Carbon Capture and Utilization in Cementitious Building Materials

Market Primer

CAGBC Canada Green Building Council | Conseil du Bâtiment Durable du Canada

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About the Canada Green Building Council

The Canada Green Building Council (CAGBC) champions Canada's green building sector. CAGBC training, services, and certifications like LEED and the Zero Carbon Building Standards help the building sector design, construct and operate buildings that increase resilience and asset value, and reduce environmental impacts. Working collaboratively with members, industry, and government, we are building our way forward to a low-carbon, resilient future. Learn more at cagbc.org.

About Pratus Group (in partnership with Quasar Consulting Group)

Pratus Group (pratusgroup.com), in partnership with Quasar Consulting Group, is a full-service mechanical, electrical, ICAT, sustainability, energy modeling, and commissioning consulting firm with multiple offices across Canada. Together, Pratus Group and Quasar provide expertise in the design, development, and operation of low-carbon, sustainable buildings and infrastructure.

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Introduction and Project Purpose

Meeting Canada's climate targets will require an 'all in' approach from all sectors of our national economy. The industrial manufacturing of materials used in the construction of buildings and infrastructure contributes to carbon emissions. Decarbonizing these heavy industries will have a significant impact on emissions, but will require unique strategies.

Concrete and cement materials have been specifically identified as building materials of interest. This is because they are the most widely used building materials in Canada, and the world.

Carbon capture and utilization in cementitious building materials (CCU-CBM) is an essential strategy for the decarbonization of cement and concrete, and is expected to account for more than 25 percent of the necessary carbon emissions reductions for the cement and concrete industry.[1] Substantial carbon emissions are released from the raw materials used in the process of manufacturing cement, so much so that traditional strategies such as the use of renewable energy or improved production efficiency will not fully eliminate them.

CCU-CBM technologies can be deployed at various points in the manufacturing process, including the capture of carbon dioxide (CO_2) emissions from the cement plant and the utilization, or sequestration, of CO_2 during the production of concrete products.

PROJECT PURPOSE

The Canada Green Building Council initiated the Burying Carbon in Buildings project to:

- Assess the current state of CCU-CBM technologies in the Canadian market.
- Conduct consultation with thought leaders to assess opportunities and challenges for continued market adoption of these technologies in Canada.
- Develop, test, and outline recommendations for quantifying and maximizing emissions reductions from these technologies.
- Prepare guidance to promote effective procurement of concrete materials made using CCU-CBM technologies.

This Market Primer summarizes the findings of the first two phases of the overall project. The research team conducted a background review to evaluate the current status of CCU-CBM technologies in the Canadian market. A series of structured interviews were also conducted with key stakeholders to discuss their experience and to gather perspectives on current needs and evolving trends.

The goals of this Market Primer are to:

- Provide an introduction to CCU-CBM technologies.
- Summarize their current status in Canada.
- Outline the potential role these technologies could play in the decarbonization of the building sector.

What is Carbon Capture?

The capture and separation of CO_2 emissions from industrial manufacturing facilities, preventing the release of CO_2 into the atmosphere.

What is Carbon Utilization?

The process of converting captured CO_2 emissions into valuable products or materials such as fuels, plastics, or construction materials through various chemical, biological, or technological means, thereby providing an alternative and beneficial use for this CO_2.

Why focus on cement and concrete?

Among commonly used construction materials, cement and concrete have the greatest opportunity to beneficially capture and use carbon emissions. Through a combination of unique chemical properties and mass scale of production, cement and concrete have the potential to be a major 'sink' for carbon emissions that would otherwise enter the atmosphere.

COMPONENTS OF THE BURYING CARBON IN BUILDINGS PROJECT

Technical Research

Research underway at the University of Toronto will contribute to advancing the state of knowledge on CCU-CBM technologies in Canada.

Industry and Expert Consultation

Additional consultation will be conducted with expert stakeholders to solicit feedback and to share findings on priorities for public policy, requirements for code and standard evaluation and acceptance of CCU-CBM technologies, and developing guidance for assessing the environmental impact of these technologies.

Informing Procurement

Guidance will be developed to enable effective specification and procurement of concrete materials utilizing CCU-CBM technologies.

WHERE DO WE GO FROM HERE?

The Market Primer provides context for ongoing technical research, consultation, and development of effective procurement strategies. These aspects of the project will be incorporated into future reports.

What We Learned

The research and engagement conducted focused on opportunities, barriers, and potential solutions to increasing market awareness and adoption of CCU-CBM approaches and technologies. Key findings are summarized under the following themes:

Capturing the Opportunity

CCU-CBM technologies provide an opportunity to fully decarbonize cement and concrete, and create potential economic benefits.

CCU-CBM technologies are the only strategy for mitigating the more than 60 percent of cement manufacturing carbon emissions that result from chemical processes.

Cement and concrete products are manufactured based on the same fundamental chemical process, meaning that solutions that work in Canada can be adopted globally. Successful development and deployment of CCU-CBM technologies in Canada could therefore create opportunities to export CCU-CBM expertise and technology solutions, and potentially increase demand for low-carbon cement produced in Canada. This would create significant economic benefits for Canadians.

Nascent Technologies

CCU-CBM technologies are being deployed in Canada today, but experience is still limited.

Several potential CCU-CBM strategies are emerging across Canada, but nearly all are in the pilot stage. Key technologies have performance and cost uncertainty, while others remain in the research and development stages. Few designers or contractors have ever used concrete materials made with CCU-CBM technologies, and there is a need for greater awareness and education on the qualities and performance of these materials and information on whether there are any different considerations for their use. Available data is limited or proprietary, and continued research and development will support industry adoption of CCU-CBM technologies and validate the emissions reduction potential of these technologies.

Deployment Ready Solutions

The market is constrained by rational risk aversion.

There are multiple risks that influence market behaviour. Key concerns include safety risk, economic risk, and reputational risk. Concrete codes and standards have been developed to ensure the safety of people and property, and to prevent catastrophic failure of concrete structures. Economic risks relate to potential delays in project time lines, changes to existing supply chains or business models, reduced performance and/or service life, or non-compliance with mandated codes and standards. Impacts to project delivery from the use of new approaches, technologies, or materials could also have serious consequences for designers and contractors, affecting their reputation and professional standing. All partners in the concrete supply chain want to limit these risks, which further reduces their willingness to try new approaches such as CCU-CBM technologies.

Codes and Standards

Structural barriers must be overcome for these technologies to scale.

There are rigid requirements for the testing and validation of concrete materials due to its use in critical infrastructure and in the structural elements of buildings. Regulatory bodies and industry codes and standards that approve the use of new materials in concrete operate on slow adoption cycles. Even when standards are permissive, there can be perceived risk to project developers and reluctance to embrace new products or approaches. Concrete materials must meet well-defined standards for physical properties and desired performance, and any changes in material composition or production methods may require new testing or evaluation requirements. These factors disincentivize change for cement and concrete manufacturers.

Defining Low-Carbon Materials

There is no recognized standard definition of 'low-carbon' concrete.

The variability and adaptability of concrete means that there can be significant variance in the carbon intensity of any specific product. It can be difficult to attribute emissions reduction benefits to CCU-CBM technologies, as multiple factors (e.g., geographic sourcing of materials, use of alternative cementitious materials, etc.) can influence the carbon footprint of concrete materials. There is also inconsistency in standards and data disclosure for low-carbon products. Evolving industry practices also mean that defining low-carbon concrete is relative and continues to change. What is currently a lower-carbon approach may become the standard baseline in future years. Different methodologies also exist for quantifying emissions from concrete materials, with some methodologies considering emissions from manufacturing alone and others considering emissions from the full life-cycle of the material. This lack of clarity in attributing benefits to CCU-CBM technologies limits the potential efficacy of procurement strategies intended to support these technologies.

Economics of CCU-CBM

There is strong sensitivity to increased costs for concrete materials.

Concrete is a commodity material. While some adoption of CCU-CBM technologies has occurred, the cost of manufacturing concrete using CCU-CBM technologies is typically higher than prevailing market prices. Purchasers of concrete are unwilling to accept these cost increases. Increased domestic production costs would likely lead to increased material imports, potentially resulting in lower quality products and comparatively higher emissions from the cement and concrete used in Canada.

Public Policy and Procurement

The public sector will play a key role in creating demand for these technologies.

