more than just buildings. All major physical assets are relevant including infrastructure like streets, sewers, airports, ports, water treatment facilities, bridges, and anything else that uses significant quantities of construction materials.

Several industry groups have been launched to help connect and share embodied emissions resources. More will be needed with specific sub-groups for various stakeholder types, professions, and specialties.

CLF Carbon Leadership Forum

## Carbon Leadership Forum (CLF)

The CLF is a group dedicated to decarbonizing the built environment. They advance knowledge, collaboration, and action to radically reduce the embodied emissions in building materials and construction.

Their website - **carbonleadershipforum.org** - contains research, resources, networking opportunities, and links to industry challenges and initiatives. Originally created as a think tank out of the University of Washington, it has since grown into a global movement that is free to join and is successful due to the contributions of thousands of professionals across the globe. To learn more, review their website, sign up for their newsletter and online community, and get involved!

A wealth of knowledge, tools, and case studies are available in their Embodied Carbon Policy Toolkit and extremely valuable, freely accessible six-part Embodied Carbon Policy Educational Series.

## CLF Toronto Regional Hub

There are dozens of CLF Regional Hubs, including four in Canada: Vancouver, Calgary, Ottawa, and Toronto. These hubs organize local events and lectures on embodied emissions with region-specific information, case studies, and resources. Check out and join CLF Toronto at **www.clftoronto.com**.

# Additional Points for Consideration

1. **Set requirements for embodied emissions measurement, reductions, and reporting on future municipal construction projects.** Cities can take immediate action to reduce embodied emissions by making sure that new construction projects they control include language around prioritizing embodied emissions and asking their designers, suppliers, and constructors to minimize it.

2. **The information, caps, and reporting templates provided in this document are meant to be a start, not an end.** They should be continually updated as more and better information becomes available. The proposed embodied emissions intensity caps can likely be decreased faster and/or deeper once the industry seriously turns its attention to this pressing issue. The initial proposed caps should be easily achievable by industry, allowing for broad acceptance and minimal push-back. As better data is created and becomes available from an increasingly larger data set, and a clearer picture emerges, consider revising the cap values and timelines.

3. **Ongoing training will be required for all stakeholders,** especially municipal staff so that embodied emissions reports can be reviewed and verified.

4. **Effective best practices should be collected and shared** as implementation plans for municipalities, developers, owners, designers, and manufacturers to learn from their peers.

5. **Review existing plans and policies to identify unintended drivers of embodied emissions,** such as minimum parking requirements, and develop strategies to eliminate or revise them.

6. **Additional policies should be implemented for material disassembly, deconstruction, material salvaging and reuse, building rehabilitation and reuse, and carbon-storing and bio-based materials.**

7. **Consumption-based emission inventories** can be created by municipalities.[5] These measure emissions associated with all goods and services *used* in the region, as opposed to the more traditional production-based emissions inventories which focus on the emissions of goods and services *produced* in a region. The former includes the emissions associated with products and materials that are manufactured elsewhere but imported and used in a region and would include materials like concrete and steel used in buildings built in a region even if they were made elsewhere.

8. **Municipality-wide embodied emissions reduction targets** can set the stage for rolling out project-specific embodied emissions reduction targets. Vancouver City Council set a goal to reduce embodied emissions in new construction by 40% by 2030 from 2018 levels.

5 Sweden has committed to becoming the first nation to use a consumption-based emissions inventory

# Ideas for Potential Future Work

1. Provide case study examples including potential interplay between embodied emissions and operational carbon in the Ontario context. For example, understanding the 'return on carbon investment' when adding more materials to a design including solar panels, geothermal systems, triple glazed windows, additional insulation, etc.

2. Achieve a consistent approach across the country including NRC, CAGBC, and leading municipalities, on the inclusion of parking areas in embodied emissions intensity values. Currently some organizations and guides exclude parking from the area value which leads to artificially high intensity values being reported (see section 2.4 for more).

3. Conduct reviews and revisions of existing provincial and municipal official plans, urban design guidelines, etc. from an embodied emissions perspective.

4. Consider how to thoughtfully account for biogenic carbon storage and the time value of carbon. For example, how to value temporary storage and discount future avoided emissions.

5. Quantify the embodied emissions benefits of reusing and renovating existing buildings and using salvaged materials.

6. Deep embodied emissions reductions and potential impacts on Ontario's supply chains construction schedules.

7. Put more resources towards creating zero carbon construction sites (to reduce or eliminate emissions from phase A5) including electric and biofuel powered construction equipment.

8. Study how the season of construction (winter vs summer) impacts the embodied emissions of a project. Concrete mix ingredients (and carbon impact) vary due to weather conditions. High-emitting propane space heating is often used when concrete is poured in winter.

9. More data, tools, and proxies to use as average values for A4 – transportation of materials to site, and A5 – construction processes, for Ontario projects. Similar proxies can be created for use phase B and end of life phases C.

10. More EPDs for 'expanded scope' systems including mechanical (including renewable energy systems), electrical, plumbing, and recognition and quantification of emissions from excavation, site work, and landscaping.

# PART 2

## Methodology and Data Recommendations

# 2.1 / LIFE CYCLE ASSESSMENT AND BUILDING PHASES

## Embodied emissions are calculated using a methodological approach known as Life Cycle Assessment (LCA)

International standards (ISO 14044), European standards (EN 15978) and a newly released Canadian national guidelines (June 2022) exist – see *National guidelines for whole-building life cycle assessment (National Guidelines)* – to help practitioners use a common approach allowing for consistency and comparability between whole building LCA (WBLCA) results including embodied emissions (sometimes also referred to as embodied carbon or global warming potential or GWP).

See Figure 6 for a proposed simplified initial system boundary that is limited to "upfront" embodied emissions (emissions from pre-occupancy activities), which includes:

- **A1** – raw material harvesting and supply
- **A2** – transport of raw materials to manufacturer
- **A3** – manufacturing processes
- **A4** – transportation of finished materials and products to the construction site
- **A5** – construction and installation processes

These upfront carbon emissions are set as the simplified initial system boundary for three key reasons:

1. They represent a significant majority of cradle-to-grave (A1-C4) embodied emissions, with most studies noting them to represent over 75% of emissions and some up to 90%.
2. They happen "now" (during procurement and construction, not during future renovations or building end of life), so they represent the most immediate opportunity to reduce emissions.
3. Since they are based on current practices and supply chains, complete data and complete management should be possible. The use stage (B), end-of-life stage (C), and beyond stage (D) all happen in the future – likely many decades for C and D – and therefore require assumptions about future processes and technologies based on today's abilities, which are bound to be incorrect and over-estimate future emissions.[6]

6 These future phases are important and should eventually be added to the system boundary once the industry is more familiar with LCA, and better data and tools are available. However, it is recommended to exclude them from the initial years of relevant policies for simplicity and maximum impact.

