Strategies for low carbon concrete: primer for federal government procurement: low carbon assets through life-cycle assessment (LCA)² initiative

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https://doi.org/10.4224/40002759

Low Carbon Assets through Life-Cycle Assessment (LCA)[2] Initiative

Strategies for Low Carbon Concrete

Primer for Federal Government Procurement

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1 Executive **Summary**

A large amount of carbon emissions is generated by the harvesting, transportation, manufacture and end of life disposal/recycling of construction materials. These emissions are referred to as “embodied carbon” and are measured using a technique called life cycle assessment (LCA). As buildings become more efficient in their annual operating energy and thus lower their operational carbon, the construction industry and policy makers around the world have become increasingly concerned with the growing relative impacts of embodied carbon.

An LCA conducted on a LEED-certified Ontario government building that was built in 2013 shows that over a 60-year time frame, embodied carbon accounts for over 40% of the total whole life carbon footprint of a building.[1] A 2018 Intergovernmental Panel on Climate Change[2] report indicated that approximately a 12-year window remained for significant emission reduction before catastrophic effects of climate change become unavoidable. If the 12-year timeframe is considered instead of the standard LEED 60-year timeframe, embodied carbon becomes the dominant source of emissions, accounting for closer to 75% of emissions (Figure 1). That same LCA study found that the concrete in the building was responsible for approximately 50% of the embodied carbon.[3] Therefore, in the first 12-years of a building’s life cycle, concrete alone is responsible for nearly 40% of the building’s total carbon impact.

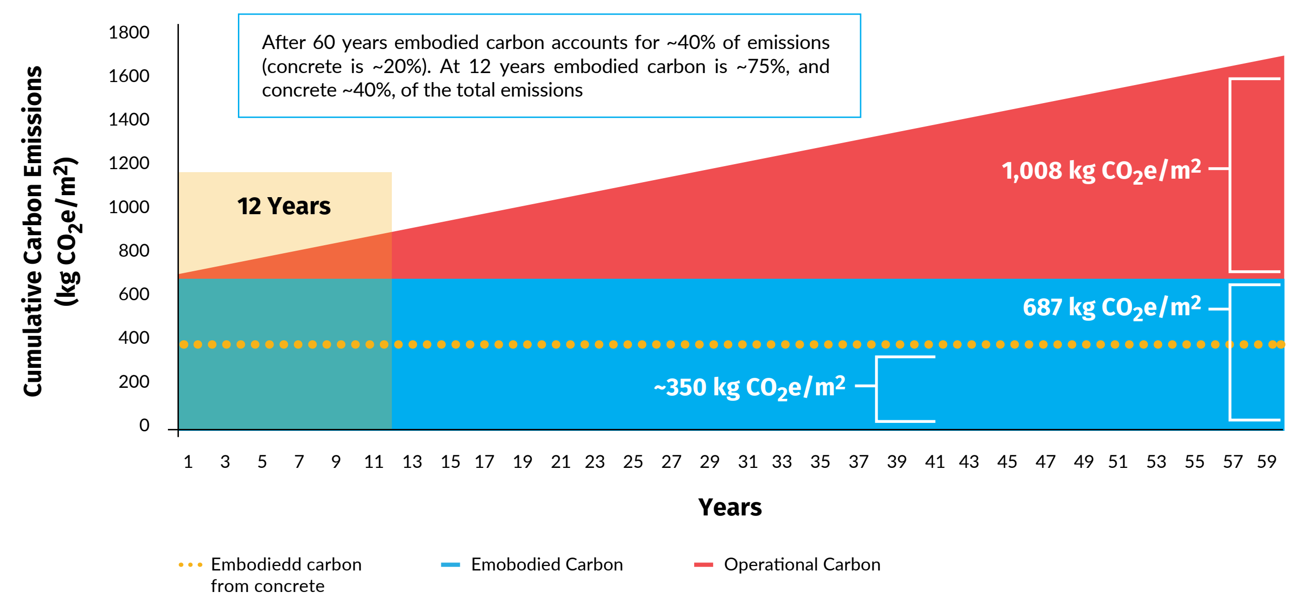


Figure 1: Life cycle carbon footprint for a LEED-certified government building in Ontario, completed in 2013

There are numerous strategies that can be used to reduce the embodied carbon of concrete, many of which can be accomplished for no additional cost and with minimal performance impacts. This primer has been developed to assist government officials to better understand these strategies in support of updating procurement policies and procedures towards the goal of lowering embodied carbon from concrete in government construction. This primer can also be used as a discussion point between government project owners and designers. In general, most concrete mix designs can be altered to reduce CO_2 footprints by employing the following strategies:

[1] *Mantle314, Integrating Life-cycle Assessment (LCA) into Ontario’s Infrastructure Planning and Decision Making, August 2018*
[2] *Intergovernmental Panel on Climate Change, Global Warming of 1.5C – Summary for Policymakers, October 2018.*
[3] *This is the embodied carbon impact from the concrete alone, without the reinforcing steel, which would add even more to the embodied carbon. The concrete embodied carbon data was sourced from Canadian Ready-Mixed Concrete Association’s CRMCA Member Industry-Wide EPD, 2017. Available at www.crmca.ca*

1. **Consider performance-based design requirements** some specifications are prescriptive meaning they specify a minimum amount of cement required and/or a maximum allowable amount of supplementary cementing materials (SCMs), for example. In some cases, this may lead to excess cement use and/or leave opportunity for additional SCMs – both of which mean the mix could have been lower carbon. Instead, use performance-based specifications for strength and durability, while noting that low-carbon options are required, or preferred. This allows designers the flexibility to vary the concrete mix ingredients in the most carbon-efficient manner possible while achieving the desired performance.

2. **Material efficiency.** Ask designers to prioritize a materially efficient design (right-size / avoid over-engineering). In general, less materials means less carbon.

3. **Use Portland-limestone cement – also called "general-use limestone" (referred to as GUL and/or PLC).**[4]
Portland cement – also called "general-use cement" (GU and/or PC) is one of the main components of concrete and accounts for approximately 90% of its carbon footprint (if used as sole binder). PLC incorporates between 5 - 15% limestone, reducing the PC clinker content and reducing the carbon footprint by around 10%. PLC is approved for a 1-to-1 replacement substitution with PC without requiring any changes to the concrete mix design. It should also be a cost-neutral substitution in most regions in Canada.

4. **Maximize the use of supplementary cementing materials (SCMs), alternative cementitious materials or blended cements.**
SCMs reduces clinker content of the concrete binder by incorporating industrial by-products such as blast furnace slag, silica fume, ground glass, natural pozzolans and fly ash or use of alternative cementing materials such as calcined clay. Less clinker means lower carbon.

5. **Maximize recycled content in reinforcing steel (rebar).** Most rebar in Canada contains recycled content. Consideration should be given for a language that prioritizes or requires a high level of recycled content in rebar to minimize its embodied carbon.

6. **Adjust testing age.** Adjust "age strength" by structural element or application. The strength of concrete increases over time; more cement means strength is achieved faster. Specifying a certain strength achieved by 28-days is typical. However, not all structural elements / applications require full strength within 28- days that has become standard in the industry. If this timeline can be extended for some elements (like footings, columns and walls), less cement is required and embodied carbon is reduced. Structural engineers should be involved in discussions of adjusting testing age.

7. **Aggregate optimization and gradation.** Aggregate optimization reduces cementitious content of the concrete meaning less cement is needed.

8. **Use of water reducing admixtures.** These chemicals are added to the concrete mix to reduce the amount of water used for a given amount of cement while still maintaining good flow and improving concrete compressive strength. It is possible, however, to use them to reduce cement content for a given water to cement ratio due to improved dispersion and uniform distribution of cement grains.

These measures may be used to make significant reductions in the CO_2 footprint of concrete mix designs by reducing the amount of cement clinker content.

[4] *Portland-limestone cement may also be referred to as: General Use Limestone (GUL), Portland Limestone Cement (PLC) or branded trade names (e.g. Contempra).*

2 Glossary of **Key Terms**

Embodied Carbon as a concept has had a relatively low profile until recently and is still not widely understood by industry and policy makers. The various life cycle stages involved and their carbon categorization is show in Figure 2.

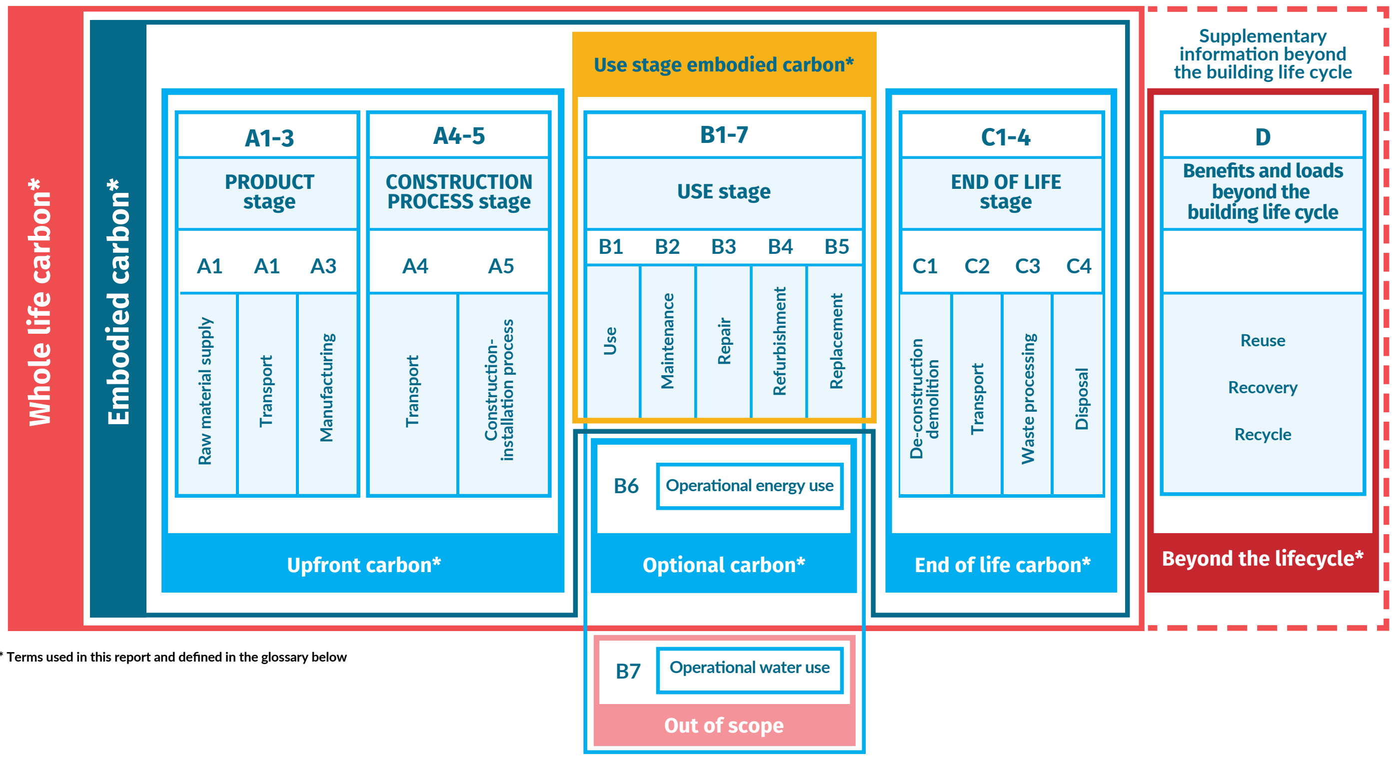


Figure 2: Life cycle phases and carbon categorization[5]

Whole life carbon: Emissions from all life cycle phases, encompassing both embodied and operational carbon together (i.e. modules A1 to C4, with module D reported separately).
Whole life carbon = embodied carbon + operational carbon.