Direct government procurement of low-carbon concrete for the construction of roads and sidewalks, water and wastewater pipes, public buildings, and other forms of infrastructure represents more than 50 percent of all concrete consumption in Canada. Coordinated and consistent low-carbon procurement by governments at all levels would create a strong demand signal by incentivizing the uptake and deployment of CCU-CBM technologies, mobilizing capital, and driving innovation to reduce costs.

Financial tools such as investment tax credits, carbon credits, and other incentives can reduce structural costs and de-risk private sector investment. Governments can also use their own construction projects as case studies to demonstrate the performance of materials made with CCU-CBM technologies, providing important data to support the evolution of specifications, codes, and standards.

Overview and Context

Introduction

The future green economy in Canada will arise in part from the deployment of clean technologies and lower-carbon materials in the construction sector.

Some construction materials, such as wood and concrete, have the capacity to capture and store large quantities of carbon emissions, which can contribute to Canada's strategy to meet its 2030 and 2050 climate targets.

Concrete consumption in Canada is more than double that of all other construction materials combined.[1]

Meeting Canada’s climate targets will require an ‘all in’ approach from all sectors of our national economy. The industrial manufacturing of materials used in the construction of buildings and infrastructure is a contributor to carbon emissions. Decarbonizing these heavy industries will have a significant impact on carbon emissions but will require unique strategies.

Concrete and cement materials have been specifically identified as building materials of interest for industrial decarbonization. This is because they are the most widely used building materials in Canada, and the world. The future homes, roads, bridges, and buildings that we will build to support our communities will be largely built with concrete. It will be important to develop capacity to manufacture concrete materials through lower-carbon approaches.

Carbon capture and utilization (CCU) is one of the unique approaches that shows promise for reducing the carbon emissions associated with cement and concrete production.

This emerging class of technologies is expected to account for more than 25 percent of the necessary carbon emissions reductions for these materials and is an essential strategy for achieving net-zero concrete. Substantial carbon emissions are released from the raw materials used in the process of manufacturing cement, so much so that traditional strategies such as the use of renewable energy or improved production efficiency will not fully eliminate them.

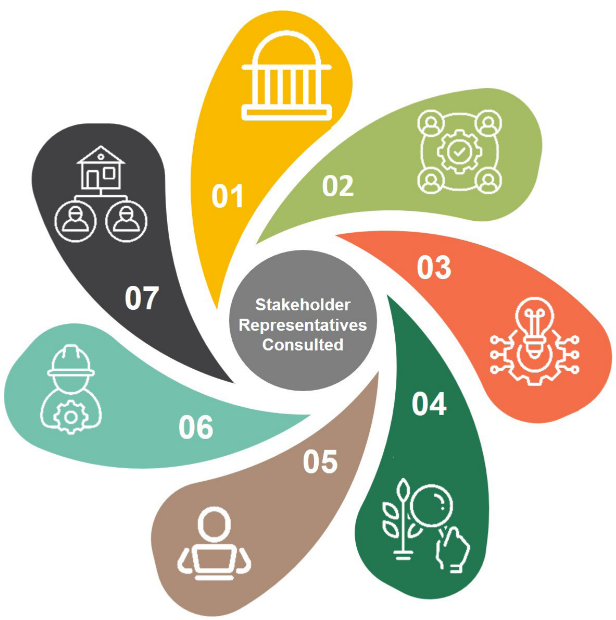
While governments and industry recognize the importance of these CCU technologies, knowledge gaps remain in understanding their full potential and cost implications. Policy-makers and innovators seeking to inform policy development and investment decisions need to understand carbon reduction potential and any impacts to existing design and construction practices, supply chains, and manufacturing processes. However, without incentivizing the continued development of CCU technologies, there will not be an industry that requires a policy framework.

The Canada Green Building Council (CAGBC) initiated the Burying Carbon in Buildings project to develop, test, and outline recommendations for quantifying and maximizing potential emissions reductions from carbon capture and utilization in cementitious building materials (CCU-CBM).

For the first phase of this project, CAGBC commissioned Pratus Group to consult with thought leaders and assess opportunities and challenges with continued market adoption of CCU-CBM technologies in Canada.

The research team conducted a background literature review to evaluate the current status of CCU-CBM technologies in the Canadian market. To supplement this research, a series of structured interviews were conducted with key stakeholders to discuss their experiences with CCU-CBM technologies and their perspectives on current market needs and evolving trends.

One of the goals of this project is to support continued market adoption of CCU-CBM technologies by sharing relevant technical assessment, policy development, industry training, and procurement practice recommendations. This report summarizes relevant findings addressing these points from the research and consultation conducted.



01 – Government

02 – Industry

03 – Innovators

04 – Researchers

05 – Designers

06 – Contractors

07 – Owners

Based on current cement and concrete methods, manufacturing of net-zero concrete at scale in Canada will not be possible without the use of CCU technologies.[2]

How Concrete is Made

Concrete is not a single product – it is thousands of different products made from different locally sourced materials and varying proportions.

While concrete may look the same to the untrained eye, it is actually the result of an endless variety of material compositions designed to deliver specific physical and performance properties.

Within this diverse range of products, Portland cement is the mainstay. Portland cement is a crucial and main component of concrete mixes, and concrete is the most widely used manufactured material in the world.

Cement is made by heating a precise mixture of limestone, clay, and sand in a rotating kiln. The kiln operates at temperatures of more than 1,400 degrees Celsius. Within the kiln, the mixture of raw materials undergoes a calcination reaction. During this reaction, the raw material mixture converts calcium carbonate ($CaCO_3$) into calcium oxide (CaO; also known as quicklime) and CO_2. The resulting product is known as cement clinker, which is finely ground into a powder, while the CO_2 is emitted to the atmosphere. The emissions arising from the cement kiln typically account for 90 percent or more of the overall carbon footprint of concrete products, with the calcination reaction accounting for two-thirds of these emissions.