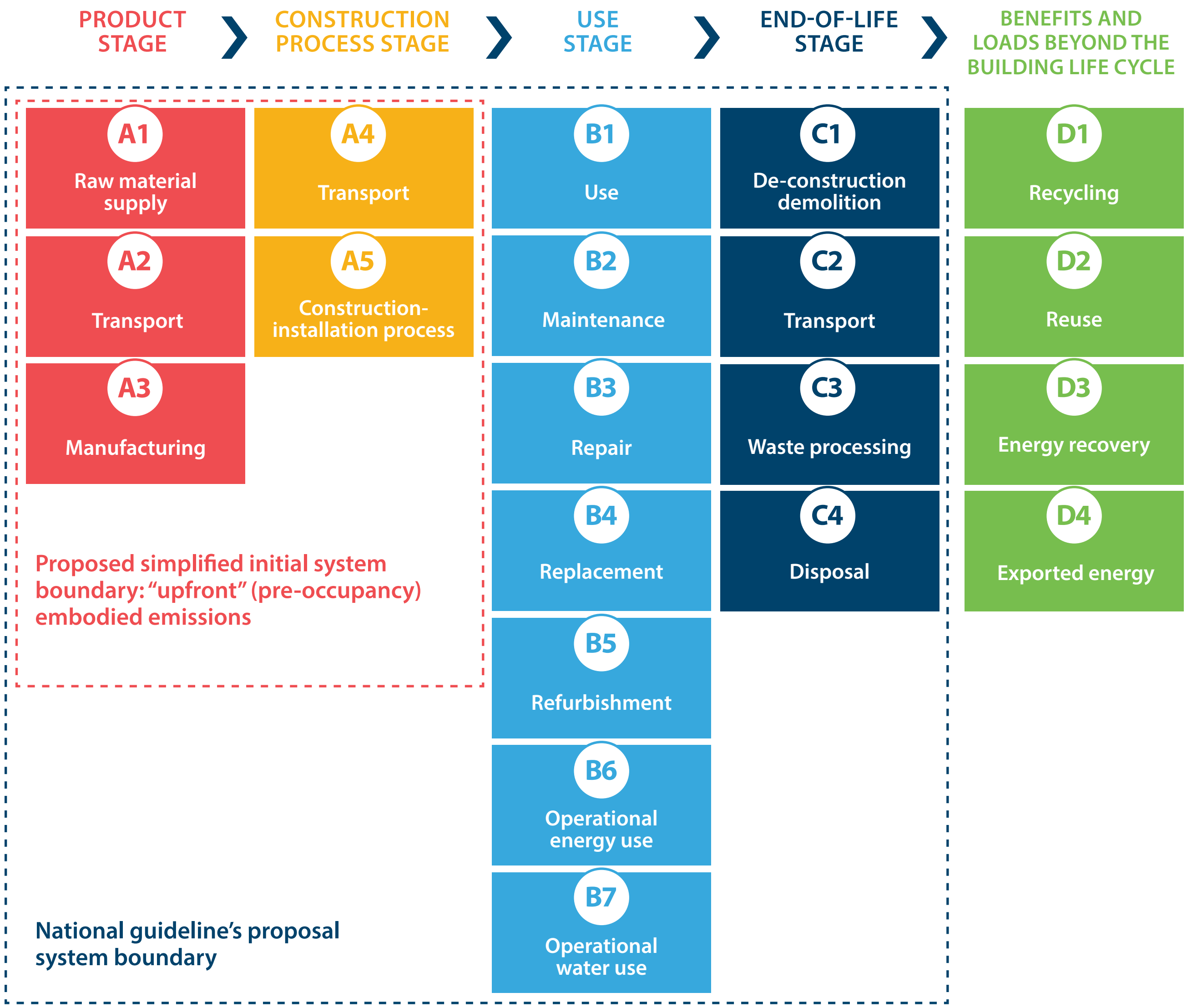



**Figure 6:** Proposed simplified initial system boundary for upfront (pre-occupancy) embodied emissions (red dashed line). Based on Figure 4 in the National Guidelines.

Other than avoiding new construction altogether, preserving and reusing existing buildings is the most effective embodied emissions reduction policy. Policymakers who wish to place a heightened emphasis on this may wish to include the end-of-life stage (phase C) for any required demolition and waste disposal from buildings that are currently on an infill site and need to be removed to make room for new developments. For example, this scope of assessment could be phase C for all current buildings or components to be removed + phase A for all new construction and materials.

## Life Cycle Scope / System Boundary Definitions

LCAs can include different stages or phases of a building's life cycle. Below are some of the most common terms. When comparing the LCA results for different projects it is important to note if the project results cover the same life cycle phases, which is required for a high-quality comparison.

- **Cradle-to-gate (A1-A3):** emissions that occur up until the finished materials/products are ready to leave the manufacturer's "gate" and be shipped to a construction site.
- **Cradle-to-substantial completion** (A1-A5) – also called "upfront embodied emissions": emissions that occur up until the project is fully constructed and ready for occupancy.
- **Cradle-to-grave** (A1-C4, typical excluding a few key stages like B6 and B7): emissions that occur over the entire life cycle, but not considering future recycling/ reuse beyond the project.
- **Cradle-to-cradle** (A1-D, typically excluding a few key stages like B6 and B7): emissions that occur over the entire life cycle, including future construction projects reusing materials beyond the project. The D phase is reported separately and not aggregated with the other phases.
- **Whole-life carbon:** the total of a projects operational emissions + embodied emissions.