Operational carbon: The emissions associated with energy used (B6) to operate the building or in the operation of infrastructure.[6]

Embodied carbon: Carbon emissions associated with materials and construction processes throughout the whole life cycle of a building or infrastructure. Embodied carbon therefore includes: material extraction (module A1), transport to manufacturer (A2), manufacturing (A3), transport to site (A4), construction (A5), use phase (B1) which includes concrete carbonation[7], maintenance (B2), repair (B3), refurbishment (B4), replacement (B5), [but excluding operational carbon (B6)], deconstruction (C1), transport to end of life facilities (C2), processing (C3), disposal (C4). Benefits beyond the system boundary (D) should also be reported separately from modules A-C (not aggregated together).

[5] *Figure and definitions from "Bringing Embodied Carbon Upfront"' by World Green Building Council. September 2019. Image adapted from EN 19578.*
[6] *This could also include secondary emission sources such as refrigerant leaks, depending on the scope of the LCA.*
[7] *Carbonation (long term absorption of atmospheric carbon into exposed concrete) happens in phase B1 but is often not included in LCA studies or their resulting EPDs. Research into this important topic continues and effort should be made to better understand and integrate carbonation's atmospheric carbon removal into future studies.*

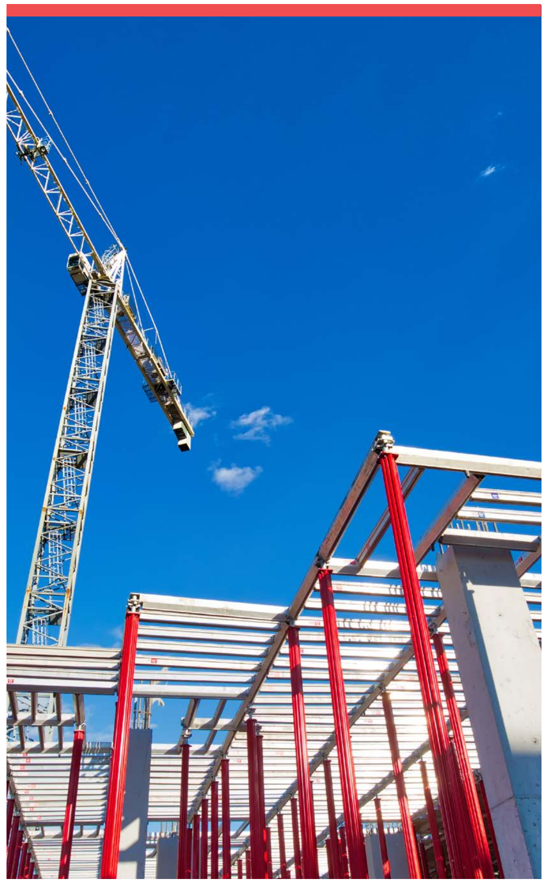
Life cycle assessment (LCA): LCA is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product or material throughout its life cycle.[8]

End of life carbon: The carbon emissions associated with deconstruction/demolition (C1), transport from site (C2), waste processing (C3) and disposal (C4) phases of a building or infrastructure's life cycle which occur after its use phase.

Upfront carbon: The emissions caused in the materials production and construction phases (A1-A5) of the life cycle before the building or infrastructure begins to be used. In contrast to other categories of emissions listed here, these emissions have already been released into the atmosphere before the building is occupied or the infrastructure begins operation. Upfront carbon can be reduced through changes to the procurement process that prioritizing lower carbon materials, supply chains and processes.

Beyond the life cycle: Carbon emissions or reductions incurred due to reuse or recycling of materials or emissions avoided due to using waste as a fuel source for another process (module D). Consideration of module D is key for maximizing resource efficient uses of materials at the end of life. Results from module D should always be presented alongside other life cycle phases and not aggregated together.

Use stage embodied carbon: Emissions associated with materials and processes needed to maintain the building or infrastructure during use including refurbishments. These are additional emissions to the "use stage".



[8] *Several LCA standards exist including ISO 14040 and ISO 14044. Multiple other standards exist which apply LCA methodology to products (EN 15804, ISO 14067, ISO 21930) and to buildings (EN 19578, ISO 21929, ISO 21931), for example.*

3 About this **Primer**

Prioritizing lower carbon materials is not yet a mainstream practice in the construction industry. Even leading voluntary green building systems like LEED have only introduced meaningful strategies to tackle this issue in recent updates. Lately, awareness around the concept and importance of embodied carbon is surging. Policies are being introduced around the world to reduce the carbon footprint of construction materials.

This Strategies for Low Carbon Concrete Primer (Primer) introduces approaches in concrete mix design and specification which can be used to reduce CO_2 footprint. This is also part of the Government of Canada's *Low-carbon assets through life cycle assessment* (LCA2) initiative.[9] The Primer will introduce the concept of embodied carbon of concrete, present current industry best practices to reduce CO_2 emissions associated with concrete production, and provide a high-level overview of the federal procurement process with potential insertion points where new low-carbon concrete policies and procedures could be introduced into the federal procurement process.

The intended audience for this Primer is federal government procurement policy makers, business owners (project authorities), technical authorities and contracting authorities. This Primer is designed to demonstrate the need in reducing embodied carbon in procurement in order to meet Canada's carbon reduction goals, and to provide easy-to-implement strategies for consideration to incorporate into procurement documents. This primer can also be used as a discussion point between government project owners and designers - the strategies presented here could be adopted with relative ease and minimal cost to drive down the embodied carbon of government procured concrete. Government of Canada has completed a carbon footprint study of its procurement which estimates that emissions associated with procurement is greater than twice those of its operations, which highlights the urgency with which procurement-based emissions must be addressed.

The appendices provide information about a range of changes to standard concrete production that are being explored by industry and may be viable opportunities over time to further reduce the embodied carbon of construction in Canada.

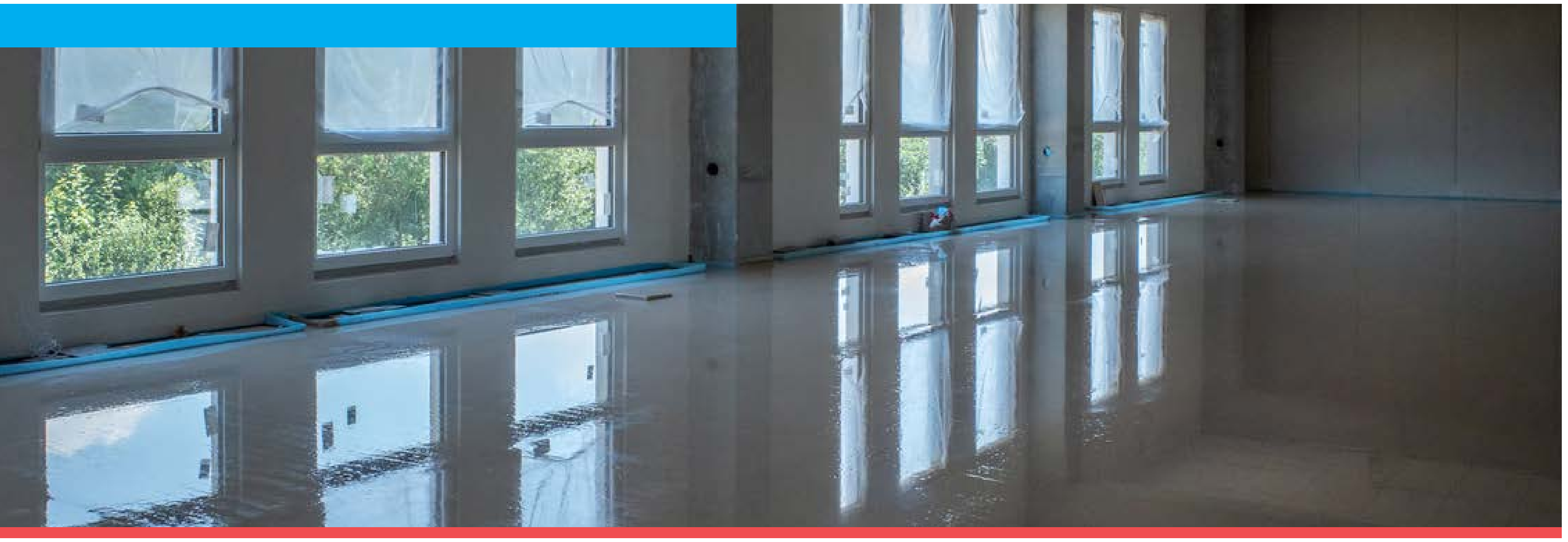
[9] *For more information on the initiative, please refer National Research Council Canada's website https://nrc.canada.ca/en/research-development/research-collaboration/programs/low-carbon-assets-through-life-cycle-assessment-initiative*

4 The Growing Importance of **Embodied Carbon**

The profile of embodied carbon has grown significantly in the past few years, as the design and construction industry has increasing appreciation for its significant, growing, and often overlooked carbon footprint.

In the past, buildings were far less energy efficient and our energy system was more carbon intensive. Subsequently, operational carbon emissions far outweighed embodied carbon over the life cycle of a building. As such, taking action to reduce embodied carbon was not a priority. Over the past decades, buildings have become increasingly energy efficient and energy systems are decarbonizing as investments in renewables surge. This ongoing shift has greatly decreased the operational carbon footprint of new buildings. As a result, embodied carbon is now a significant portion of new building's whole life carbon and growing. In fact, embodied carbon can be nowadays considered as the dominant source of emissions from new buildings if we consider the shorter time scales in which significant emissions reductions are needed.