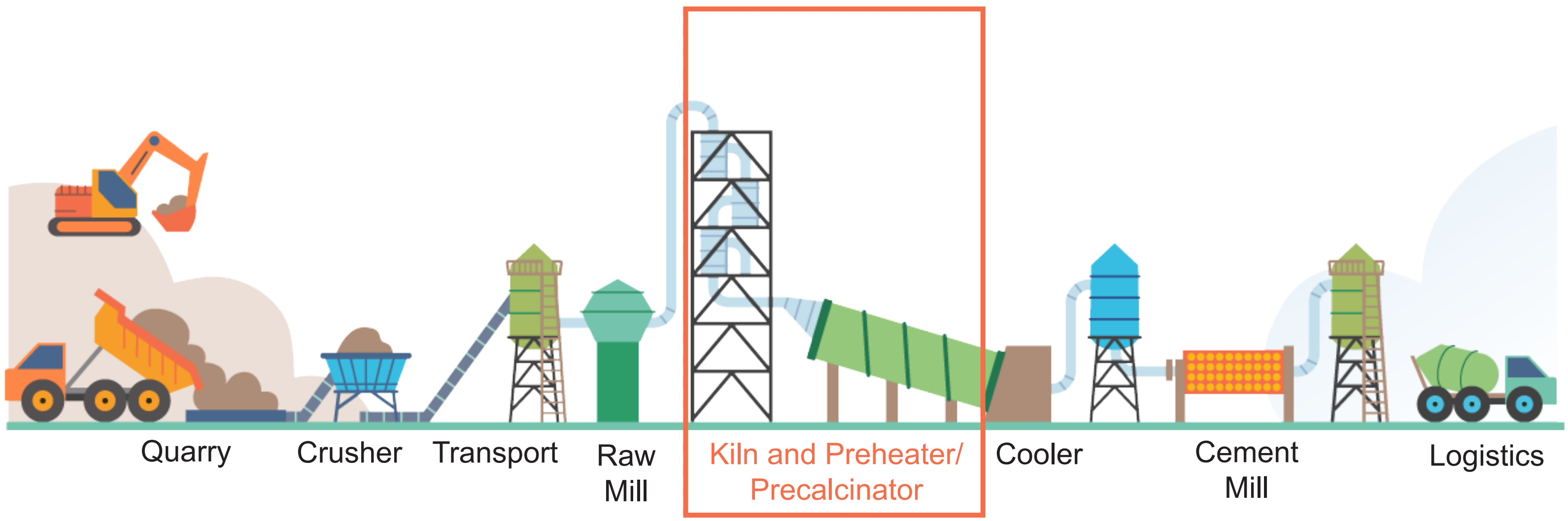
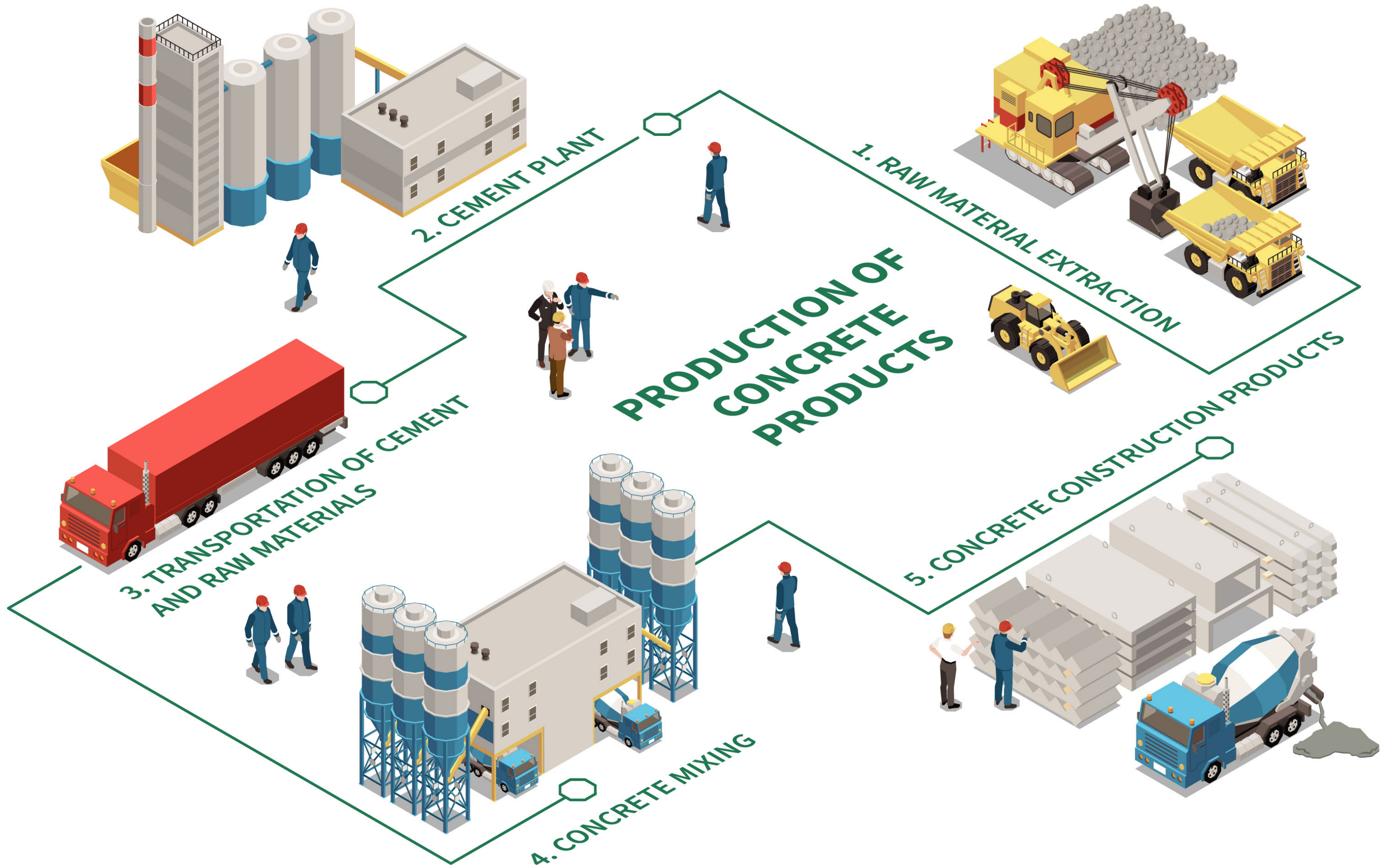


Figure 1: Adapted from Czigler et al (2020)



Cement vs. Concrete

These terms are often used interchangeably, but they are not the same. Cement is the key ingredient in concrete. It is the critical binding material that, when mixed with water and aggregates like sand and gravel, produces concrete.

Cement is a fine powder, while concrete is the finished product that we see in the sidewalks and buildings around us.

Concrete mixtures are created through mixing different proportions of water, cement, and fine and coarse aggregates such as sand, silt, and gravel. The primary ingredients of concrete can be mixed in a wide variety of proportions to create concrete products with different performance properties. Cement alternatives, known as supplementary cementitious materials, can also be used in addition to, or to partially replace the Portland cement.

Chemicals, known as admixtures, are also often added to the concrete mixing process to provide desired physical and performance properties. The volume of admixtures is generally immaterial in comparison to the quantities used for the other constituent materials of concrete products.

Constituent Materials of Concrete Mixes

Concrete Use in Canada

Cement contributes 90% or more of emissions from concrete, and is the second largest industrial CO_2 emitter accounting for 7% of global CO_2 emissions each year. In Canada, cement emissions represent about 1.4% of total emissions as of 2020.[3]

Concrete materials play a critical role in Canadian buildings and infrastructure. It is a preferred material due to its durability, strength, versatility, and availability. More than 14 million tonnes of cement and 60 million tonnes of concrete are produced in Canada each year.[1]

TYPES OF CONCRETE

Most concrete produced in Canada is ready mixed concrete. This concrete is mixed on demand before being delivered to job sites, and the mixer trucks that deliver this product to construction projects are one of the most visible aspects of the cement and concrete industry.

Other types of concrete include masonry and precast concrete products. These products are prefabricated in a controlled and centralized environment and are sold as finished products.

ECONOMIC IMPACT

Fifteen cement plants and more than 1,100 concrete manufacturing plants are operating in Canada, representing more than $76 billion in economic impact to the economy. In addition to meeting national consumption demands, more than $750 million of cement is exported each year mostly to the United States of America. Approximately $225 million of cement was imported to Canada in 2022, with half of all imports coming from the United States of America.[4]

Production and consumption of concrete is highest in the Provinces of Ontario, Alberta, Quebec, and British Columbia, mirroring the provinces with the largest populations and rates of new construction. Concrete consumption can be expected to change based on these factors. As Canada's population continues to grow and its cities become denser, we can expect that the demand for concrete will also grow.