# 2.2 / THE OBJECT OF ASSESSMENT

The National Guidelines *Appendix B – Building model scope definition* includes a full itemized list of all building systems which could potentially be included in a WBLCA model. Ideally, the total carbon impact from all building systems and materials should be included; this should be a future goal as better tools and data become available. However, to maximize impact and due to the realities that embodied emissions material data in the form of environmental product declarations (EPDs) are not yet available for many building systems and materials, most LCA frameworks require the inclusion of a simplified object of assessment subset to start – mainly focused on structure and envelope – aligning with the approach taken by LEED and the CAGBC (Table 4). An expanded object of assessment scope including additional systems and materials could also be used by project teams wishing to take a more holistic approach, however the simplified scope should always be reported so it can be used for comparisons against other projects.

An expanded list with links to the UniFormat and OmniClass numbers (based on the National Guidelines' Appendix B) is provided in Appendix D of this primer.

**Table 4:** Proposed simplified object of assessment and optional expanded scope of assessment

| SIMPLIFIED (MUST BE INCLUDED) | EXPANDED (CAN BE ADDED IN SEPARATE MODEL) |
|---|---|
| **All new materials that are part of:**<br>▪ Structural systems including footings and foundations, basements, floors (slabs), walls, columns, beams, and stairs<br>▪ Envelope systems including exterior glazing and frames, cladding, framing, insulation, roofing<br>▪ Interior vertical finishes (gypsum and/or other) on structural elements<br>▪ Parking structures (above or below grade) | **All new materials that are part of:**<br>▪ Site works, excavation, and shoring<br>▪ Mechanical, electrical, plumbing<br>▪ Fire detection and alarm systems<br>▪ Elevators and transportation systems<br>▪ Interior horizontal finishes (flooring and ceiling) like carpets, ceiling tiles, etc<br>▪ Interior vertical finishes (gypsum and/or other) on non-structural elements<br>▪ Surface parking lots<br>▪ Interior (non-structural) partitions, doors, glazing |

To encourage building and material reuse, the LCA should cover new materials only (including materials with recycled content). Any existing structures on the site that are reused as part of a new (re)development, and any materials that are reused / salvaged should be counted as zero embodied emissions in the LCA.[7]

Focusing on this simplified object of assessment captures the typical largest sources of embodied emissions while limiting the effort, time, and cost required to perform the assessment. These larger volume materials are also the ones that are most likely to have information available demonstrating the carbon footprint of the materials (called EPDs – see next page), and potential substitutes for lower carbon alternatives.

All projects should report their embodied emissions intensity results according to the simplified object of assessment systems, and this value should be the one used to demonstrate achievement of the embodied emissions cap and for benchmarking against other building results. If project teams wish to include some of the proposed expanded systems and materials in assessments to obtain a more holistic picture of project embodied emissions those results should be reported separately.

Obtaining the quantity of materials for each of the included building systems can be time consuming if calculated by performing take-offs from design documents. From the start of the project, relevant team members (architect, structural engineer, cladding and envelope engineer, constructor) should be informed that quantities of their materials will be needed for the materials noted in Table 4. Updated quantities will be needed at various times throughout the design to run and update LCA models. Encourage them to have a system in place to easily collect and report on these quantities as the design matures.

One approach is to design with BIM (for example Revit) which can easily output material quantities of key systems when setup to do so from the outset. Another good source of material quantities is cost estimates that have quantities of materials listed – cost estimators should be requested to note the quantities of each material in their report, and listed according to the OmniClass or UniFormat numbers shown in Appendix C.

7 Materials that are salvaged from other sites and shipped to the new construction site will have transportation (A4) and construction (A5) emissions associated with their reuse, but it is recommended to ignore these currently since emissions from these stages are typically minor. These emissions can be added in the future with better tools and data.

## Environmental Product Declarations (EPDs)

EPDs are disclosure documents created by construction material manufacturers or industry associations. They can be thought of as a "nutritional label" of sorts, showing the environmental impacts for a given declared unit (similar to a "serving size") – typically in a weight (example: tonnes of steel), volume (example: cubic meters of concrete), or area (example: square meters of gypsum board).

EPDs can be "generic", based on industry averages where the environmental impacts of many different producers are averaged. An example of an industry average, generic EPD created by national product association is the Canadian Ready-mixed Concrete Association's EPD. Generic EPDs are a useful data point to understand the national impact from a given type of material.

However, WBLCAs that use EPDs based on the project-specific material manufacturing facility data are of higher quality and provide much more specific and accurate results at the building level. These are called "facility-specific EPDs" and should be used instead of industry-average EPDs where possible.

Third party verified, facility-specific EPDs should be requested from product and material manufacturers, and used wherever possible. If no facility-specific EPDs exist for the actual products used on a given project, it is acceptable to use EPDs from a different manufacturer if they use similar methods of production and ideally are located in the same province – this substitution should be noted in the final report. Failing that, industry average EPDs can be used.

The first Ontario-specific generic EPD for ready-mixed concrete was published in July 2022. This should be used to estimate the embodied emissions of ready-mixed concrete in Ontario unless facility-specific (or manufacturer-specific) EPDs are available for the mixes being used on a given project, which some manufacturers are starting to offer.

# 2.3 / TIMING AND "CLASS" OF LCA ASSESSMENTS

It can be useful to think of LCAs like costing estimates. Neither costing nor LCAs will have complete and perfect data until the project is complete and all values can be accurately measured. However, costs and cost ranges are estimated at early stages of design and used (as imperfect as they may be) to drive decisions. The same can be done with early design embodied emissions estimates as calculated by LCAs. We can refer to the resolution or quality of the estimate as a "class".

Construction projects often classify the quality of their cost estimates from a scale of "Class D" at conceptual design to "Class A" at tender documents. A similar approach can be taken with LCAs. See Table 5 for an example approach that links LCAs at various stages of a project to potential decisions that can reduce carbon.