An LCA study was conducted to calculate the environmental impacts from a recent reinforced concrete LEED-certified government building completed in 2013 in southern Ontario. The results showed that over a 60-year timeframe, embodied carbon represented over 40% of the total whole life carbon footprint of a building. While the study showed that over a 12-year timeframe, embodied carbon becomes the dominant source of emissions, accounting for closer to 75% of emissions (Figure 3). The 12-year timeframe was recommended by the Intergovernmental Panel on Climate Change report to significantly reduce carbon emissions before catastrophic effects of climate change become unavoidable. That same LCA study found that the concrete in the building was responsible for approximately 50% of the embodied carbon.[10]



[10] *This is the carbon impact from the concrete alone, without reinforcing steel, which would add to the embodied carbon footprint.*

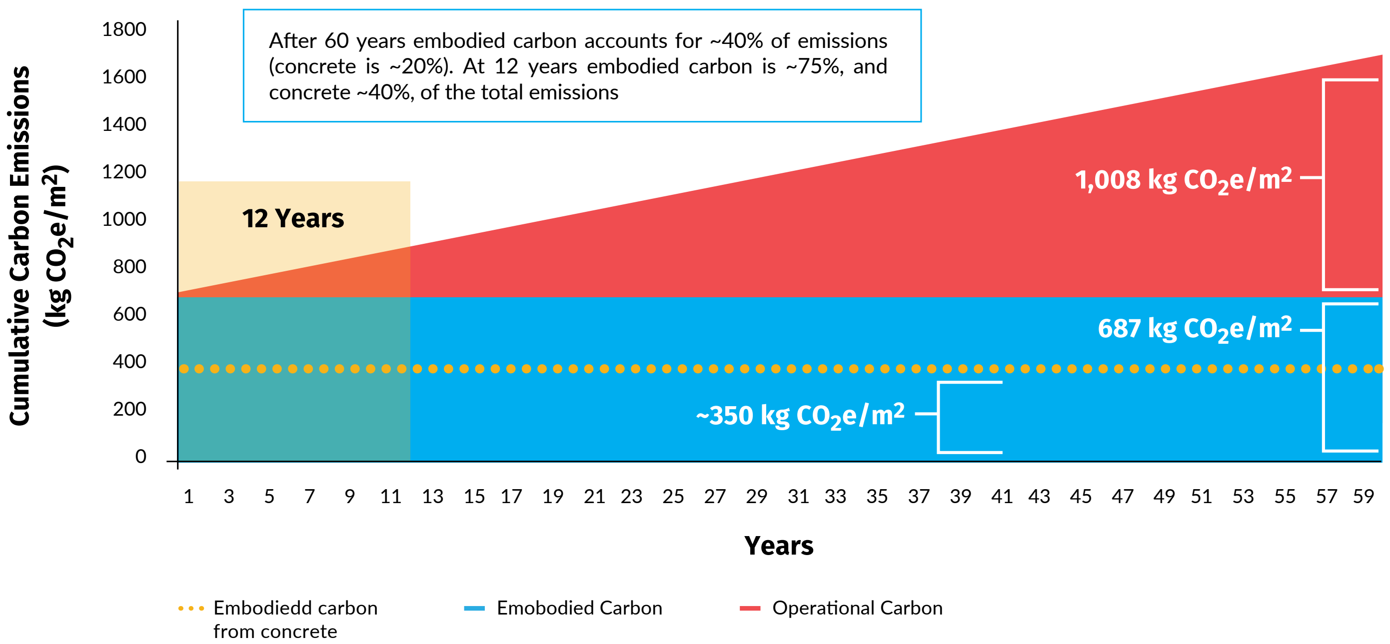


Figure 3: Life cycle carbon footprint for a government building in Ontario, completed in 2013.[11]

It should be noted that the relationship between operational and embodied carbon emissions and the percentage values provided in the previous example are specific to the study in question; the relationship should not be assumed to apply uniformly to buildings across the country. For example, another LCA study[12] of a reinforced concrete building in Vancouver found the embodied carbon to make up 83% of the whole life carbon at year 12 and 50% at year 60. Other examples are expected to differ even more widely since various buildings aspects will impact the ratio of embodied to operational carbon, including:

- **Energy efficiency of the building design.** Highly efficient buildings will use less energy and therefore less carbon for operations. Energy efficiency standards (for example, as outlined in building codes) varies by province and even by municipality in some cases where cities have set more stringent energy targets, including examples like the *Toronto Green Standard*, and Vancouver's Zero Emissions Building Plan. Additionally, some projects target more stringent voluntary standards like LEED or the Zero Carbon Building Standard.

- **Electricity generation source.** A given unit of electricity can be high or low carbon, depending on how it was generated / produced. Some provincial electricity grids are very low carbon, where most electricity is generated using hydro-electric dams which generate nearly no carbon. Other provinces use fossil fuels like natural gas and coal, and thus their electricity has a higher carbon footprint. Some provinces which use a mix of hydro, nuclear and natural gas, are somewhere in between (but still on the low-carbon end of the spectrum).

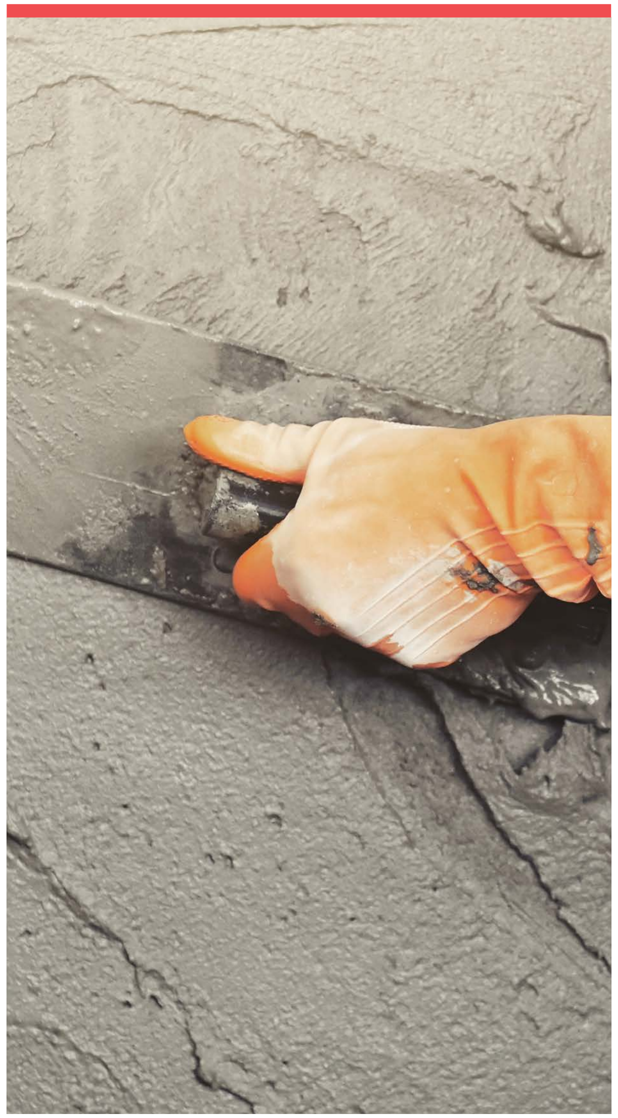
[11] *These findings will vary based on properties of the building assessed, including material decisions, energy efficiency, and climate (energy demand), among others. The scope of this LCA was limited to structural and envelope systems in the building (a common LCA scope). Most embodied carbon impacts are associated with structural and envelope materials that are not replaced during the use phase. Typically, small increases of embodied carbon would occur during the use phase when items such as windows are replaced but would be a small portion of total embodied carbon. Larger increases would occur during major renovations. Only the initial upfront embodied carbon was calculated in this study; no major renovations were assumed.*

[12] *Marceau et all, Life Cycle Assessment for Sustainable Design of Precast Concrete Commercial Buildings in Canada, www.athenasmi.org*

- *Embodied carbon reductions should be especially prioritized in regions with low-carbon electricity. In these regions, codes and programs which reduce electricity use will have a relatively small carbon benefit. In these regions, increased effort could be placed in reducing carbon from areas such as fuel use or embodied in materials during production and transportation.*

- **Heating demand**. A building in Vancouver will require significantly less heating energy than one in Winnipeg. The more heating a specific climate requires, the more operating (heating) energy and thus carbon it will emit. The source of this heating energy also matters. For example, an electrically heated building in an area where electricity is very low carbon might use relatively little carbon. The same electrically heated building in another region that uses fossil fuels to generate electricity would have a vastly different carbon impact. Many parts of Canada use natural gas for heating – the carbon content of which is mostly consistent across the country, although mechanical system efficiencies and local conditions can cause some variations.

- **Embodied carbon and materials**. The above three examples all deal with concepts that will impact the scale of operational emissions of a project. Of course, there are also decisions that would impact the scale of the embodied emissions, such as local material production processes, transportation mode and distance, and material efficiency. The specifics of how materials are made also matters a great deal.[13]



[13] *As this primer explains, examples exist of high-carbon and low-carbon concrete. A similar situation exists for steel. Timber harvested from an old-growth forest would have a much larger carbon impact than timber harvested from a responsibly managed secondary forest.*

5 Understanding **Concrete and Carbon**

Manufacturing construction materials such as concrete and steel (among others) is responsible for 11% of global emissions.[14] In Canada, concrete is one the most widely used construction materials with annual production rate of 60 million tonnes, while cement – the main binder in concrete – has a production rate of 14 million tonnes.[15] In 2017, 1.5% (10.8MT) of Canada's GHG emissions was from concrete and cement.[16] Average Canadian cement has been calculated and verified in an environmental product declaration[17] (see Section 5.2) to have a cradle-to-gate[18] global warming potential (GWP) of 0.940 kg CO_2e / kg of cement for standard Portland cement and 0.856 kg CO_2e / kg of cement for lower carbon Portland-limestone cement.[19]

5.1 Embodied carbon of concrete

The embodied carbon of a product is the sum of the carbon emissions associated with the material and construction processes from all phases of a product's life cycle. See Section 2.

Concrete is a mixture of aggregates (e.g. sand, gravel or crushed stone), water and cement (made of limestone, sand, and clay) that hardens over time. Chemical admixtures are sometimes added to produce a higher quality concrete and to modify fresh and hardened concrete properties. These admixtures could include many types of compounds such as water reducer, superplasticizer, retarders, viscosity modifying, air entraining, and shrinkage reducing admixtures. Supplementary cementing materials (SCMs) – sourced from industrial by-products may be utilized to reduce concrete permeability and also improve its long term durability performance. Incorporating SCMs in concrete will reduce the amount of cement content required for a particular mix design. See Figure 4.