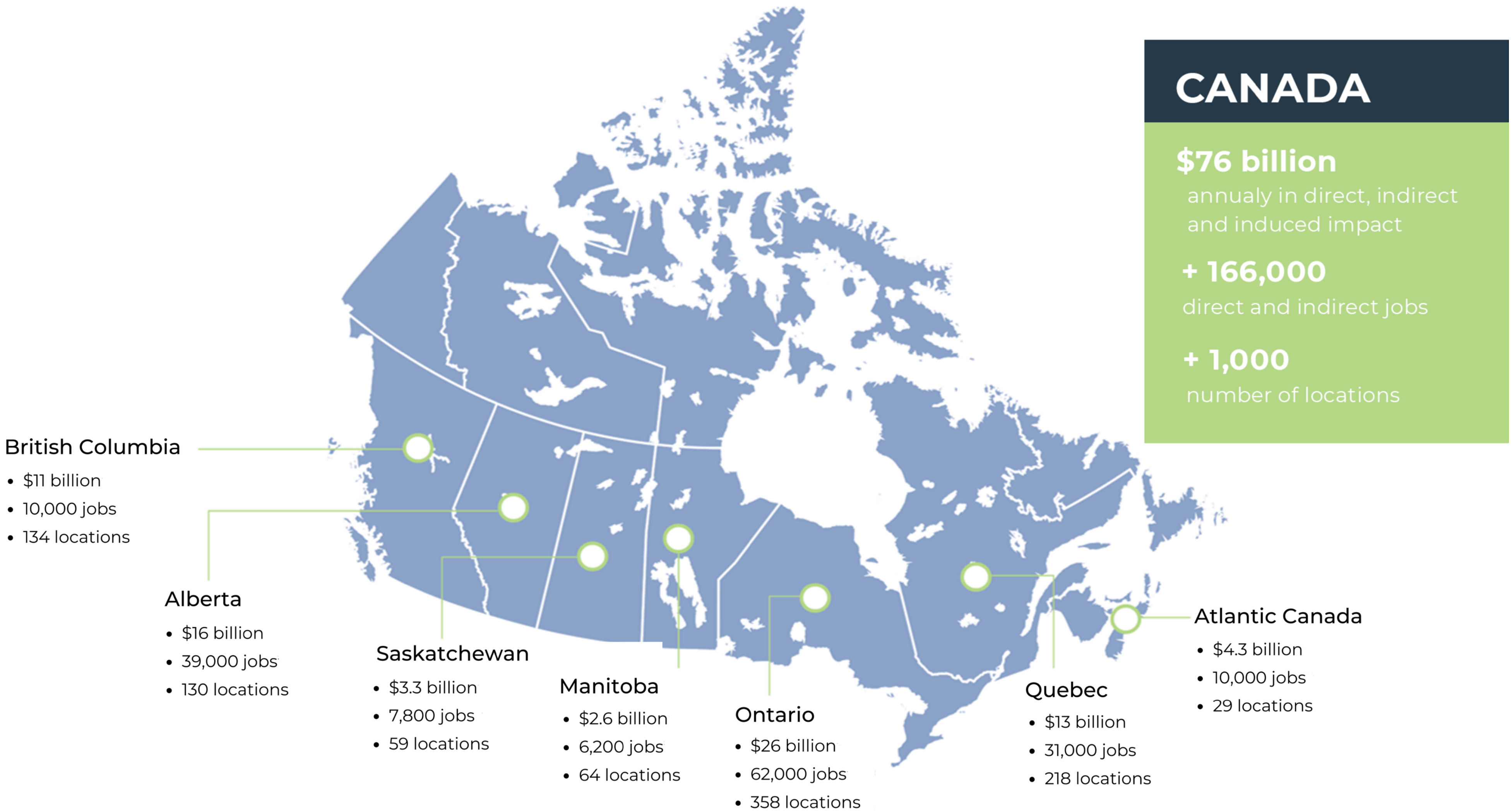


Figure 2: Economic Impact of the Cement and Concrete Industry in Canada

Embodied Carbon Context

Embodied carbon refers to the carbon emissions associated with materials and construction processes throughout a building's life cycle.

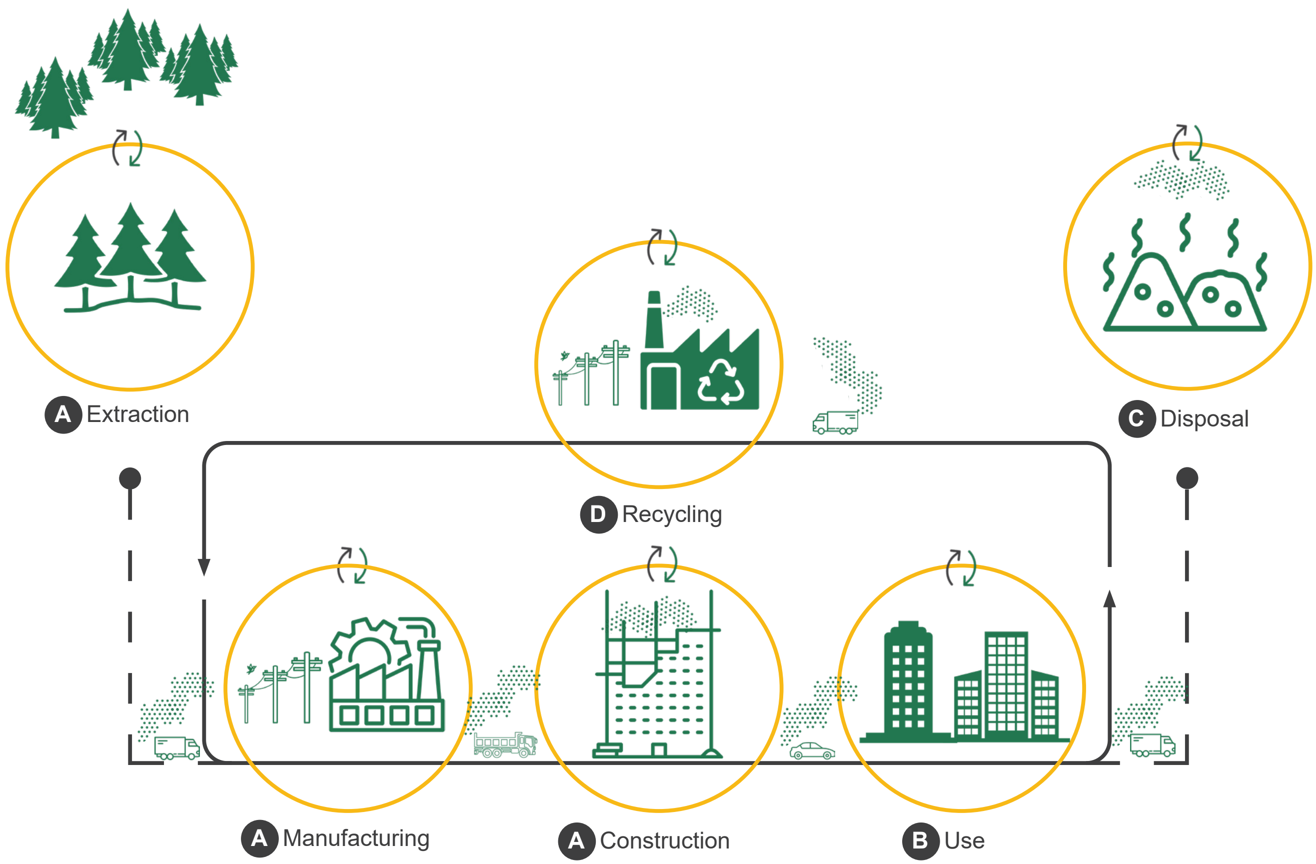
Embodied carbon from building construction accounts for as much as 10% of global emissions.[5]

Embodied carbon is the total greenhouse gas emissions associated with a material, product, or building, excluding emissions from energy used in operations. Building materials generate environmental impacts throughout their life cycle, including during their production, transportation, manufacturing, installation, maintenance, and disposal at end of life.[5]

- **Production** includes the energy and resources used to extract raw materials from the natural environment, to transport materials to manufacturing sites, and to manufacture the finished product.
- **Construction and Installation** includes the energy and emissions to transport materials to construction sites, to power equipment used during construction, and to dispose of waste materials.
- **End of Life** includes the energy and emissions associated with demolition and disposal of buildings or infrastructure and to process the waste.

For the building sector, most embodied carbon stems from the raw material, extraction, manufacture, transportation, and installation of materials used in construction. Referred to as upfront carbon, these emissions are released into the atmosphere well before a building is operational.

Once materials are selected and procured, options for reducing the embodied carbon impact are more limited, highlighting the importance of procurement decisions.



Life cycle stages typically considered in the quantification of embodied carbon emissions

MEASURING EMBODIED CARBON

Embodied carbon emissions are quantified using a technical methodology called life cycle assessment (LCA). This methodology assesses the environmental impacts produced at each stage of the life cycle, including upstream and downstream processes associated with each stage. Impacts are then summed for all components and reported using consistent metrics.

When applied to specific building products or materials, the environmental impact of a given product or material can be reported using a tool known as an Environmental Product Declaration, or EPD.

In addition to carbon emissions, other environmental impacts are often also reported, such as ozone depletion or acidification potential.

Whole-building LCAs can also be completed that quantify the embodied carbon of a whole building utilizing the information from the individual EPDs for constituent materials and the quantity or volume of materials used in the construction of the building.