**Table 5:** Class D to Class A estimates for costs and LCAs

| | COSTING | LCA | EMBODIED EMISSIONS DECISIONS INFORMED |
|---|---|---|---|
| Class D | Conceptual design. +/- 20% to 30% | Conceptual / schematic design | Amount of underground parking; main structural material type: concrete vs steel vs timber; reuse existing structures; massing and foundation types; setbacks. |
| Class C | 33% design development. +/- 15% to 20% | Design development | Cladding materials and window-to-wall ratio; insulation type; floor plan; interior partitions; concrete types and strength classes |
| Class B | 66% design development. +/- 10% to 15% | Tender documents, "for construction" | Local and low-carbon suppliers; transportation distances and electric vehicles; material properties including recycled content, concrete mix specifics and curing time requirements, steel supplier, certified wood. |
| Class A | 100% tender documents. +/- 5% to 10% | Construction completed, "as-built" | Maximize salvaged materials; low-carbon concrete mixes; minimize transportation distances (use local suppliers); low-carbon construction equipment. |

As projects move from the initial Class D estimates towards revised / updated Class C, B, and finally Class A estimates, the material quantities should move from estimates and/or ranges towards actual values purchased. Similarly, the environmental data (EPDs used) should move from industry average (generic) to facility-specific for the actual manufacturers and manufacturing facilities used (where this information is available).

Potential links to building approvals process stages can also be made if desired. Since projects must be initially (or conditionally) approved earlier than high quality embodied emissions results will be available, preliminary results via a Class D LCA, could be asked for with approval conditional on the later LCA (Class B or A for example) coming in below the required cap. Missing this condition of approval could lead to a monetary penalty if not met, for example.

Toronto has language in its Official Plan supporting embodied emissions reductions, sustainable building materials and a carbon neutral built environment. Rezoning applications now require preliminary embodied emissions calculations ("Preliminary LCA") and reporting, based on conceptual or schematic design, to be submitted with the Energy Strategy Report. Projects aiming for the voluntary Tier 2 of Toronto Green Standard compliance must also submit a materials emissions assessment or full LCA, based on final design, as part of the verification report. Toronto is also considering adding requirements to Site Plan Approvals.

Vancouver's Green Buildings Policy for Rezoning's Appendix A lists the embodied emissions requirements at different phases of the building approvals process, as shown in Table 6. Note that these specific requirements and/or approval stages may not be appropriate in Ontario but are a useful precedent to be familiar with.

**Table 6:** Vancouver's embodied emissions requirements linked to approvals stages (Vancouver Green Buildings Policy for Rezoning – Appendix A)

| APPROVALS STAGE | EMBODIED EMISSIONS REQUIREMENT |
|---|---|
| **Rezoning Application** | Preliminary embodied emissions calculation |
| **Building Permit** | Calculations of embodied emissions |
| **Occupancy Permit** | Final calculations of embodied emissions |

# 2.4 / CALCULATIONS AND TOOLS

Projects should calculate their gross floor area in accordance with the CAGBC (see page 14) or the National Guidelines' Appendix A which notes the measurements should be taken from the outside face of the enclosing walls and include attached parking and/or garages above and/or below ground. It can be useful to separate this gross floor area into above grade and below grade values as below grade construction is typical higher embodied emissions due to retaining walls. It can also be useful to know the space dedicated to parking vehicles, which may be worth collecting separately. Note this may require separate area calculations from what is typically used in operational energy models, which is often gross heated area measured from the interior face of walls. This is not appropriate for LCA since it doesn't include all materials in the project.

Some municipalities and users of the CAGBC's Zero Carbon Building Standard may exclude parking structure areas from gross floor area values, but the authors of this report recommend for the purposes of embodied emissions intensity values, the area reported should include all parking (following the National Guidelines approach).

When comparing embodied emissions intensity values against other project values and/or benchmarks, its important to consider if the comparison includes parking in the area value. Projects that include parking materials in the embodied emissions but exclude the parking area in the denominator will show an artificially higher intensity value. Including the parking in both the embodied emissions and the area value reduces the resulting intensity value and makes the caps easier to achieve.

Several WBLCA tools exist which greatly streamline the process, including EC3, Athena Impact Estimator for Buildings, One Click LCA, Tally, and for smaller scale residential buildings, the BEAM Estimator.

In some instances, it is possible to perform the LCA analysis on a representative structural bay and section of envelope instead of the whole building. The results would then need to be scaled up to represent the full size of the building as appropriate.

It is recommended to submit results using the template found in Appendix A which is based on the CAGBC's Zero Carbon Building Standard Embodied Carbon Reporting Template.

## Biogenic Carbon

Biogenic carbon, sometimes called sequestered carbon is carbon stored in bio-based materials. It is carbon that has been removed from the atmosphere and stored in plant matter. Whether this carbon will ultimately return to the atmosphere is not possible to know with certainty as it will depend on the end-of-life process ranging from salvage and reuse, recycling, and/or landfilling or burning. As such, current LCA best practice is to not subtract this stored carbon from the embodied emissions values of the project (even if only reporting upfront embodied emissions), since it might give an artificially low value that isn't ultimately realized. Instead, it should be reported as a separate line item.

Although this approach is conservative (no risk of artificially underestimating eventual emissions), it fails to value the very real benefits that come with carbon removal and storage – even if that storage is only temporary, on the order of decades as when locked in building materials. After all, it is not the total amount of carbon in the atmosphere that matters, but the time it's in the atmosphere for, which causes climate impact.

Future research is needed along with the development of an approach for thoughtful ways to value this (potentially temporary) carbon storage. Future building carbon metrics may wish to consider the tonne-years that carbon is in the atmosphere for and apply a discount rate to future tonne-years to account for the "time value of carbon". This would value carbon temporary removed from the atmosphere even if it ultimately is rereleased at building end of life.

For more on this, see Build Beyond Zero: New Ideas for Carbon-Smart Architecture (Chris Magwood and Bruce King).

# APPENDICES

# APPENDIX A / EMBODIED EMISSIONS REPORTING TEMPLATE

The following template is recommended, which is based on the CAGBC's Zero Carbon Building Standard Embodied Carbon Reporting Template.