[14] *Architecture2030.org*
[15] *Statistics Canada, 2018*
[16] *Canadian Green Building Council, Taking Concrete Steps to a Carbon Neutral Future, December 11, 2019*
[17] *Cement Association of Canada, Environmental Product Declaration for General Use (GU) and Portland-Limestone (GUL) Cements. v1.1. March 2016.*
[18] *See Figure 2: cradle-to-gate corresponds to A1-A3*
[19] *Cement Association of Canada, General use (GU) and Portland-limestone (GUL) cements, March 31, 2016*

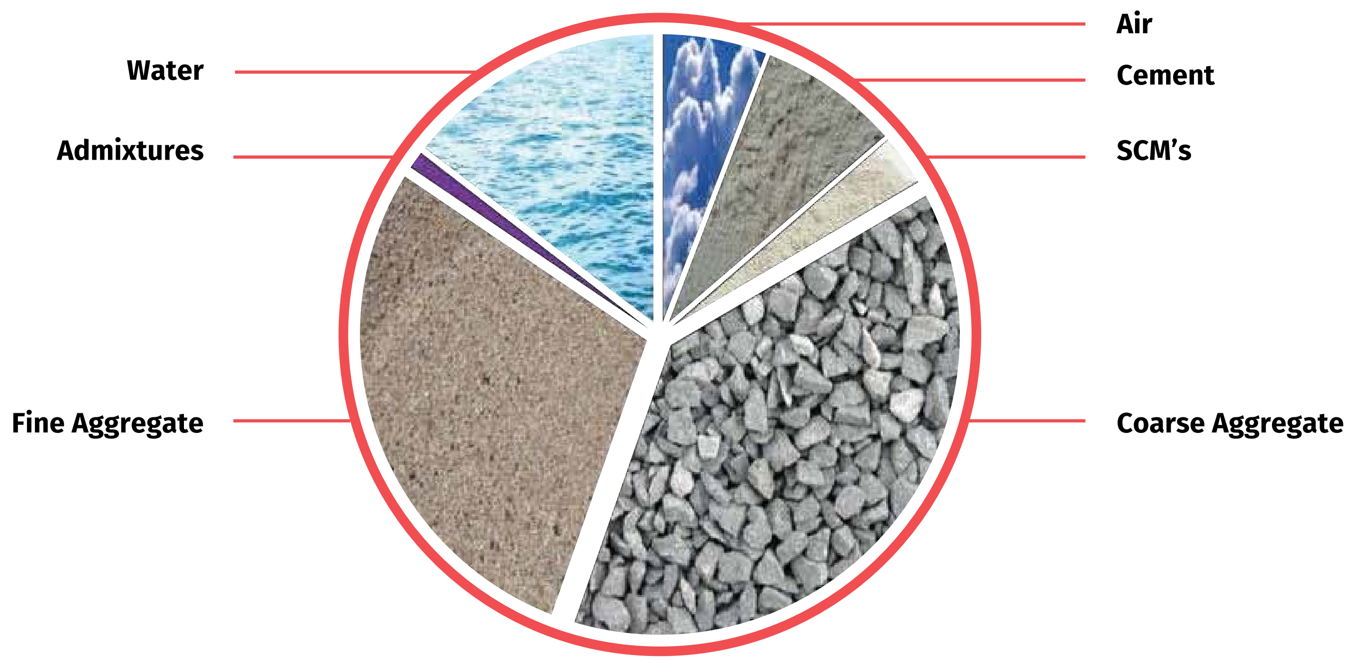


Figure 4: Concrete ingredients and typical relative amounts[20]

The embodied carbon of a specific concrete mix is dependent on the embodied carbon of each ingredient and their relative amounts. The embodied carbon of each ingredient is dependent on the chemical and manufacturing processes they undergo (including the efficiency and fuels consumed in the processes and plants, for example), and the transportation of all raw materials. See Figure 5.

[20] *Construction Canada, "Cement and concrete, still outperforming in the sustainability era", November 2019.*

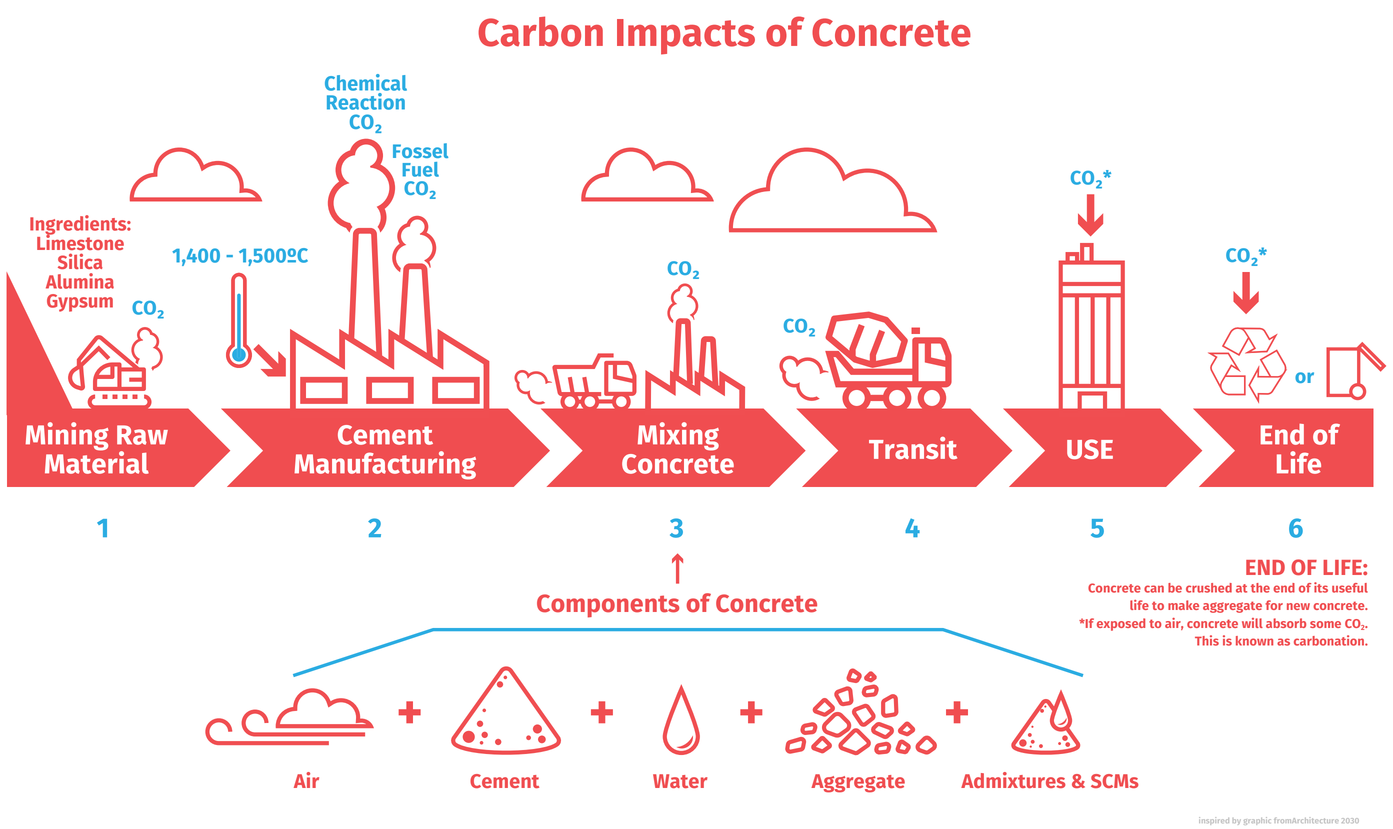


Figure 5: Illustration of life cycle carbon impacts of concrete. Inspired by graphic from Architecture 2030 [21]

In most cases, relatively little carbon is emitted during the process of mining the aggregates, combining the materials at the concrete plant, and transporting the concrete to the construction site. By far the biggest source of emissions in the concrete production process is the manufacturing of cement.[22] Therefore, the amount of embodied carbon in concrete is primarily a function of how much cement is used in the mix. **Minimizing the cement content is an effective way to reduce the carbon footprint of concrete.**

One third of cement manufacture emissions are due to combustion of fossil fuels to heat up the cement kiln for raw materials such as limestone, clay, etc. Two thirds of emissions are from chemical reactions or calcination of carbonates such as limestone producing CO_2.[23]

It should also be noted that concrete is nearly always reinforced with reinforcing steel, also called rebar, which is another source of embodied carbon but will not be examined in detail in this primer. In general, reinforcing steel in North America typically has recycled content around 97% with specialty high strength and stainless steel closer to 75% recycled.[24]

[21] *Architecture2030.org*
[22] *National Ready Mixed Concrete Association, Concrete CO_2 Fact Sheet, June 2012 [Concrete CO_2 Fact Sheet]*
[23] *Canadian Green Building Council, Taking Concrete Steps to a Carbon Neutral Future, December 11, 2019*
[24] *Concrete Reinforcing Steel Institute. LEED Position Statement. https://www.crsi.org/Resources/misc/CRSI-LEED_Position_Statement.pdf*

5.2 Environmental product declarations (EPDs)

An environmental product declaration (EPD) is a disclosure document that reports a product's environmental impacts (as calculated from an LCA) in a standardized way. EPDs can be used during the procurement process to better understand the embodied carbon of materials being evaluated. Some EPDs that are third-party verified and adhere to standards such as ISO 14025 are published by program operators.[25] These third-party databases of EPDs helps ensure high standards.

The scope of EPDs can vary in a few important ways:

- **Representativeness**. Some EPDs are prepared with industry-averaged values, meaning they do not represent the unique characteristics of specific products or manufacturers, but rather demonstrate the average impact for a product type or industry. Alternatively, facility-specific (or manufacture-specific) EPDs capture the upstream supply-chain and manufacturing impacts of a specific facility or manufacturer.

- **Life Cycle Phases / Scope.** EPDs can also vary in which life cycle phases they include. Most EPDs are "cradle-to-gate" meaning they include all upstream supply-chain processes from raw material harvesting (the material "cradle") to the end of the manufacture process (the manufacturer's "gate"). These are shown as phases A1, A2 and A3 in Figure 2. Cradle-to-gate is the most typical EPD scope since manufacturers are typically the ones who commission the creation of the EPD (setting the scope) and are able to use EPD results to improve efficiency, including by changing upstream supply chain providers and in-house equipment efficiency and fuel. Also, it would be difficult for a manufacturer to estimate the environmental impacts associated with its product once it has left the 'gate'. For example, it is hard to estimate where a product will be shipped to and how it will be disposed of. Some manufacturers make assumptions for these future life cycle phases. If all future phases are included in an EPD, it would be known as a "cradle-to-grave" or "cradle-to-cradle" EPD and include life cycle phases A, B, and C in Figure 2. Finally, an EPD could also be "gate-to-gate" meaning it only includes the manufacturer's internal processes from 'entrance gate to exit gate'.

In 2017, the Canadian Ready-Mixed Concrete Association (CRMCA) released an industry-wide cradle-to-gate EPD26 that covers concrete mixes produced by CRMCA members across Canada. The industry-average representative nature of the EPD means the results show the environmental impacts for an average concrete mix produced in an average Canadian plant. Actual impacts for a specific plant would vary depending on plant technology, transportation modes and distances and the provincial electricity grid, among other things. This EPD is valid until 2022 and provides data on 15 life cycle impact assessment indicators (environmental impacts) including Global Warming Potential (GWP) which is the metric for embodied carbon. The EPD provides a range of mixes with varying cement types (GU and GUL)27, percentage of SCMs, admixtures, by various strength classes. It also notes the benchmark / standard mix type for each strength class.

[25] Program operators administer and manage EPDs and website databases of them among many other related responsibilities which are fully described in ISO 14025.
[26] Although most EPDs are "cradle-to-gate", most whole-building LCAs are "cradle-to-grave" meaning the environmental impacts from future life cycle phases are estimated. Although most EPDs are "cradle-to-gate", most whole-building LC. As are "cradle-to-grave" meaning the environmental impacts from future life cycle phases are estimated. s 'Portland-limestone cement', or PLC. GU means 'general use', also known as 'Portland cement'. GUL means 'general use-limestone',also known as 'Portland-limestone cement', or PLC."
[27] GU means 'general use', also known as 'Portland cement'. GUL means 'general use-limestone',also known as 'Portland-limestone cement', or PLC.