Enabling Measures for Addressing Embodied Carbon in Canada

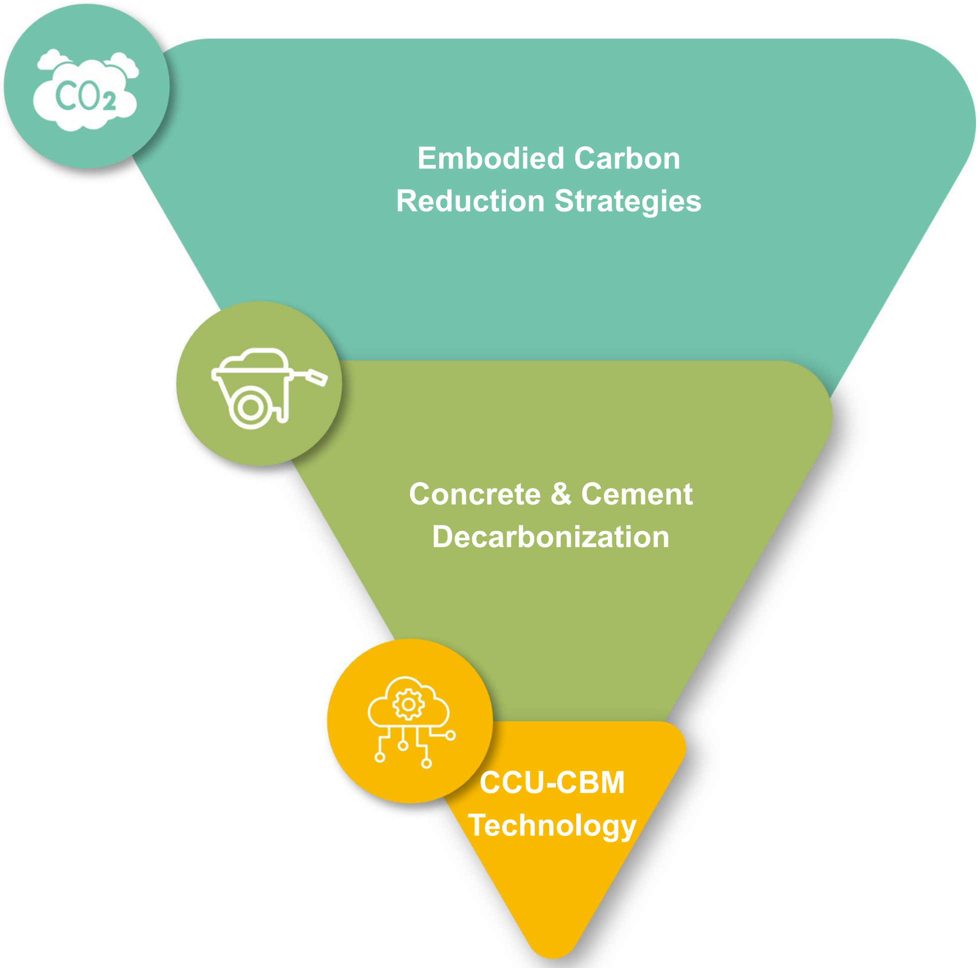
Embodied carbon has been identified as an increasingly important consideration for building design and construction, particularly as ongoing greening of electricity sources and improved building efficiency have reduced operational carbon emissions. In some provinces with low-carbon electricity grids, embodied carbon may account for more than 90% of all emissions between now and 2050.[5]

In some cases, concrete materials can be the single largest contributor to the embodied carbon of new buildings and infrastructure due to the sheer quantity of concrete required and its emissions intensity.

Multiple initiatives are underway across Canada to enable greater understanding of embodied carbon impacts, to better quantify and measure impacts, and deliver new mechanisms for restricting or reducing the emissions impact of materials used for new construction projects.

These initiatives focus on changing practices and creating resources related to:

- **Guidance** – the creation of educational resources, databases, rule sets, methodologies, and tools to enable practitioners to make more informed decisions on materials.
- **Codes and Standards** – the continued development of codes and standards that govern the use of concrete materials to include guidance on reducing embodied carbon emissions.
- **Procurement** – deployment of procurement strategies that prioritize consideration of carbon impacts in addition to material costs.



There are a range of strategies available to address embodied carbon for buildings and infrastructure that utilize concrete materials. Overarching reduction strategies include decisions around the desired material properties and performance, selection, source location and the size and configuration of the planned building our infrastructure asset

Effective design choices can reduce the total quantity of materials needed or result in the selection of materials with a lower environmental impact.

Within the concrete material class, the use of decarbonization strategies such as supplementary cementitious materials, optimized concrete mix designs, alternatives to Portland cement, or more efficient production and construction methods can also reduce embodied carbon emissions.

CCU-CBM technologies can further reduce the embodied carbon of materials by capturing and either storing or utilizing CO_2 emissions created from the manufacturing of cement and concrete.

Some of the leading initiatives underway or completed in Canada are outlined on the following page.

Buy Clean

The Treasury Board of Canada Secretariat Centre for Greening Government leads federal efforts to achieve emissions reduction, promote climate resilience, and green government initiatives. One of the Treasury Board's commitments is to low-carbon construction through its Buy Clean policy. Buy Clean is a type of public procurement policy that is intended to promote the purchase of products with lower embodied carbon emissions. This procurement policy is structured to foster the development of lower-carbon products and industries while reducing the environmental impact of products purchased using public funds. Under this policy, federal projects must disclose the quantity of embodied carbon and achieve defined reductions. Projects are evaluated on a performance basis, meaning that industry suppliers can leverage a range of available solutions to achieve the required emissions reductions.

Low Carbon Assets through Life Cycle Assessment (LCA2) Initiative

The Government of Canada launched the low-carbon assets through life cycle assessment (LCA2) initiative in 2019 to develop a science-based approach to support the selection of materials and designs that would offer the lowest carbon footprint to government projects. A consortium of stakeholders led by the National Research Council was tasked with building capacity for LCA analysis in Canada, developing a repository of data, developing a framework for conducting life cycle analyses, and other efforts to support low-carbon procurement. The work completed by the LCA2 Initiative informed the development of the Platform to Decarbonize the Construction Sector at Scale research program. Additional information is available from the National Research Council.

2030 National Building Code

The Canadian Board for Harmonized Construction Codes is in the process of reviewing the National Model Codes to further support the decarbonization of Canada's building stock. It is expected that updates to the Codes that will be published in 2030 will establish limits for embodied carbon emissions for the first time. Draft policy recommendations are currently being developed to inform the 2030 Codes.

Municipal Initiatives

Major urban centres including the cities of Toronto and Vancouver have developed resources to promote low embodied carbon design and construction and, in some cases, have implemented embodied carbon limits. For example, the Vancouver Building By-Law currently requires the quantification and reporting of embodied carbon emissions for some classes of buildings and, beginning in 2025, new construction projects will be required to demonstrate either a 10% or 20% reduction in emissions relative to the baseline design. Similarly, through the Toronto Green Standard, the City of Toronto has implemented a cap on embodied carbon emissions. While currently voluntary, the Standard will be updated in 2026 and these voluntary requirements may become mandatory.

Decarbonization Strategies for Concrete and Cement

Decarbonizing concrete and cement manufacturing will require a range of strategies and approaches. Solutions that have proven essential for other industries, such as electrification and fuel switching to renewable energy sources, **will not be sufficient to decarbonize this sector.**

There are several strategies for lower-carbon production of cement and concrete products. Strategies can be deployed across the full supply chain, starting from raw material extraction through to the construction of buildings and infrastructure.

Specific strategies include:

IMPROVED PRODUCTION EFFICIENCY

Age is the primary factor influencing the efficiency of cement kiln operations. To date, extensive modernization efforts undertaken by the Canadian cement industry have already achieved reductions in the quantity of energy required to produce cement, meaning that there are limited options to achieve greater emissions reductions in the near-term from improved production efficiency.

SWITCHING TO LOWER-CARBON FUELS

The production of cementitious materials in a kiln requires high temperatures. Fossil fuels such as coal have traditionally been used to achieve these high temperatures. The use of alternative fuel sources that have a lower carbon impact reduces the emissions generated by the manufacturing process. Possible alternatives include lower-carbon fuels such as biochar or biomass, hydrogen energy sources, heat from municipal waste incinerators, and electrification.

CLINKER REPLACEMENT AND OPTIMIZATION

As approximately 90 percent of the embodied carbon of concrete products arises from the use of Portland cement, direct replacement of some of the cement with alternative binder materials can achieve significant emissions reductions of 20 percent - 50 percent. Optimizing concrete mix designs to reduce the total quantity of cement used, or replacing some quantity of the cement with alternative binder materials are commonly deployed strategies, though alternative materials are not always regionally available and may affect project costs. However, the availability of commonly used alternatives to Portland cement such as fly ash or ground granulated blast-furnace slag is expected to decline. These alternative binder materials are byproducts of other heavy industries (e.g., coal-fired power generation) that are themselves being transitioned to lower-carbon alternatives.

CARBON CAPTURE AND UTILIZATION

In theory, direct capture of process emissions at the cement kiln could reduce total carbon emissions impact by as much as 95 percent. CO_2 can be captured from the kiln through a variety of methods, including chemical or physical solvents, membranes, or solid materials that react with CO_2 to extract it from the flue gas stream. Captured carbon can then either be stored in a secure storage location or utilized in the production of other valuable materials such as synthetic fuels, plastics, or concrete to prevent its release into the atmosphere.

CONSTRUCTION EFFICIENCIES

Reducing waste or making changes to construction schedules can reduce the cost of concrete materials for construction projects while also reducing carbon emissions. Ready mix concrete is the only construction material that is manufactured for or at the job site. Making changes to its curing times can impact the quantity of cement required. By waiting longer before putting concrete structures into service, less cement can be used, resulting in lower emissions. However, this can impact project schedules and increase costs.