## 1. GENERAL INFORMATION

| PLEASE PROVIDE THE FOLLOWING GENERAL INFORMATION ABOUT THE PROJECT | |
|---|---|
| Project Name | |
| Embodied Emissions Assessor's Name | |
| Embodied Emissions Assessor Firm | |
| Date of Assessment Completion | |
| Software & Version Number | |
| Above grade storeys (#)<br>& gross floor area ($m^2$) including parking | |
| Below grade storeys (#)<br>& gross floor area ($m^2$) including parking | |
| Total storeys (#)<br>& gross floor area ($m^2$) including parking | |
| Parking levels (#)<br>& gross parking floor area ($m^2$) | |
| Project Life | ☐ 60 year |
| Assessment Timing<br><br>(check all that apply) | ☐ Schematic Design (Class D)<br>☐ Design Development (Class C)<br>☐ Tender / Construction Documents (Class B)<br>☐ Post Construction Documents (Class A) |
| Please confirm that the analysis includes all structural and envelope components ("mandatory materials") by checking the applicable boxes to the right. | ☐ Footings and foundations<br>☐ Complete structural wall assemblies (cladding to finish)<br>☐ Structural floors and ceilings (no finishes)<br>☐ Slab on grade<br>☐ Roof assemblies<br>☐ Stairs<br>☐ Parking structure (not including surface parking) |
| Please list any additional materials that are included at the applicant's discretion (in optional 'expanded scope'). | |
| How were the material quantities obtained? | ☐ From itemized cost estimates showing material quantities<br>☐ From BIM / 3D models<br>☐ From designers (architect, structural engineer, envelope designer)<br>☐ Manual take-offs from drawings |
| Note where proxies or generic EPDs were used instead of facility-specific EPDs from actual product manufacturers. | |
| Optional: provide any alternative intensity values here, for example residential projects might want to report kg $CO_2e$/unit or /bedroom. Offices may use kg $CO_2e$/desk. Etc. | |

## 2. CARBON EMISSIONS FOR EACH LIFE-CYCLE STAGE

Provide the following breakdown by life-cycle stage. If the software used does not provide values for every stage, leave the missing ones blank. If results are grouped (ie: A1-A3), merge those cells.

| Life-cycle Stage | | | | Embodied emissions from simplified scope | | OPTIONAL: Embodied emissions expanded scope | |
|---|---|---|---|---|---|---|---|
| | | | | Absolute (kg $CO_2$e) | Intensity (kg $CO_2$e/m$^2$) | Absolute (kg $CO_2$e) | Intensity (kg $CO_2$e/m$^2$) |
| Upfront | Product | A1 | Raw Material Supply | | | | |
| | | A2 | Transport (to factory) | | | | |
| | | A3 | Manufacturing | | | | |
| | Construction | A4 | Transport (to site) | | | | |
| | | A5 | Construction & Installation | | | | |
| | | Upfront Emissions | | | | | |
| *Only the value in the red box needs to be below the relevant embodied emissions cap shown in Table 1.* | | | | | | | |
| Biogenic Carbon (stored in bio-based materials): This value should not be subtracted from the embodied emissions values reported in other rows. | | | | | | | |

Optional other phases to be reported if desired, below:

| Life-cycle Stage | | | Embodied emissions from simplified scope only | | OPTIONAL: Embodied emissions expanded scope | |
|---|---|---|---|---|---|---|
| | | | Absolute (kg $CO_2$e) | Intensity (kg $CO_2$e/m$^2$) | Absolute (kg $CO_2$e) | Intensity (kg $CO_2$e/m$^2$) |
| Use | B1 | Use | | | | |
| | B2 | Maintenance | | | | |
| | B3 | Repair | | | | |
| | B4 | Replacement | | | | |
| | B5 | Refurbishment | | | | |
| | **Use Embodied Emissions** | | | | | |
| End of Life | C1 | Demolition | | | | |
| | C2 | Transport (to disposal) | | | | |
| | C3 | Waste Processing | | | | |
| | C4 | Disposal | | | | |
| | **End of Life Emissions** | | | | | |
| Cradle to grave embodied emissions (sum of above three main sections) | | | | | | |
| Beyond the Life-cycle | D | Reuse | | | | |
| | D | Recycling | | | | |
| | D | Energy Recovery | | | | |
| | Beyond Emissions | | | | | |
| Biogenic Carbon | | | | | | |

## 3. CONTRIBUTION ANALYSIS

Please provide a contribution analysis, broken out to the best of your ability by either material type or building assembly type. The list must include the top 5 contributing items at a minimum (concrete can only count as one, although multiple mix types can be listed separately).

| Material or Building Assembly *(add additional rows if desired)* | Absolute Embodied Emissions (kg $CO_2$e) | Embodied Emissions Intensity (kg $CO_2$e/m$^2$) |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |
| 5. | | |

## 4. REDUCTION MEASURES CONSIDERED

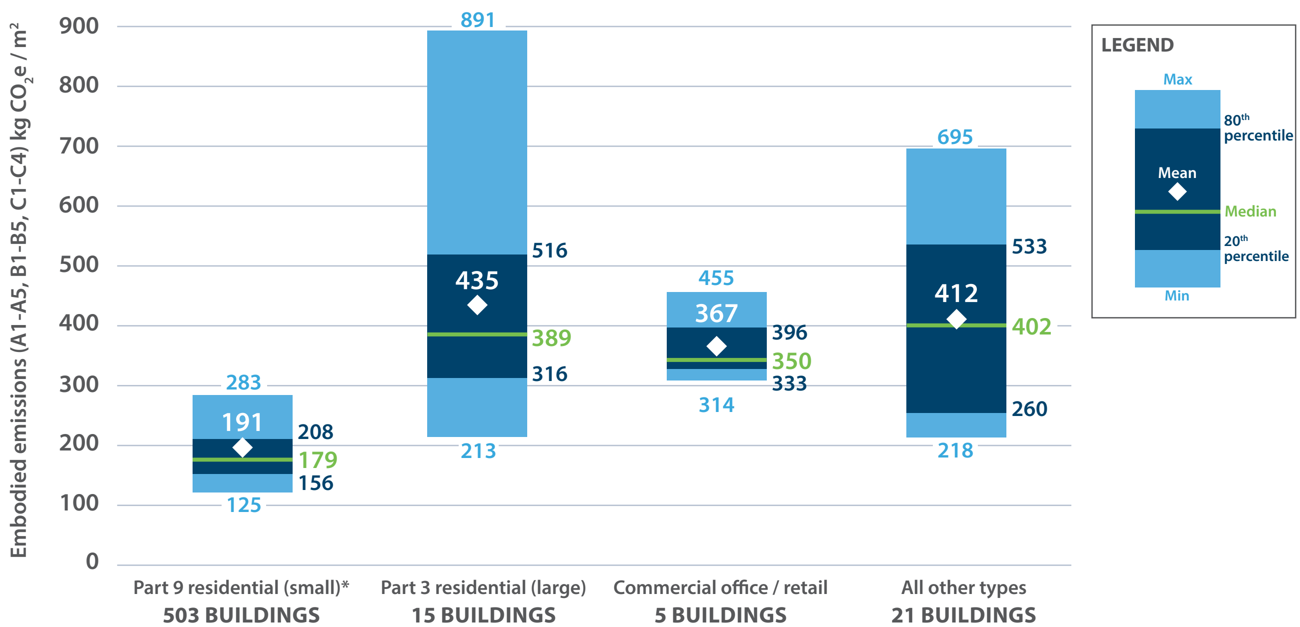
Please provide a list of embodied emissions reduction measures considered, as well as the associated embodied emissions reduction potential of each if known.