Figure 6 shows the range of carbon intensity as reported in the EPD, per concrete strength class. These results show that the carbon content of a concrete mix can vary by nearly a third between the benchmark (most common mix) and the lowest GWP option, regardless of strength requirements.

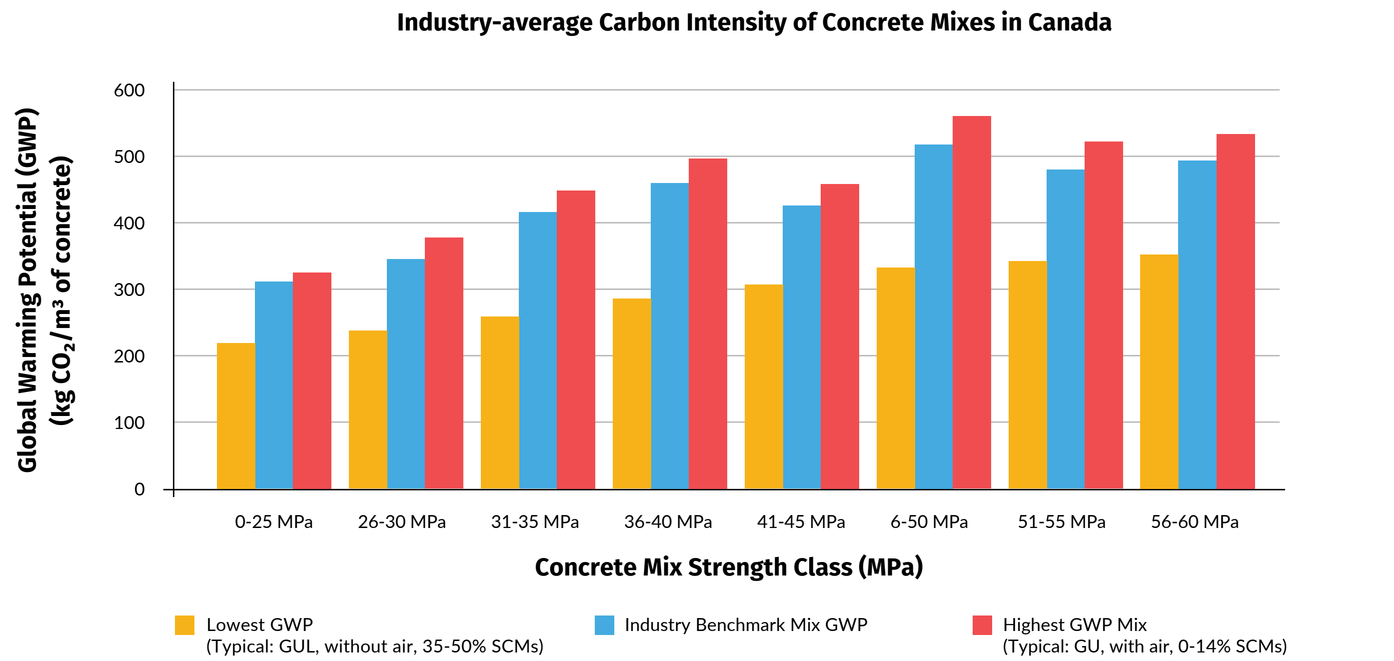


Figure 6: Embodied carbon (A1-A3 life cycle stages: material harvest, transportation to manufacture, and manufacture) for range of ready-mix concrete scenarios; Canadian industry-average. [28]

Other concrete-based industry wide EPDs have been published for North American:

- Architectural and insulated wall panels
- Structural precast concrete
- Underground precast concrete civil engineering products (pipes, boxes, etc.)
- These three EPDs were released in 2015 and all were updated in 2020, with the exception of underground precast concrete, and provide average data representing the outputs for over 1,000 facilities across North America. To understand the carbon impact of precast concrete, the total GWP of one metric tonne of a typical structural precast panel is 298.8 kgCO2, with Stage A1 Raw Material Supply accounting for 89% of impact.[29]

Canadian concrete and cement facility specific EPDs also exist, including for:

- Concrete masonry blocks
- Concrete pavers

See Appendix A for a full list of North American-wide and Canadian concrete and cement EPDs.

[28] Canadian Ready-Mixed Concrete Association, Industry-wide Environmental Product Declaration, 2017. Available www.crmca.ca [29]
CPCI, NPCA, PCI, Structural Precast Concrete Industry Wide EPD, 2015. Available at http://ww.sustainableprecast.ca/

Life Cycle Assessment (LCA) is a method of measuring the environmental impacts of a product or service over all phases of its life cycle, which are organized as follows (see Figure 2):

- **Phase A – Product and Construction Process Stage:** raw material extraction, processing, manufacture, transportation, construction
- **Phase B – Use Stage:** use, maintenance, refurbishment, repair
- **Phase C – End of Life Stage:** disassembly, transportation and ultimate end-of-life (landfill, reuse, or recycle)

LCA can be used to measure several different environmental impacts, including embodied carbon which is represented as global warming potential (GWP) and measured in kg CO_2e.

LCA Software Tools

Product- or material-level LCA software tools require production level data and make use of global databases like **ecoinvent**. These tools can be used to create EPDs. Commonly used tools include **SimaPro and GaBi**.

Other tools exist to help present and compare EPD results, such as the Embodied Carbon in Construction Calculator (EC3) – by C-Change Labs

Additionally, whole-building LCA tools can be used to aggregate results from multiple materials and compare design scenarios and material options, including:

- **Impact Estimator for Buildings** – by the Athena Sustainable Materials Institute
- **One Click LCA** – by Bionova
- **Tally** – by KT Innovations, thinkstep, and Autodesk

5.3 Embodied carbon policy

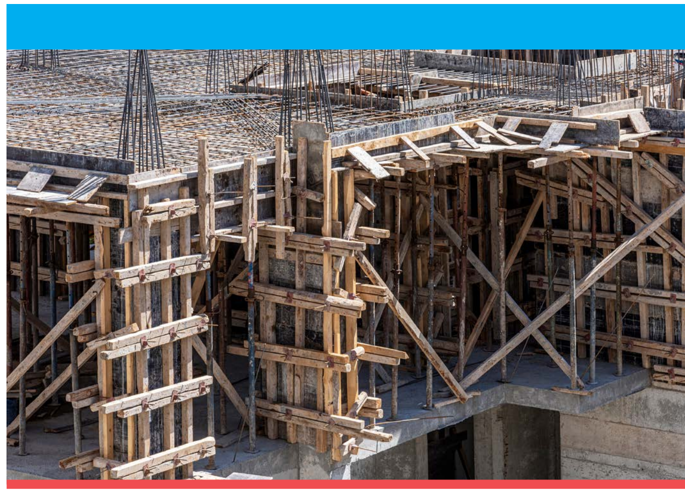
As building energy efficiency increases and energy systems decarbonize a growing proportion of the carbon impact of new buildings becomes attributed to construction material embodied carbon. Most embodied carbon is emitted during material harvest and manufacture and is emitted to the atmosphere with no chance of being reduced in the future, other than through future carbon removals. This contrasts with building operational carbon, which can be reduced in the future through the installation of more efficient energy systems and through the continued decarbonization of energy sources.

Taking action to reduce embodied carbon can lead to significant carbon reductions in the short term. These factors have led to the rapidly growing interest and emphasis on taking embodied carbon-related actions by both industry and various level of governments. Below are a few recent examples of embodied carbon policy:

- **Mandatory whole building embodied carbon calculation and reporting.** The City of Vancouver requires the reporting of embodied carbon for allprojects seeking rezoning; the City is targeting a 40% reduction in new building embodied carbon by 2030 against a 2018 baseline. The cities of Toronto and Edmonton require whole building embodied carbon reporting for all new government buildings.
- The Government of Canada's Greening Government Strategy[30] released in January 2021 includes a commitment to reduce the environmental impact of structural construction materials by:
    - disclosing the amount of embodied carbon in the structural materials of major construction projects by 2022, based on material carbon intensity or a life-cycle analysis
    - reducing the embodied carbon of the structural materials of major construction projects by 30%, starting in 2025, using recycled and lower-carbon materials, material efficiency and performance-based design standards
    - conducting whole building (or asset) life-cycle assessments by 2025 at the latest for major buildings and infrastructure projects

Similar requirements are expected to roll-out across various levels of governments, building owners and construction companies.

- **Material-specific procurement requirements:** Buy Clean California sets a ceiling on the embodied carbon content for certain construction materials that the state will purchase as of July 2021. Facility-specific EPDs will be required to demonstrate compliance with the embodied carbon limits. Note: concrete was excluded from the current version of the policy but is being targeted for inclusion in future version.
- **Changes to existing voluntary green-building rating systems:** For the first time, the newest version of LEED (v4) includes credits that award reductions in a project's embodied carbon and/or use of materials that have their embodied carbon disclosed / publicly available through EPDs.
- **New green-building rating systems:** the Canada Green Building Council's Zero Carbon Standard uses carbon as its key performance metric and requires reporting of embodied carbon. The 2020 update of the standard requires carbon offsets to be purchased for all embodied carbon. This provides a financial incentive to projects with a lower embodied carbon and will provide a driver for lower carbon materials.



[30] https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html

6 Best Practices for **Low Embodied Carbon Concrete**

There are numerous actions that can be taken to reduce the carbon content of concrete – many with no impact on cost, performanceperformance, or schedule. This section is designed to help government officials better understand these strategies so they can begin integrating them into their procurement guidelines, contracts, and projects.

It may not be possible to implement all of the following strategies in a single project as concrete design requirements may vary from region to region as do project objectives. However, these measures should be considered for inclusion in the procurement process, project specifications, or concrete mix design where appropriate.

6.1 Consider performance-based design requirements

Many changes can be made to reduce the CO_2 footprint of concrete mixtures. Performance specifications can be used to design concrete structures based on durability performance as well as to provide suppliers and contractors with the flexibly to develop more sustainable mixtures and practices. Prescriptive-based specifications, where a minimum amount of cement content or maximum allowable SCM is specified, prevents concrete producers from providing a more innovative concrete that can meet the performance requirements while maximizing low carbon approaches. In some cases, the "age at test" for compliance with required properties can be extended if early strength is not needed until 56 or 91 days.

Performance-based requirements outline the desired performance requirements including strength and durability, noting that low-carbon options are preferred. This allows designers the flexibility to vary the concrete mix ingredients in the most carbon-efficient manner possible while meeting the project requirements and desired properties.