Defining CCU

Carbon Capture and Utilization (CCU) is the process of capturing CO_2 from industrial or atmospheric sources. The captured CO_2 is then used either on-site or at a separate location as a beneficial feedstock for other industrial processes.

Carbon Capture and Utilization refers to a suite of technologies aimed at mitigating CO_2 emissions created by the manufacture of concrete materials.

Carbon Capture:

The capture and separation of CO_2 emissions from industrial manufacturing facilities, preventing the release of CO_2 into the atmosphere. Captured CO_2 must be purified from other contaminating gases to obtain high purity CO_2 before being utilized or stored.

Carbon Utilization:

The process of converting captured CO_2 emissions into economically valuable products or materials such as fuels, plastics, or construction materials through various chemical, biological, or technological means, thereby providing an alternative and beneficial use for this CO_2.

Carbon Storage:

The process of securely storing CO_2 in various forms, including in underground geological formations or in long-lasting materials to slow or prevent its release into the atmosphere.

Approaches that can be used in the cement and concrete industry include:

CARBON CAPTURE

Carbon emissions can be captured directly from the flue stack of industrial facilities such as cement kilns. CO_2 emitted from the cement kiln can be captured using solid or liquid sorbent materials, or through other methods. Solvent-based methods are currently the most common approach. For carbon capture using solvents, CO_2 exiting the stack is captured by the sorbent materials, binding to these materials. Once captured, the CO_2 must be removed or 'stripped' from the sorbent material through a process that requires electricity or thermal energy. It may then be further purified before being transported for utilization or storage.

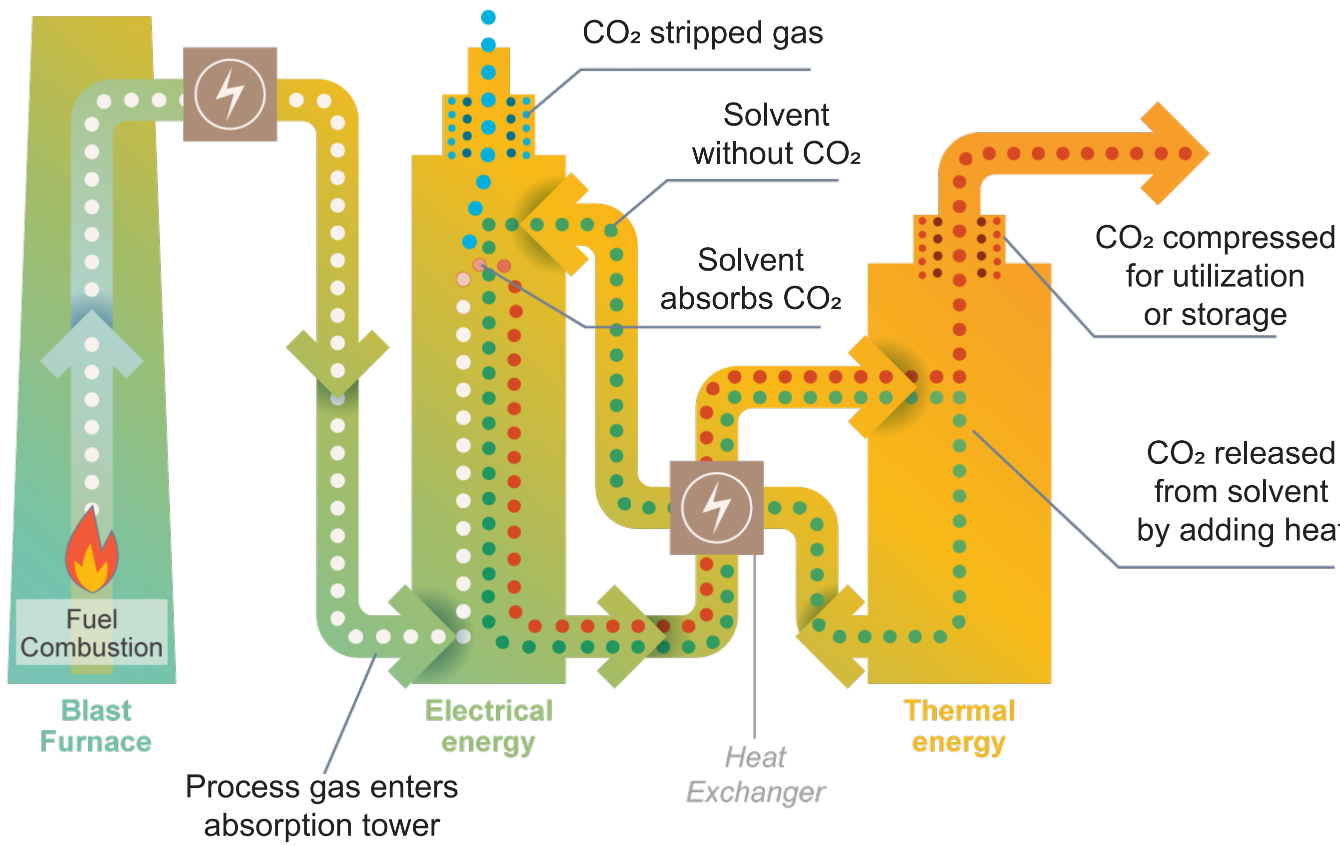


Figure 3: Example of Industrial-scale carbon capture using sorbent materials. Adapted from Natter and Merrill (2023)

CARBON UTILIZATION

There are multiple potential approaches for utilizing CO_2 in concrete manufacturing. Potential technology applications include:

CARBON MINERALIZATION

Mineralization is a form of utilization, where CO_2 is introduced into the concrete manufacturing process by combining it with components of the concrete mix to form calcium carbonate, a stable mineral. The formation of these stable minerals permanently stores the introduced CO_2 within the physical structure of the concrete material. Other forms of CO_2 mineralization include non-hydraulic cements that react with CO_2 from the air, and the use of alternative binder materials that can react with CO_2 as the concrete hardens and sets.

NOVEL SUPPLEMENTARY CEMENTITIOUS MATERIALS

It is common for supplementary materials to be used in combination with Portland cement to produce concrete. CO_2 can be used as a feedstock along with industrial byproducts or natural materials to sequester carbon in the supplementary materials. Materials treated with CO_2 may also enable higher replacement rates of Portland cement, reducing the total cement required for the concrete mix.

NOVEL AGGREGATES

Novel aggregates can be created by exposing waste concrete materials to CO_2. In this process, calcium-rich materials from the waste concrete combine with CO_2 to create lightweight aggregates that can be used in specialty concrete mixes.

CARBONATION OF CONCRETE WASTEWATER

During concrete manufacturing, some residual slurry waste is produced. A small percentage of the mix is lost as the materials are typically washed off production equipment or out of the drum of the concrete mixing truck. This concrete wastewater is highly corrosive, and there are limited options for reusing it. Carbonation of the wastewater may enable more reuse. The introduced CO_2 may reduce the corrosive properties of concrete wastewater while sequestering the CO_2.

Scope and Scale of Potential Emissions Impact

In general, for every kg of cement produced, 0.9 kg of CO_2 is created.

Complete capture and reuse could create 12.6 million tonnes of emissions reductions based on annual Canadian production of 14 MT of cement, equivalent to taking 3 million cars off the road each year.

The emissions associated with cement and concrete production are overwhelmingly driven by the calcination reaction that is used to create clinker in the cement kiln. During this reaction, limestone from raw materials is heated, causing it to split into quicklime (calcium oxide) and CO_2. Almost 90 percent of all emissions in the concrete supply chain are created during this step.

Emissions from cement clinker production come from two sources:

- Fuel consumption (fossil fuels, electricity) to create the required heat (~33 percent).
- Direct release of CO_2 from the calcination reaction (~66 percent).