| Description of Embodied Emissions Reduction Measure | Absolute Reduction Potential (kg $CO_2$e) | Intensity Reduction Potential (kg $CO_2$e/m$^2$) | Measure enacted? (Y/N) |
|---|---|---|---|
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |

# APPENDIX B / BENCHMARKING TAKE-AWAYS

Below is the benchmarking for the self-reported data collected from 41 Part 3 buildings in Ontario (columns 2-4) plus benchmarking for Part 9 (smaller) buildings (column 1) from the EMARC study (see page 11 of this report for more).

The below results are the first attempt to collect and compare embodied emissions results as calculated using whole building life cycle assessments (WBLCA) for Part-3 buildings in Ontario. We received results for 41 separate Part-3 buildings. The results are shown below and will be used to inform future policy recommendations for the City of Toronto and other governments. Note there is some 'noise' in the results due to variations in methodology, scope of assessment, and tools used by the teams who calculated these values for each building. Nevertheless, these results are an important first step in understanding embodied emissions results in the City of Toronto and other Ontario municipalities.




**Key Findings:**

1. Embodied emissions assessments are being undertaken across Ontario. Received results for 41 projects from 16 different respondents.
2. Projects predominantly used either One Click LCA or Athena software. The results of these tools seem to be relatively consistent (average intensity of 398* vs 434, respectively).
3. Embodied emissions intensities increase with building height due to increased materials per area and greater subsurface works.
4. Buildings with timber structures seem to have lower embodied emissions (~16% lower). Including sequestration makes this difference significant (~59% lower).
5. 'Upfront carbon' (A1-A5) also accounts for the vast majority of embodied emissions, on average ~90%.
6. Methodology differences make high quality comparisons between projects difficult. Any future policy should provide clear guidance for required life cycle phases, objects of assessment, material quantity data sources, and treatment of carbon sequestration.
7. Significant carbon savings are immediately available to projects in their design stage. For example, working with one City of Toronto project, three material substitutions were approved (lower carbon concrete, lower impact XPS insulation, and lower impact concrete sealant) which led to a 26% reduction in total embodied emissions and over 800 tonnes of $CO_2$e avoided!

* See footnote 4 on page 10

8 all values are embodied emissions (global warming potential) intensity, phases A1-A5, B1-B5, C1-C4, in kg $CO_2e/m^2$. These results can be seen and share widely here.

# APPENDIX C / INDUSTRY FEEDBACK

In mid 2022, four separate workshops were held with unique stakeholder groups as listed below to help spread knowledge about this topic, present initial findings, and gather feedback on what a future policy on this topic could look like (feedback helped inform the content of this document). Efforts were taken to make any future policy and/or approach most effective, efficient, and streamlined. Below are the key findings. Over 300 professionals were engaged in this process.

### WORKSHOP 1
### (Designers, specifiers & consultants)

1. Support reuse of existing buildings
2. Bring in easy-to-achieve caps (reduces pushback and minimizes changes) which reduce over time
3. Aim to expand scope over time and bring in mechanical and other systems
4. Fundamental design decisions impact embodied emissions, and should be examined
5. Consider impacts on small projects and provide ways to streamline
6. Have clear and consistent approach to carbon sequestration and carbon-storing materials
7. Enforcement and verification required
8. Education, tools, programs required
9. LETI (London Energy Transformation Initiative) as an international best practice example
10. Keep alert for unintended consequences

### WORKSHOP 2
### (Manufacturers and material producers)

1. Use performance-based requirements
2. Embodied emissions reductions should come from both material and design revisions
3. Material efficiency is important and should be a focus
4. EPDs are already being created in Ontario, but cost is a challenge for small manufacturers
5. Cement Association of Canada is interested in collaborating on co-creating policy
6. WBLCA preferred over material-specific requirements. One participant noted it's the total building's impact we should reduce, so let's focus on WBLCA requirements instead of material-specific ones.
7. Consider innovative bio-based materials in future
8. More education is needed
9. Product labelling (simplified EPDs) should be considered
10. Phase-out materials that use fossil fuels

### WORKSHOP 3
### (Developers, owners & constructors)

1. When periodized, ~30%-50% reductions are possible without impacting cost or schedule
2. Be bold and avoid incrementalism
3. Support for building embodied emissions labelling
4. Desire for repository for Ontario best-in-class material EPDs

### WORKSHOP 4 (Governments and regulators)

1. Desire for a calculator that helps calculate estimated embodied emissions for X km of specific infrastructure types (as was done in Sweden)
2. Desire for a 'embodied emissions 101' resource
3. Don't prescribe low or mid-rise over high rise for embodied emissions purposes since increased density brings other benefits
4. Guidance on what municipalities legally require and how to implement
5. Tool or guide for material substitutions
6. Database of low-carbon materials and/or vendors
7. Guidance on what LCA at rezoning looks like and how its calculated and verified
8. WBLCA needs to be standardized

# APPENDIX D / OBJECT OF ASSESSMENT

The items listed in blue are the "simplified" object of assessment scope that should be used at a minimum and reported for all WBLCAs for benchmarking and comparison purposes.