6.2 Material efficiency

Only build what is necessary, aiming to not over-build the structure, but instead to right-size it. Avoid over-engineering by working with structural engineers to understand the options to optimize material efficiency, and potentially reduce the materials used and their associated emissions. Methods may include:[31]

- **Shorter bay distances (less distance between columns)** which allows for thinner slabs. Note that more columns may be needed to make up for shorter bay sizes, which may mean more concrete; but it might still be a net concrete decrease overall.
- **Optimizing reinforcement**. For example, slabs on grade can be cast without reinforcement if alterative crack control measures are used. Alternatively, it may be worth considering high-strength, post-tensioned, and/or pre-stressed reinforcement, which often has the same embodied carbon as conventional reinforcement but allows less material to be used.

[31] *Carbon Smart - Materials Palette, Concrete – Design and Construction Guidance, 2019 [Concrete – Design and Construction Guidance]*

6.3 Use Portland-limestone cement

In 2008 the CSA A3001 specification introduced a new class of Portland-limestone cement (PLC) – also known as general use limestone or GUL -- containing 5 to a maximum of 15% limestone which is interground with clinker and calcium sulfate. Replacing a portion of cement with limestone decreases the amount of clinker required which is one of the main contributors of CO_2 emissions. This results in significant reductions in the amount of energy used by reducing the amount fuel needed for clinker production, and further reducing greenhouse gas emissions due to a smaller amount of limestone calcination taking place. It is known that use of PLC cement has a direct effect on reducing CO_2 emissions by approximately 10% while in most cases providing equivalent performance as Portland cement. The CSA A23.1 concrete standard included PLC in 2009 and this was also later adapted in Canadian and provincial building codes in 2011.[32]

Portland-limestone cement has been gaining in popularity in recent years. In British Columbia, PLC accounts for over 50% of domestic cement consumed and is also prioritized in the province's climate plan. PLC adoption is expected to accelerate as more decision makers specify it. PLC has the potential to reduce Canada's greenhouse gas emissions by up to one megaton annually.[33]

Since Portland-limestone cement is optimized to provide performance comparable to regular Portland cement manufactured in Canada, no significant changes are required to concrete mix designs when all cement is replaced with Portland-limestone cement.[34] At the standard 10% limestone replacement rate used in Canada when creating Portland-limestone cement, PC can be directly substituted with PLC without any changes to the mix design while having the same handling and performance. However, adjustments to the admixture dosage may be required. At higher than 10% replacement rates (which would require a custom higher-limestone order from a cement plant), other mix design parameters would need to be adjusted.[35]

The industry is moving towards the use of PLC by default. The Government of Canada could accelerate this transition by specifying Portland-limestone cement as its default cement type.

Note that other types of low carbon cement also exist, although most are not currently as widely available as Portland-limestone cement.

6.4 Maximize the use of supplementary cementitious materials (SCMs), alternative cementitious material or blended cements

Partial replacement of cement with supplementary cementitious materials (SCMs) – such as blast furnace slag, silica fume, ground glass, natural pozzolans and fly ash is recommended. In Canada, SCMs are generally added separately by the concrete producer. With the exception of silica fume blended cement other types of blended cements are not currently popular in Canada. Most concrete mix designs in Canada contain slag or fly ash as partial replacement of Portland cement (generally 10 – 40% replacement level). The SCM type used depends on local availability and experience. However, the replacement levels are limited either due to specification limits or by construction demand for high early strength development and rapid setting of the concrete. In addition, not all SCMs are available locally in every region and because of the continuously new environmental and

[32] *Hooton, 2014.*
[33] *Cement Association of Canada, Contempra Brochure*
[34] *Cement Association of Canada, Portland- Limestone Cement (ContempraTM) Brochure, November 2018*
[35] *Cement Association of Canada, Presentation at Building Show, December 2019*

safety regulations being imposed on coal burning power plants (the source for fly ash), the quality and availability of some are becoming concrete. In addition, not all SCMs are available locally in every region and because of the continuously new environmental and safety regulations being imposed on coal burning power plants (the source for fly ash), the quality and availability of som are becoming further limited. Therefore, alternative supplementary cementitious materials (ASCM) not yet defined as SCM under CSA A3001 may be suitable for use in concrete to provide pozzolanic or hydraulic benefits provided their manufacture is low in CO_2 emissions and meet CSA A3001 requirements for ASCM.

Replacing a portion of cement with SCM will result in further carbon reductions and can also bring other benefits including lower permeability, increased resistance to chlorides and sulfates, mitigation of alkali silica reaction, greater strength, lower temperatures for mass concrete, and improved workability.[36]

There is opportunity to further increase the amount of SCMs used in concrete or encourage the use of ternary blends. However, increasing the SCM content may result in lower early age strength development and its durability performance with regards to freezing and thawing, chloride ingress and carbonation has to be carefully examined before application. A properly designed and cured concrete containing high levels of SCMs can have exceptional performance. SCM levels of up to 70% could be possible in some applications.[37] Concrete designers are best suited to determine the specific SCMs and percentages to use. Therefore, instead of prescribing a specific SCM percentage, consider updating specifications to performance based and giving the suppliers the opportunity to aim for the lowest carbon concrete possible. This performance-based approach allows the designer flexibility and the opportunity to innovate, including by maximizing SCMs as appropriate for the given application. See Section 6.8 for more on performance-based design.

Note that in some cases, a high percentage of SCMs can lead to impacts on concrete colour. In cases where the concrete colour is important, be sure to discuss this requirement with your concrete mix designer

6.5 Maximize recycled content in reinforcing steel (rebar)

Reinforced concrete contains steel (rebar). Most rebar in Canada contains recycled content. Consider language that prioritizes or requires a high level of recycled content in rebar to minimize its embodied carbon. Projects should be able to achieve rebar steel recycled rates above 95% for typical steel, and above 75% for specialty product like high strength or stainless-steel rebar.[38]

6.6 Adjust “age strength” by structural element or application.

The strength of concrete increases over time; more cement means strength is achieved faster. Consider allowing the specified date at which compressive strength is reached to vary above the standard 28 day “age strength”. Responsible structural engineer should be asked to identify building components that can have a longer “age at test” (longer period of 56 or 90 days could be reasonable depending on the project and application), which means less cement can be used and therefore lower embodied carbon. Generally, the concrete used for foundations and certain structural elements – footings, mat slabs, shear walls or lower level columns – does not require full strength by 28 days, making these elements prime candidates for longer age at test and thus less cement and carbon.[39]

[36] *Lafarge Canada.*
[37] *For example, BASF's Green Sense Concrete technology replaced 71% of the Portland cement with SCMs, while achieving all construction requirements. For more information, refer to BASF's Green Sense Concrete: The Concrete Technology for Sustainable Construction.*
[38] *Concrete Reinforcing Steel Institute. LEED Position Statement. https://www.crsi.org/Resources/misc/CRSI-LEED_Position_Statement.pdf*
[39] *P. Melton, Building Green, The Urgency of Embodied Carbon and What You Can Do about it, September 2018*

6.7 Aggregate optimization

Current North American specifications for fine and coarse aggregate grading can result in less than ideal particle packing. The cement paste content of a concrete mixture is typically 25 to 40% by volume, and the aggregate takes up most of the rest of the volume. The cement content for a given concrete mix design may be reduced by optimizing the particle packing of the aggregates and increasing the finer mineral filler content. As the cement content fraction decreases, the total aggregate fraction increases; therefore, properties such as concrete strength, drying shrinkage, and resistance to fluid penetration may be improved. Aggregate particle packing optimization may then reduce the required cement content without compromising concrete performance and therefore, further reducing the embodied carbon of concrete.

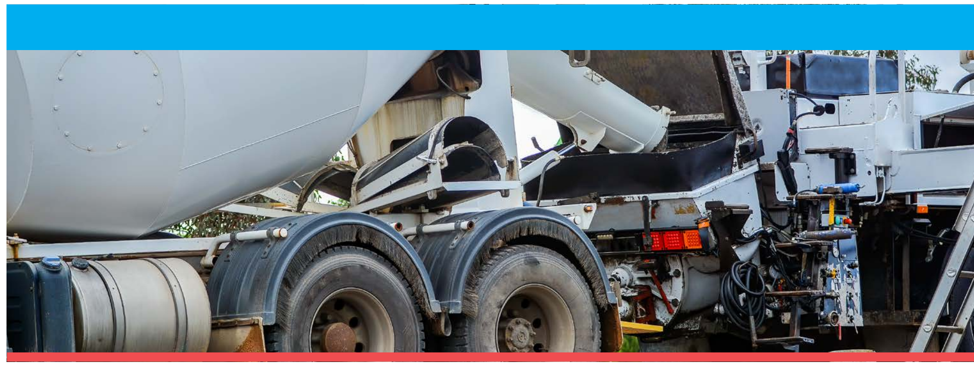
6.8 Use of water reducing admixtures

Water reducing admixture are typically used in concrete to produce a higher quality concrete. Use of this admixture results in dispersing cement grains, providing better workability and uniform distribution of cement particles while reducing the amount of water used in the concrete mix for a constant amount of cement. However, it is also possible to use them to reduce both the cement and water while maintaining a given water-to-cement ratio. Additionally, use of high range water reducer (HRWR) can also provide higher workability and further reduce the cementitious content of a concrete mix design. Therefore, use of these admixtures should be considered to reduce the cement content of the concrete.

6.9 Special Mention: Recycling / reuse of crushed concrete

Note: this strategy is not applicable to the design of new concrete mixes (as all other above strategies are), however has been included as a 'special mention' since it is a simple way to minimize environmental impacts through smarter use of crushed concrete.

Crushed concrete (such as from building demolition) can be used for many applications on-site including fill and road / parking lot base. Consider prioritizing the reuse of any crushed concrete on-site when low quality aggregate is needed. This will reduce the environmental and financial impacts of both bringing virgin aggregate to site and disposing of crushed concrete off-site.



7 Procurement **Strategies**

7.1 Overview of Canada's Federal Procurement Policy

The Treasury Board of Canada (Treasury Board) has been delegated overall responsibility for establishing general expenditure policies as they pertain to the federal procurement process. In addition to setting general principles of contracting, the Treasury Board is also responsible for approving contracts entered into by federal contracting agencies when such contracts exceed certain monetary thresholds, which are periodically established by the Treasury Board.

Public Services and Procurement Canada (PSPC),[40] formerly Public Works and Government Services Canada, is the principal purchasing agent of the federal government, and is responsible for providing procurement sources for most federal departments. The statutory basis and administrative framework of PSPC is established by the Department of Public Works and Government Services Act.[41] As it relates to procurement for building materials, PSPC must act in accordance with the Financial Administration Act, the Government Contracts Regulations, and directives issued by the Treasury Board.