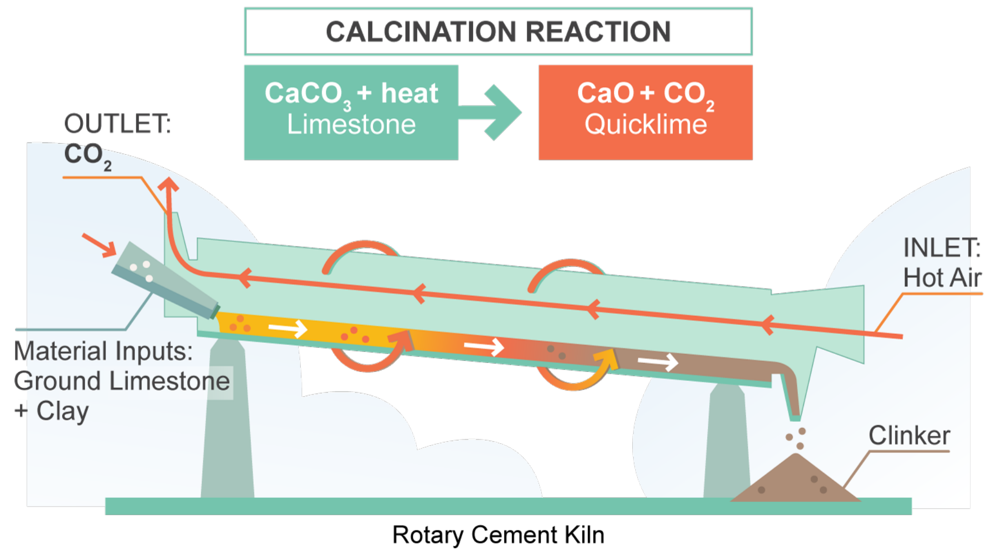


Figure 4: Cement Production (and Source of C0₂ Adapted from Waldrop (2022)

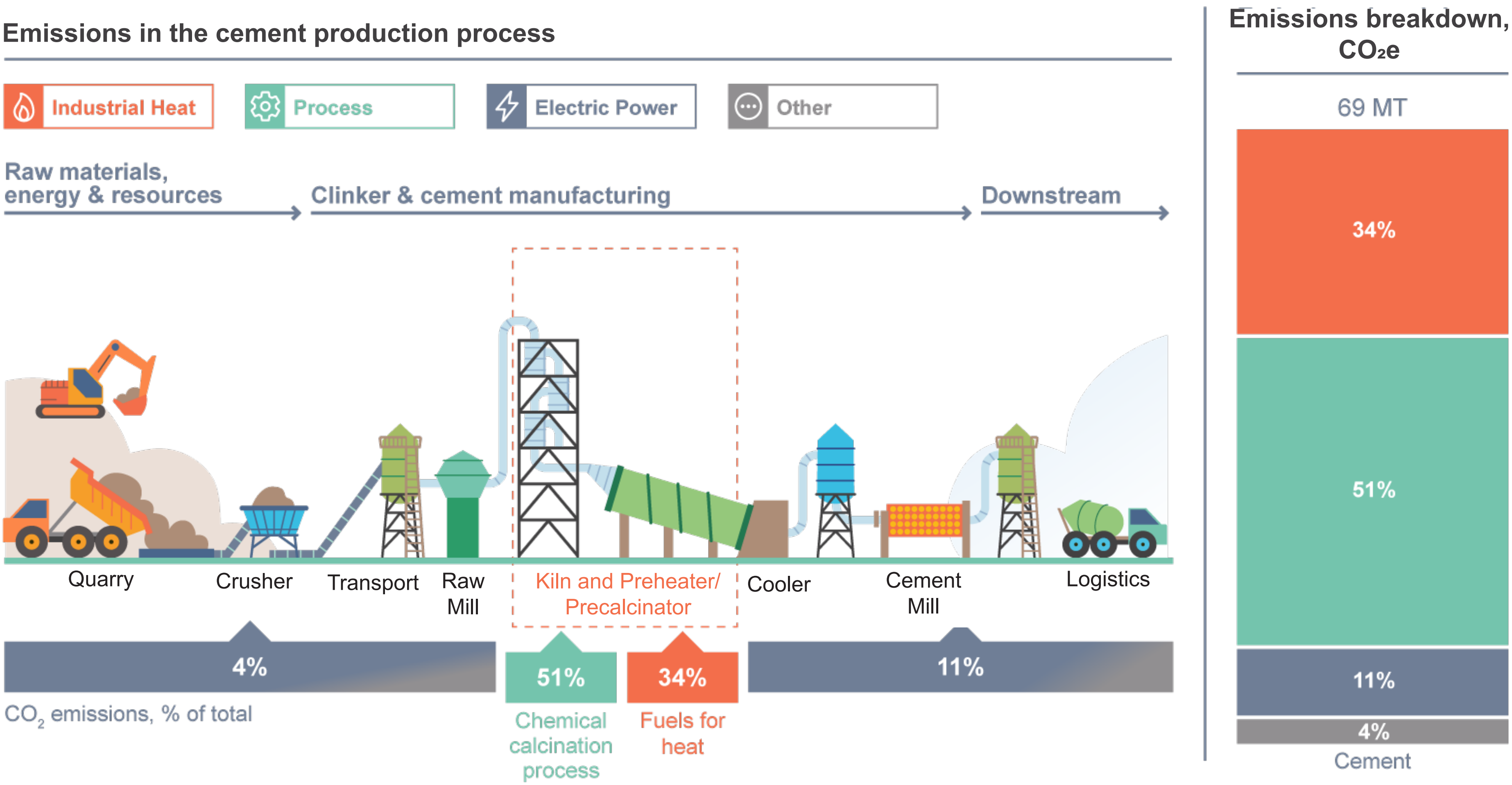


Figure 5: Image adapted from United States Department of Energy (2023)

Note that the image above is one example based on the United States Department of Energy study. The actual emissions contribution from the production process stages will vary based on local materials, fuel sources, travel distance, and the concrete mix produced.

When accounting for downstream and upstream emissions sources, emissions from cement clinker production remain the overwhelming driver of the impact of concrete products. The remaining emissions that are part of the carbon footprint of concrete come from raw materials processing and transportation of raw materials and the finished product.

Using CCU technologies, the CO_2 generated by the calcination reaction could be captured at source and then redirected for reuse or stored underground. These technologies target the most carbon-intensive phase of the cement and concrete production process, offering a significant opportunity for emissions reduction.

CCU-CBM In Canada

Canada hosts multiple CCU-CBM innovators. These innovators have been supported through a range of funding and incentive measures, with more than $2.3 billion invested since 2017 in the development and commercialization of technology entrepreneurs and adopters.

Funding has also been provided at the provincial level. The Province of Alberta for example has offered funding support for CCU-CBM technologies through its Emissions Reduction Alberta program. Alberta also played host to the $20 million NRG COSIA Carbon XPRIZE, a competition dedicated to innovators focused on converting CO_2 into usable products.[6]

Pilot projects are currently planned or underway in jurisdictions across Canada, deployed at both cement and concrete plants. Examples of Canadian pilot projects are shown on the following page.

Investment Tax Credit

The Government of Canada has proposed an investment tax credit for capital invested in projects deploying CCU-CBM technologies. Until 2030, the investment tax credit offers a refundable credit of up to 50% of the value of carbon capture equipment and 37.5% on qualified carbon transportation, storage, or usage equipment. The credit is available solely to Canadian corporations and eligible projects must operate for at least 20 years.

Carbon Up-cycling mineralizes CO_2 with industrial waste products to create constituent materials for concrete manufacturing, and has provided this material to projects in **Alberta.**

Heidelberg Materials is developing a carbon capture facility in **Edmonton, Alberta** that is expected to capture more than 1 million tonnes of CO_2 per year.

Project CO₂MENT in **Richmond, British Columbia** is a carbon capture demonstration project by Lafarge and Svante that captures one tonne of CO_2 per day from Lafarge's cement kiln. Captured CO_2 is planned to be utilized in the production of synthetic fuels.

In partnership with Hyperion Global Energy Corporation, Lafarge is piloting a project at its **Bath, Ontario** cement plant to capture CO_2 to create high purity minerals that can be used in concrete production. The pilot project has the capacity to remove up to 1,000 tonnes of CO_2 per year. [7]

Concrete blocks with a near-zero carbon footprint are manufactured in Quebec and Ontario using a technology created by CarbiCrete that combines waste steel slag, a byproduct of the steelmaking process, with CO_2 in a specialized chamber.

Concrete producers operating in **Alberta, British Columbia, Ontario,** and **Nova Scotia** utilize a carbon mineralization technology produced by CarbonCure Technologies to manufacture a variety of concrete products.

CarboClave's technology uses CO_2 to cure concrete blocks in **Ontario** and **Quebec**.