Project teams wishing to perform a more holistic analysis are welcome to also calculate a separate scope using the "expanded" object of assessment scope, however results using this scope should be reported separately, with a combined Expanded + Simplified results.

| ALL NEW MATERIALS THAT ARE PART OF THE FOLLOWING SYSTEMS: | |
|---|---|
| S1 | Structural systems including footing and foundations, basement, floors, walls, columns, beams, and stairs |
| S2 | Envelope systems including exterior glazing and frames, cladding, framing, insulation, and roofing |
| S3 | Interior vertical finishes (gypsum and/or other) on structural elements. |
| S4 | Parking structures (above and below ground) |
| E1 | Site work, shoring, and excavation |
| E2 | Mechanical, electrical, plumbing |
| E3 | Fire detection, alarm, and data systems |
| E4 | Elevators and transportation systems |
| E5 | Interior horizontal finishes (flooring and ceiling) like carpets, ceiling tiles, etc. |
| E6 | Interior vertical finishes (gypsum and/or other) on non-structural elements |
| E7 | Surface parking lots |
| E8 | Interior (non-structural) partitions, doors, glazing |

| EXPANDED | SIMPLIFIED | UNIFORMAT NUMBER | OMNICLASS NUMBER | TITLE |
|---|---|---|---|---|
| | | A | 01 00 00 | Substructure |
| | | A10 | 01 10 | Foundations |
| | S1 | A1010 | 01 10 10 | Standard Foundations |
| | S1 | A1020 | 01 10 20 | Special Foundations |
| | | A20 | 01 20 | Subgrade Enclosures |
| | S1 | A2010 | 01 20 10 | Walls for Subgrade Enclosures |
| | | A40 | 01 40 | Slabs-On-Grade |
| | S1 | A4010 | 01 40 10 | Standard Slabs-on-Grade |
| | S1 | A4030 | 01 40 20 | Structural Slabs-on-Grade |
| | S1 | A4040 | 01 40 30 | Slab Trenches |
| | S1 | A4040 | 01 40 40 | Pits and Bases |
| | S1 | A4090 | 01 40 90 | Slab-On-Grade Supplementary Components |
| | | A60 | 01 60 | Water and Gas Mitigation |
| E1 | | A6010 | 01 60 10 | Building Subdrainage |
| E1 | | A6020 | 01 60 20 | Off-Gassing Mitigation |
| | | A90 | 01 90 | Substructure Related Activities |
| E1 | | A9010 | 01 90 10 | Substructure Excavation |
| E1 | | A9020 | 01 90 20 | Construction Dewatering |
| E1 | | A9030 | 01 90 30 | Excavation Support |
| E1 | | A9040 | 01 90 40 | Soil Treatment |

| EXPANDED | SIMPLIFIED | UNIFORMAT NUMBER | OMNICLASS NUMBER | TITLE |
|---|---|---|---|---|
| | | B | 02 00 00 | Shell |
| | | B10 | 02 10 | Superstructure |
| | S1 | B1010 | 02 10 10 | Floor Construction |
| | S1 | B1020 | 02 10 20 | Roof Construction |
| | S1 | B1080 | 02 10 80 | Stairs |
| | | B20 | 02 20 | Exterior Vertical Enclosures |
| | S2 | B2010 | 02 20 10 | Exterior Walls |
| | S2 | B2020 | 02 20 20 | Exterior Windows |
| | S2 | B2050 | 02 20 50 | Exterior Doors and Grilles |
| | S2 | B2070 | 02 20 70 | Exterior Louvers and Vents |
| | S2 | B2080 | 02 20 80 | Exterior Wall Appurtenances |
| | S2 | B2090 | 02 20 90 | Exterior Wall Specialties |
| | | B20 | 02 30 | Exterior Horizontal Enclosures |
| | S2 | B3010 | 02 30 10 | Roofing |
| | S2 | B3020 | 02 30 20 | Roof Appurtenances |
| | S2 | B3040 | 02 30 40 | Traffic Bearing Horizontal Enclosures |
| | S2 | B3060 | 02 30 60 | Horizontal Openings |
| | S2 | B3080 | 02 30 80 | Overhead Exterior Enclosures |
| | | C | 03 00 00 | Interiors |
| | | C10 | 03 10 | Interior Construction |
| E8 | | C1010 | 03 10 10 | Interior Partitions |
| E8 | | C1020 | 03 10 20 | Interior Windows |
| E8 | | C1030 | 03 10 30 | Interior Doors |
| E5 | | C1040 | 03 10 40 | Interior Grilles and Gates |
| E5 | | C1060 | 03 10 60 | Raised Floor Construction |
| E5 | | C1070 | 03 10 70 | Suspended Ceiling Construction |
| E5 | | C1090 | 03 10 90 | Interior Specialties |
| | | C20 | 03 20 | Interior Finishes |
| E6 (on non-structural elements) | S3 (on structural elements) | C2010 | 03 20 10 | Wall Finishes |
| E5 | | C2020 | 03 20 20 | Interior Fabrications |
| E5 | | C2030 | 03 20 30 | Flooring |
| E5 | | C2040 | 03 20 40 | Stair Finishes |
| E5 | | C2050 | 03 20 50 | Ceiling Finishes |
| | | D | 04 00 00 | Services |
| | | D10 | 04 10 | Conveying |
| E4 | | D1010 | 04 10 10 | Vertical Conveying Systems |
| E4 | | D1030 | 04 10 30 | Horizontal Conveying |