PSPC retains considerable discretion to set policies and procedures respecting the procurement process. This has been accomplished through several guidance documents, including the Supply Manual, which contains policies and procedures, as well as references to acts and directives for the procurement of goods, services and construction.[42]

7.2 High-level government commitments on green procurement

Consistent with the United Nations' 2030 Agenda for Sustainable Development and the Canadian Federal Sustainable Development Strategy, the federal government has developed its Greening Government Strategy. Specific to the federal procurement process, the strategy lists commitments related to low-carbon building materials and construction procurement:[43]

The government will reduce the environmental impact of structural construction materials by:

- disclosing the amount of embodied carbon in the structural materials of major construction projects by 2022, based on material carbon intensity or a life-cycle analysis
- reducing the embodied carbon of the structural materials of major construction projects by 30%, starting in 2025, using recycled and lower-carbon materials, material efficiency and performance-based design standards
- conducting whole building (or asset) life-cycle assessments by 2025 at the latest for major buildings and infrastructure projects

7.3 Policy-based insertion points

The following policy-based insertion points provides examples of specific policies or guidelines / manuals where embodied carbon requirements could be integrated. Though they are central documents that govern green procurement in Canada, there does not appear to be specific requirements around purchasing low carbon materials, or anything specific to concrete, SCMs, or cement type in the Supply Manual or Canadian Policy on Green Procurement. Policy-based insertion points for integrating embodied

[40] Public Services and Procurement Canada main page.
[41] SC 1996, c. 16
[42] Public Services and Procurement Canada, Supply Manual, Version 2019-3 [Supply Manual]
[43] Government of Canada, Greening Government Strategy, 2017

carbon generally revolve around reporting, designing, comparing materials and designs, and setting benchmarks.

Please note that this primer should be used in conjunction with existing procurement policies and best practices, including adherence to trade treaties.

Canadian Policy on Green Procurement

- Introduced in 2006 and updated in 2018, this document aims to integrate environmental considerations into procurement activities.[44] This includes planning and buying, use and maintenance, and disposal to reduce the environmental impact and ensure best value.
- The policy could be revised to require, prioritize or incentivize materials which have corresponding EPDs accompany procurement bids which could demonstrate embodied carbon below a certain threshold, for example.
    - In California, for example, the *Buy Clean California Act* will require by 2020 that project teams submit facility-specific EPDs. By 2021, the state will publish a set of embodied carbon thresholds / caps that specific construction materials must meet in order to be purchased by the state.[45] Note: concrete was excluded from the current version of the policy but is being targeted for inclusion in future version.

PSPC Supply Manual[46]

- Provides policies and procedures for PSPC contracting officers going through the procurement process.
- S. 1.10.10 lists "procurement best practices"; this is a location where requirements prioritizing low embodied carbon could be inserted.
- S. 4.15.5 outlines several requirements for contracting officers to consider green procurement in preparing solicitation documents. A revision could require that officers consider integration of low carbon material requirements into solicitation documents.
- S. 1.60.1(e) lists requirements for contracting officers overseeing the procurement process. Point (ii) indicates that officers must "incorporate environmental considerations into the commodity management process for all procurement instruments, if applicable".
    - There is no standalone definitions section in the Supply Manual, however s. 1.60.1. could define "environmental considerations" to include embodied carbon of materials.

Canadian National Master Construction Specification (NMS)

- Comprehensive master specification serving as a framework for writing construction project specifications in Canada.[47]
- Document contains over 850 master design and construction specification sections meant to be edited from the original to produce a project-specific document, intended for use by federal

[44] Government of Canada, Policy on Green Procurement, 2018
[45] Buy Clean Washington Study, p. 2-6. See also: Buy Clean California Act
[46] Government of Canada, Public Services and Procurement Canada Supply Manual ,2021-1
[47] National Research Council of Canada, National Master Construction Specification

- Document contains over 850 master design and construction specification sections meant to be edited from the original to produce a project-specific document, intended for use by federal government, public organizations, and the private sector in the preparation of construction and renovation contracts.
- NMS is regularly reviewed by government and industry specialists to ensure content reflects current standards, practices and technology.
- The NMS describes options for construction materials that meet or exceed applicable codes, standards or project-owner requirements. Although highly focused on requirements of federal government departments, NMS may not be the most appropriate tool to mandate requirements for low carbon materials. Rather, NMS can serve as a platform to convey project-specific, quantifiable requirements and act as an enabler for the Architecture, Engineering and Construction (AEC) community to meet government policy targets.
- Each NMS Section includes specification notes embedded in the text to help designers select which material they will use for their construction project.
- Division 03 – Concrete, of the NMS, includes 18 specifications' Sections that specify different kinds of concrete either by prescriptively or by performance, and other materials used in relation to concrete, such as forming or epoxy.
- The NMS (2021-01) Publication included the following:
    - "Division 01 – General Requirements" – introduction of Product Category Rules (PCR) and Life Cycle Assessments to support the submittal procedures for Environmental Product Declarations (EPD).
    - "Division 03 – Concrete":
        - Introducing the latest standards and technologies, Portland-limestone cement (GUL), SCMs, recycled content, and CO2 entrainment requirements.
        - Placeholders for setting material-specific limits or reduction targets for global warming potential (GWP), and submittal of EPDs.
    - Master performance-based specifications – reference to the Greening Government Strategy, and introduction of project-level design considerations for low carbon systems and materials

7.4 Procurement and potential embodied carbon policy insertion points

Below are the main steps in the construction procurement process.[48] Procurement is a vital tool for the Canadian government as it allows for the integration of low embodied carbon requirements into its building design and construction operations. The suggestions below outline several potential insertion points for low embodied carbon requirements into the government's procurement process for a construction project. Note that certain strategies may be more applicable for larger value projects, as they will likely have additional time, scope, budget, resources, and carbon reduction potential.

[48] *Public Services and Procurement Canada Supply Manual*

1. Planning

Planning includes developing and organizing the project delivery strategy and preparing complete project instruction to the project team based on parameters of scope, time, cost, and risk. The procurement strategy must satisfy the client's operational requirements and comply with legal requirements, while achieving best value, and advancing national objectives, including any commitments to use low carbon materials.

Embodied carbon insertion point: Consider inserting wording around prioritizing lower carbon materials into project strategy documents. Links can be made to federal targets and programs, including several of the Greening Government Strategy's commitments referenced in Section 7.2 above.

2. Procure design services

Procurement of design services includes developing a Statement of Work (SOW) and procurement documents to engage a prime consultant for architectural and/or engineering services. Service requirements are subsequently formalized in a contract.

Embodied carbon insertion point: State a requirement (mandatory, based on policy) or desire to consider or use low carbon concrete in the SOW or procurement document to engage design services. Ensure these low-carbon requirements are also integrated into design contract documents. Related government targets or policy requirements along with examples of best practices such as those found in Section 6 could be included to guide designers.

3. Design and costing

Design includes developing construction documents comprised of plans and specifications complying with the project objectives and requirements and producing the approval documents required for effective project approval.

Embodied carbon insertion points: Through the design stage the designer will follow the instructions agreed to in the design service contract, which could include low-carbon considerations. Throughout the design process ensure these low-carbon contract requirements are being followed. Considerations include prioritizing lower carbon materials, disclosing the embodied carbon of the project and specific materials and processes.

4. Procure construction services

Construction services are acquired to deliver the product defined in the approved design solution that meets project objectives and requirements as set out in the construction contract documents including plans and specifications. The builder, whether a general contractor or a concrete sub-trade, will provide a price to complete the services based on the contract documents.

Embodied carbon insertion point: General contractor could require construction teams to provide EPDs for materials purchased and/or prioritize lower carbon construction methods and materials, disclose the embodied carbon of the project and specific materials and processes, and reuse crushed concrete on-site where appropriate. Construction contracts could also include requirements around tracking carbon-related information for materials purchased such as quantity, recycled content and manufacture name and location (and thus transportation distance). These requirements should be considered during the project design stage and included in project specifications, and any associated project operating instructions and service provider contracts.

5. Construction

All construction-related activities are carried out in this step according to contract documents. Commissioning ensures that a building will meet all requirements when handed over to its owner. The builder, whether a general contractor or a concrete sub-trade, will complete the services based on the contract documents.

Embodied carbon insertion point: Ensure carbon-based construction contract requirements are followed throughout the construction process. Considerations could include collecting data during construction including material quantities and suppliers for concrete. This is valuable information to calculate the embodied carbon associated with concrete and the project as a whole. These requirements should be considered during the project design stage and included in project specifications, and any associated project operating instructions and service provider contracts.

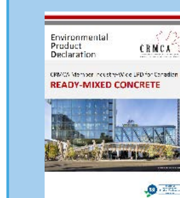
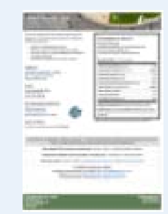
6. Handover, operations and maintenance

Following completion of construction and commissioning, a handover is done between the constructor and the agent of Crown and tenants move into the building. A warranty period of typically one year begins.

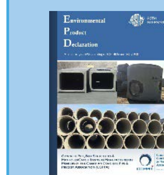
Embodied carbon insertion point: Building owners and operators can prioritize and specify low carbon materials for all future maintenance, repair and refurbishment activities. Lower carbon strategies for material end-of-life can also be adopted including requirements for disassembly and reuse / recycling instead of demolition. Ongoing reporting / disclosure of annual carbon footprint of operations can also be required. These requirements would typically be created during earlier project phases and could be included in project specifications, service provider contracts or in project operating instructions. These requirements should be considered during the project design stage and included in project specifications, and any associated project operating instructions and service provider contracts.

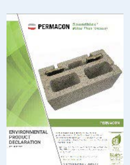
8 APPENDIX A – North American-wide & Canadian **Concrete and Cement EPDs**

Below is a complete list of North American-wide and Canadian concrete and cement EPDs as of October 2021.
See Section 5.2 for more.

Cover	Product Type	Product	Company	EPD type	Link
	Ready-mixed concrete	Ready-mixed concrete	Canadian Ready-Mixed Concrete Association (CRMCA)	Industry-average	https://www.crmca.ca/ (available in English and French)
	Ready-mixed concrete, Plant specific for 8 locations in BC	Ready-mixed concrete, Plant specific for 8 locations in BC Ready-mixed concrete, ECOPact	Lafarge Canada	Facility-specific	https://www.lafarge.ca/en/ecopact-epds Plant locations: Chilliwack Clearbrook (Abbotsford) Kent Avenue (Vancouver) Maple Ridge North Vancouver Port Mann (Coquitlam) Surrey Vancouver Harbour
	Cement	General-use (GU) and Portland-limestone (GUL) cement	Cement Association of Canada	Industry-average	https://www.csaregistries.ca/
	Cement (facility-specific) Lafarge Richmond BC Cement Plant	General-use (GU) and Portland-limestone (GUL) cement	Lafarge	Facility-specific	https://www.csaregistries.ca/

Cover	Product Type	Product	Company	EPD type	Link
	Cement, Lehigh, Edmonton AB	General-use (GU), Blended Portland-limestone (GULb/HSLb), High Sulphate (HS) and High Early (HE)	Lehigh Cement	Facility-specific	https://www.lehighhanson.com/resources/epds
	Cement, Lehigh, Delta BC	General-use (GU), Portland-limestone (GUL) and High early (HE)	Lehigh Cement	Facility-specific	https://www.lehighhanson.com/resources/epds
	Cement, Lehigh, Picton, ON	General-use (GU), Portland-limestone (GUL), Moderate Sulphate (MS), High early (HE), and Masonry Cement	Lehigh Cement	Facility-specific	https://www.lehighhanson.com/resources/epds
	Concrete masonry units	Normal weight and light weight concrete masonry units	Canadian Concrete Masonry Producers Association (CCMPA)	Industry-average	https://ccmpa.ca/wp-content/uploads/2021/01/311.EPD_for_CCMPA_Normal-Weight_And_Light-Weight_Concrete_Masonry_Units.pdf