| EXPANDED | SIMPLIFIED | UNIFORMAT NUMBER | OMNICLASS NUMBER | TITLE |
|---|---|---|---|---|
| | | D1050 | 04 10 50 | Material Handling |
| | | D1080 | 04 10 80 | Operable Access Systems |
| | | D20 | 04 20 | Plumbing |
| E2 | | D2010 | 04 20 10 | Domestic Water Distribution |
| E2 | | D2020 | 04 20 20 | Sanitary Drainage |
| E2 | | D2030 | 04 20 30 | Building Support Plumbing Systems |
| E2 | | D2050 | 04 20 50 | General Service Compressed-Air |
| E2 | | D2060 | 04 20 60 | Process Support Plumbing Systems |
| | | D30 | 04 30 | Heating, Ventilation, and Air Conditioning (HVAC) |
| E2 | | D3010 | 04 30 10 | Facility Fuel Systems |
| E2 | | D3020 | 04 30 20 | Heating Systems |
| E2 | | D3030 | 04 30 30 | Cooling Systems |
| E2 | | D3050 | 04 30 50 | Facility HVAC Distribution Systems |
| E2 | | D3060 | 04 30 60 | Ventilation |
| E2 | | D3070 | 04 30 70 | Special Purpose HVAC Systems |
| | | D40 | 04 40 | Fire Protection |
| E3 | | D4010 | 04 40 10 | Fire Suppression |
| E3 | | D4030 | 04 40 30 | Fire Protection Specialties |
| | | D50 | 04 50 | Electrical |
| E2 | | D5010 | 04 50 10 | Facility Power Generation |
| E2 | | D5020<br>D5030 | 04 50 20<br>04 50 30 | Electrical Service and Distribution<br>General Purpose Electrical Power |
| E2 | | D5040 | 04 50 40 | Lighting |
| E2 | | D5080 | 04 50 80 | Miscellaneous Electrical Systems |
| | | D60 | 04 60 | Communications |
| E3 | | D6010 | 04 60 10 | Data Communications |
| E3 | | D6020 | 04 60 20 | Voice Communications |
| E3 | | D6030 | 04 60 30 | Audio-Video Communication |
| E3 | | D6060 | 04 60 60 | Distributed Communications and Monitoring |
| E3 | | D6090 | 04 60 90 | Communications Supplementary Components |
| | | D70 | 04 70 | Electronic Safety and Security |
| E3 | | D7010 | 04 70 10 | Access Control and Intrusion Detection |
| E3 | | D7030 | 04 70 30 | Electronic Surveillance |
| E3 | | D7050 | 04 70 50 | Detection and Alarm |
| E3 | | D7070 | 04 70 70 | Electronic Monitoring and Control |

| EXPANDED | SIMPLIFIED | UNIFORMAT NUMBER | OMNICLASS NUMBER | TITLE |
|---|---|---|---|---|
| E3 | | D7090 | 04 70 90 | Electronic Safety and Security Supplementary Components |
| | | D80 | 04 80 | Integrated Automation |
| E3 | | D8010 | 04 80 10 | Integrated Automation Facility Controls |
| | | E | 05 00 00 | Equipment and Furnishings |
| | | E10 | 05 10 | Equipment |
| | | E1010 | 05 10 10 | Vehicle and Pedestrian Equipment |
| | | E1030 | 05 10 30 | Commercial Equipment |
| | | E1040 | 05 10 40 | Institutional Equipment |
| | | E1060 | 05 10 60 | Residential Equipment |
| | | E1070 | 05 10 70 | Entertainment and Recreational Equipment |
| | | E1090 | 05 10 90 | Other Equipment |
| | | E20 | 05 20 | Furnishings |
| | | E2010 | 05 20 10 | Fixed Furnishings |
| | | E2050 | 05 20 50 | Movable Furnishings |
| | | F | 06 00 00 | Special Construction and Demolition |
| | | F10 | 06 10 | Special Construction |
| | | F1010 | 06 10 10 | Integrated Construction |
| | | F1020 | 06 10 20 | Special Structures |
| | | F1030 | 06 10 30 | Special Function Construction |
| | | F1050 | 06 10 50 | Special Facility Components |
| | | F1060 | 06 10 60 | Athletic and Recreational Special Construction |
| | | F1080 | 06 10 80 | Special Instrumentation |
| | | F20 | 06 20 | Facility Remediation |
| | | F2010 | 06 20 10 | Hazardous Materials Remediation |
| | | F30 | 06 30 | Demolition |
| E1 (for building being removed) | | F3010 | 06 30 10 | Structure Demolition |
| E1 (for building being removed) | | F3030 | 06 30 30 | Selective Demolition |
| E1 (for building being removed) | | F3050 | 06 30 50 | Structure Moving |
| | | G | 07 00 00 | Sitework |
| | | G10 | 07 10 | Site Preparation |
| E1 | | G1010 | 07 10 10 | Site Clearing |
| E1 | | G1020 | 07 10 20 | Site Elements Demolition |

| EXPANDED | SIMPLIFIED | UNIFORMAT NUMBER | OMNICLASS NUMBER | TITLE |
|---|---|---|---|---|
| E1 | | G1030 | 07 10 30 | Site Element Relocations |
| E1 | | G1050 | 07 10 50 | Site Remediation |
| E1 | | G1070 | 07 10 70 | Site Earthwork |
| | | G20 | 07 20 | Site Improvements |
| E7 | | G2010 | 07 20 10 | Roadways |
| E7 | S4 (parking structures above and below ground) | G2020 | 07 20 20 | Parking Lots |
| E7 | | G2030 | 07 20 30 | Pedestrian Plazas and Walkways |
| E7 | | G2040 | 07 20 40 | Airfields |
| E1 | | G2050 | 07 20 50 | Athletic, Recreational, and Playfield Areas |
| E1 | | G2060 | 07 20 60 | Site Development |
| E1 | | G2080 | 07 20 80 | Landscaping |
| | | G30 | 07 30 | Liquid and Gas Site Utilities |
| E2 | | G3010 | 07 30 10 | Water Utilities |
| E2 | | G3020 | 07 30 20 | Sanitary Sewerage Utilities |
| E2 | | G3030 | 07 30 30 | Storm Drainage Utilities |
| E2 | | G3050 | 07 30 50 | Site Energy Distribution |
| E2 | | G3060 | 07 30 60 | Site Fuel Distribution |
| E2 | | G3090 | 07 30 90 | Liquid and Gas Site Utilities Supplementary Components |
| | | G40 | 07 40 | Electrical Site Improvements |
| E2 | | G4010 | 07 40 10 | Site Electric Distribution Systems |
| E2 | | G4010 | 07 40 50 | Site Lighting |
| | | G50 | 07 50 | Site Communications |
| E3 | | G5010 | 07 50 10 | Site Communications Systems |
| | | G90 | 07 90 | Miscellaneous Site Construction |
| E1 | | G9010 | 07 90 10 | Tunnels |

# APPENDIX E / ADDITIONAL RESOURCES

1. Embodied Emissions Guide for BC Municipalities
2. RMI: Reducing Embodied Carbon in Buildings. *Carbon Leadership Forum* https://carbonleadershipforum.org/rmi-reducing-embodied-carbon-in-buildings/ (2021)
3. A recent study found that embodied emissions in buildings can be reduced by between 24% and 46% at cost premiums of less than 1%.
4. Ontario embodied emissions benchmarking in small Part 9 buildings study
5. Ha/f Studio publications on Ontario embodied emissions. 2021 article. 2022 article.
6. Recording of one of the industry workshops undertaken as part of this project.

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