Cover	Product Type	Product	Company	EPD type	Link
	Precast concrete civil engineering products	Concrete pipe, box structures and manholes / catch basins	Canadian Concrete Pipe and Precast Association (CCPPA)	Industry-average	https://ccppa.ca/environmental-product-declaration/
	Precast concrete	Architectural and Insulated Wall Panels	Canadian Precast/ Prestressed Concrete Institute (CPCI)	Industry-average	http://www.sustainableprecast.ca/en/pcr_epd/
	Precast concrete	Structural Precast Concrete Products	Canadian Precast/ Prestressed Concrete Institute (CPCI)	Industry-average	http://www.sustainableprecast.ca/en/pcr_epd/
	Precast concrete	Underground Precast Concrete Products	Canadian Precast/ Prestressed Concrete Institute (CPCI)	Industry-average	http://www.sustainableprecast.ca/en/pcr_epd/
	Concrete bricks, blocks, pavers	Cassara Slab and Boulevart Paver	Permacon	Facility-specific	https://permacon.ca/en/pro/leed
	Concrete bricks, blocks, pavers	Melville Silk Bricks	Permacon	Facility-specific	https://permacon.ca/en/pro/leed

Cover	Product Type	Product	Company	EPD type	Link
	Concrete bricks, blocks, pavers	Standard Block and Noble Architectural Block with Glass Powder	Permacon	Facility-specific	https://permacon.ca/en/pro/leed
	Concrete bricks, blocks, pavers	Light Concrete Block with Glass Powder	Permacon	Industry-average	https://permacon.ca/en/pro/leed
	Concrete bricks, blocks, pavers	Standard Concrete Block	Permacon	Industry-average	https://permacon.ca/en/pro/leed
	Concrete bricks, blocks, pavers	Soundblox	Permacon	Industry-average	https://permacon.ca/en/pro/leed
	Concrete pavers	Interlocking concrete pavers and paving slabs	Expocrete	Facility-specific	http://www.expocrete.com

9 APPENDIX B: Additional strategies for **lower carbon concrete**

In addition to the strategies that can be easily integrated into procurement documents (see Section 6) there are additional ways to reduce carbon in concrete. Some of these strategies are ready for implementation now and others are innovations which are still being developed. The below list can help provide options to discuss with your concrete suppliers about future investments they could consider making to their production facilities which could lead to lower carbon concrete in the future.

9.1 Switching to lower carbon fuels

The industry is transitioning to lower carbon fuels by replacing fossil fuels currently used in the cement manufacture process (e.g. coal, petcoke, and natural gas) with lower carbon alternatives from the waste stream. This cost competitive pathway can lead to emissions reductions estimated at 20-30%.[50] Prioritize actions that help cement manufacturers decarbonize their production process.

9.2 Mixing methods

Some methods for mixing concrete can create high-strength concrete with a lower volume of cement. For example, the scattering-filling aggregate process (controlled particle size distribution) adds an additional 10-30% of volume as aggregates are being mixed.[51] This increase in volume means that 10-30% less cement is used when compared to conventional concretes, consequently reducing carbon emissions while also increasing the compressive strength of the mix.

9.3 Hard, clean and strong aggregates

Using stronger aggregates, when possible, will reduce the cement required to achieve the desired mix strength, and can create concrete with a high resistance to abrasion and increased life span.[52]

9.4 Carbon sequestration

Inquire with concrete suppliers if they can use carbon sequestration or CO_2 injection methods where appropriate. New carbon capture technology captures the carbon emitted during the cement manufacturing process and injects it back into the concrete during mixing. This is known as CO_2 mineralization, where a portion of the CO_2 is converted to a mineral and becomes permanently captured. Examples of companies that provide carbon capture, utilization and storage (CCUS) technologies include: Carbon Cure, Carbon8, International CCS Knowledge Centre, Pondtech, Blue Planet, CO_2 Solutions, Svante, Carbon Engineering, and Carbon Upcycling. Examples of manufacturers investing in CCUS include: Lehigh Hanson's $3 million advanced feasibility study for full-scale CCUS at an Edmonton cement facility, or Lafarge Canada's complete installation of CCUS flu gas pre-treatment system in Richmond, BC.[53] This method may be more applicable to concrete blocks or architectural precast concrete, further work and research is required on the influence of carbon sequestration for reinforced concrete.

[49] *Canadian Green Building Council, Taking Concrete Steps to a Carbon Neutral Future, December 11, 2019*
[50] *Shen. W, et. al, Low Carbon Concrete Prepared with Scatter-Filling Coarse Aggregate Process, December, 2014*
[51] *Concrete – Design and Construction Guidance*
[52] *Canadian Green Building Council, Taking Concrete Steps to a Carbon Neutral Future, December 11, 2019 [Taking Concrete Steps to a Carbon Neutral Future]*

9.5 Carbonation curing of precast concrete

Precast concrete products are typically manufactured using highly mechanized processes including energy and water intensive curing. Precast concrete products include blocks, paving stones, panels, pipes and barriers.

Current method of curing precast concrete uses steam curing, which consumes significant amounts of energy and CO_2 could be implemented where applicable. Carbonation curing is an alternative method being researched. The process involves exposing fresh precast concrete to CO_2, to react and form thermodynamically stable carbonate microstructures. The unique feature of carbonation curing is that it consumes the CO_2 released from an external fossil fuel combustion source. Designing for (re)carbonation could remove up to 20% of the industrial process emissions associated with cement content.[53] However, further work and research is required to study the effect of carbonation curing on reinforced concrete.

The benefits of this process include:[54]

- **Reduction of up to 120 kg CO_2 per tonne of concrete.** Precast concrete plants may consume more CO_2 than they produce.
- **Low-cost adaptation and upgrade of standard industry equipment:** The process is intended as a bolt-on solution to existing or new precast concrete plants that will complement standard process equipment and minimize retrofit costs.
- **Lower costs for unit production and plant operations:** Reduced precast plant operating costs from lower energy and water consumption achievable through a low cost retrofit of existing plant equipment. Plants may lower other operational expenses associated with faster production, less inventory handling and fewer shrinkage defects.
- **Equal or higher material performance:** This includes improved freeze/thaw durability, and reduced water absorption.
- **Accelerated strength development**
- **Uses waste SCMs** such as slag and fly-ash in replacement of cement.
- **No chemical requirements**

Reductions achieved at a single average plant retrofit was estimated to equal the annual emissions of 700 cars, or if widespread implementation is achieved then the estimated carbon reduction could be on the order of several million tonnes per year.

Pilot trials of this process is managed by Carbon Sense Solutions Inc. based in Halifax, Canada. The pilot achieved 15% stronger concrete, resulting in a 10% reduction in cement usage, a 38% reduction in energy requirement, and improved productivity.[55]

[53] *Taking Concrete Steps to a Carbon Neutral Future*
[54] *S. Monkman, R. Niven, Integration of Carbon Dioxide Curing into Precast Concrete Production*
[55] *Province of Nova Scotia, Technical Paper: Carbon Sense Solutions Inc., 2017*

10 APPENDIX C: Examples of Low Carbon Concrete Policy

10.1 City of Portland, Oregon – Low carbon concrete purchasing

In 2016, the City of Portland (Portland) identified that construction services were the top spend category contributing to their supply chain emissions. Concrete was one of the most emission intensive materials commonly used by the City of Portland.

In May 2019, The City of Portland released a notice for the following new requirements to the approval process for the supply of Portland Cement Concrete (PCC):[56]

- *January 2020*: Product-specific Type III Environmental Product Declarations (EPD) will be required for all concrete on Portland's (Pre)Approved Concrete Mix Design List or proposed for use over 50yd^3 on Portland's construction projects.
- April 2021: Portland Procurement Services will publish the maximum acceptable GWP based on the data collected from the industry and other stakeholders.
- January 2022: All concrete submitted to be on Portland's (Pre) Approved Concrete Mix Design List or using on Portland's construction projects will need to have a GWP below the established GWP maximum value within its strength class.

This stepped approach in collecting product specific EPDs and using the data to create GWP limits signals a swift shift in procurement best practices to address embodied carbon.

10.2 Marin County, California – Low carbon concrete codes

The Low Carbon Concrete Codes[57] project aims to modify the local building standards to support embodied carbon emissions reductions of building materials, starting with concrete. The approach is:

- In the fall of 2019, model code language was adopted by local governments.
- By 2022, create low embodied-carbon concrete specifications for residential and non-residential applications, and apply to four pilot projects.
- Create a Bay Area Concrete Working Group as an extension of the Embodied Carbon Network.

These codes are based on local realities and do not represent a theoretical best practice.

The documents include drafts of the:

- Low Carbon Concrete Code
- Sample Residential Specification
- Sample Non-residential Specification
- Low Carbon Concrete Compliance Form (Cement)
- Low Carbon Concrete Compliance Form (Embodied Carbon)

[56] *City of Portland, Notice of New Requirements for Concrete, May 15, 2019*
[57] *County of Marin, Bay Area Low Carbon Concrete Codes Project, October 20, 2019*

- Study of Limits for Cement and Embodied Carbon of Concrete

A sample compliance form for low carbon concrete is shown in Figure 7. A similar compliance form could be made for the Government of Canada.

Low Carbon Concrete Compliance Form (Embodied Carbon)

This form shall be completed by the party indicated under each section for compliance with project Low-Carbon Concrete requirements

Project name ____________________________ Date ______________________

DESIGN TEAM TO COMPLETE FOR PLAN CHECK APPROVAL						**CONCTRACTOR TO COMPLETE**				
Structural engineer shall complete and include within concrete specification of the Project Manual submitted to the building department for plan check.						*General Contractor shall complete and submit to the Architect within 6 weeks of completion of the concrete work.*				
Date:						Date:				
Structural Engineer Company Name:						General Contractor Company Name:				
Signature:						Signature:				
Print Name:						Print Name:				
Concrete mixture name	Design strength, f'c **per spec** (psi)	Used for (indicate if needs early strength)	Volume Estimated (cyd)	Max EC **per spec** (kg/m^3)	EC Limit **per code** (kg/m^3)	Volume Supplied (cyd)	Concrete Supplier Name	Concrete Batch Code	Actual EC (kg/m^3)	EC Limit **per code** (kg/m^3)
These rows only for use if contractor is pursuing budget method		Total EC of all concrete used on Project (kgCO2e)				Total EC of all concrete used on Project (kgCO2e)				
		Total EC allowed for all concrete on Project (kgCO2e)				Total EC allowed for all concrete on Project (kgCO2e)				
Signature of Approval at Plan Check:						Signature of Approval for TCO Permit:				
Print Name:						Print Name:				
Date:						Date:				

Figure 7: County of Marin - Bay Area Low-Carbon Concrete Codes Project - Sample Compliance Form