Carbon Capture
Carbon Utilization

Example CCU-CBM Technology Deployments in Canada

CCU-CBM in a Global Context

Global efforts to address carbon in materials have encouraged different approaches to support CCU-CBM research. For example, in 2021, the European Union Commission proposed a Carbon Border Adjustment Mechanism covering steel, cement, aluminum, fertilizer, and hydrogen production. This mechanism establishes a tariff on imported cement with higher carbon intensity than domestic European production, maintaining a price on European manufactured carbon while protecting against imports that are not subject to the tax and other environmental regulations. This could help maintain domestic competitiveness while incentivizing investment in lower-carbon production methods. Further cost savings could be realized if CCUS technologies use low-carbon electricity, meet technical criteria for the transportation of carbon dioxide, and use underground permanent geological storage or be permanently chemically bound.[8]

In China, cement manufacturers are in the early phases of launching projects to enable carbon capture at the cement kiln. As the largest producer and consumer of cement in the world, China accounts for more than half of total global cement production and use. China's national policy is broadly supportive of CCUS as a key element of long-term industrial decarbonization.[9]

In 2022, the United States Congress signed the Inflation Reduction Act (IRA) into law. During the Act's run, it allocated approximately $780B of investment into energy and climate focused efforts, including provisions that directly invested in or subsidized emerging CCU-CBM technologies. These investments included driving the development of more than 14,000 new Environmental Product Declarations for concrete, a 15 percent increase, and $2B to promote the use of lower embodied carbon materials in federal building projects, including approximately $750M dedicated to concrete materials.[10]

Following the 2024 US federal election, the implementation of the IRA was halted. However, some elements of the IRA relevant to CCU-CBM technologies were already completed (e.g., Environmental Product Declarations). Other elements of the IRA ultimately may not be implemented or may be implemented in a different form or at a different scale than that envisioned.

As Canada explores future opportunities related to CCU-CBM, including for international exports of Canadian cement, our CCU-CBM technologies and expertise will be critical. Realizing Canada's potential in this sector will require continuous support in convening and engaging Canada's CCU-CBM industry players.

Pilot Projects

In Norway, Heidelberg Materials' Brevik cement plant is host to the first operating industrial-scale carbon capture system, designed to capture 400,000 tonnes of CO_2e, or approximately 50 percent of annual emissions for storage under the North Sea.[11] Heidelberg plans to deploy additional carbon capture systems at its facilities in France, Germany, Sweden, the United Kingdom, and other locations across Europe.

CCU-CBM Opportunities and Benefits for Canada

Beyond achieving carbon emissions reduction, CCU-CBM technologies could create significant co-benefits for the Canadian economy.

WORKFORCE

A focus on the decarbonization of cement and concrete will lead to the creation of direct and indirect employment. Retrofitting of existing facilities will also create additional opportunities for good-paying construction jobs. Growing experience with emerging technologies will continue to drive innovative research at Canadian post-secondary institutions. Any changes to the existing processes and supply chains for cement and concrete production may also drive demand for skilled trades and further training and development of existing workers.

AIR QUALITY

In addition to CO_2, cement production also generates additional emissions that impact air quality. Investments to reduce the carbon footprint of cement and concrete may provide opportunities to similarly reduce the impact of these pollutants. The introduction of carbon capture systems, for example, could also provide opportunity to implement new pollution-control measures to increase CO_2 capture efficiency by removing contaminants.

RAW MATERIALS

The availability of supplementary cementitious materials such as fly ash and ground granulated blast-furnace slag is in decline. To achieve its targeted emissions reduction goals, the cement and concrete industry will need to develop new supplementary cementitious materials to replace diminishing stocks of existing alternative binder materials. Carbonation has been shown to increase the performance of some existing commonly used supplementary materials. The carbonation of additional industrial waste products could also lead to the development of new supplementary materials, providing additional opportunities to reduce the use of Portland cement. Increased use of supplementary materials sourced from industrial wastes in concrete materials provides a means to beneficially reuse them and keep these wastes out of the landfill.

IMPROVED COMPETITIVENESS

Production of low-carbon cement and concrete materials in Canada that meets or exceeds embodied carbon requirements established by major trading partners could also protect or increase the competitiveness of Canadian exports.

What We Learned

Capturing the Opportunity

The Cement Association of Canada expects that more than a quarter of emissions from cement and concrete production can only be mitigated through CCU-CBM technologies.[1] The Global Cement and Concrete Association similarly expects that CCU-CBM technologies will be needed to mitigate more than one-third of total cement and concrete emissions.[12] This universal identification of CCU-CBM as a critical and necessary class of technology demonstrates the economic opportunity associated with their development and deployment. As cement and concrete are manufactured worldwide using the same fundamental chemical process, made in Canada solutions could be exported globally.

Increasing the focus on the carbon impact of industrial materials by Canada's largest trading partners incentivizes domestic investment in carbon reduction initiatives. The United States is the single largest export market for Canadian cement, accounting for the overwhelming majority of $750M+ in annual exports[4]. Industrial policy in the United States promoted in recent years promoted the disclosure of the carbon impacts of raw materials like cement and concrete.

Future administrations could choose to deploy policies that further incentivize lower-carbon products, or recent steps to promote low-carbon procurement of cement and concrete materials could prove temporary. The relative interest and commitment by Canada's trading partners to managing and reducing the carbon intensity of materials will likely be a significant influencer of domestic investment in such technologies.

Choosing to continue to reduce the carbon impact of Canadian cement and concrete could help protect existing and trade and may create opportunities for increased international exports of Canadian cement and CCU-CBM technologies and expertise beyond traditional trading partners. Unlocking this potential will depend on marshalling stakeholders across the cement and concrete value chain. There is no efficient or centralized way to reach all design and construction practitioners across Canada involved in the specification and use of concrete materials. Tactical strategies to reach key decision-makers in regions where CCU-CBM technologies are emerging will build demand and incentivize further domestic investment and deployment. Data and information needs for key stakeholders involved in the manufacturing and consumption of cement and concrete are summarized in the table on the following page.

Demonstration Facilities

Centralized testing facilities that would enable transparent and consistent third-party evaluation of CCU-CBM technologies to validate claims of performance and environmental benefits would accelerate the rate of adoption. Data made available from central testing facilities that are accessible to public agencies across Canada would reduce the cost of trialling new technologies, improve the efficiency of testing and reporting, reduce concerns of bias, and promote awareness and understanding among stakeholders.

Key stakeholder information gaps for CCU-CBM technologies across the cement and concrete manufacturing value chain.

	Stakeholder Role	Information Needs
Policy-Makers	Creating an enabling policy environment focused on industrial decarbonization to foster development and deployment of emerging technologies	Technical knowledge that can be integrated into policy development
Owners & Procurers	Permitting and/or requesting the use of products, materials, or technologies in the design and construction of their assets	Strategies for competitive and fair procurement. Clear information on industry emissions baselines.
Engineers & Designers	Capacity to assess and evaluate the expected performance benefits of products, materials, or technologies used in their projects	Technical validation (both for performance and for claimed carbon benefits)
Contractors & Trades	Expertise in the use of products, materials, or technologies, and capacity to evaluate and procure them	Reliability and cost. Technical performance. Guidance on installation and use.
Concrete Manufacturers and Suppliers	Ability to effectively manufacture in-demand products and materials reliably and at an affordable cost	Technical performance and cost

Nascent Technologies

CCU-CBM technologies are being deployed across Canada today, but direct experience with these technologies is still limited.

The limited availability of CCU-CBM technologies in major markets in Canada means that few engineers, contractors, or project developers have direct experience with them. Where technologies are available, there can be limited capacity due to the small size of the pilot operations. Some innovators are not yet able to supply enough material for the concrete required for an average construction project.

Stakeholders reported that while they had interest and had researched the availability of concrete materials made using CCU-CBM technologies, they were often unable to acquire these materials due to this limited supply and availability.

Early technology deployment has been based in the Province of Alberta, with other pilot projects underway in Vancouver Island, southern Ontario, and Quebec.

CO_2 Supply

Captured CO_2 must be connected to existing facilities where it can be beneficially reused, or to secure underground storage locations. Not all areas of Canada have suitable geology to permit storage of captured CO_2. There is no climate benefit from producing CO_2 for the purpose of CO_2 utilization. It should be obtained from existing industrial or atmospheric sources.

The decentralized production of cement and concrete (due to the costs of transporting materials and the need to serve local markets) is an economic barrier. Improved CO_2 transport and/or pipeline infrastructure will be a critical enabling factor in reducing the cost of moving CO_2, improving the economics of CCU-CBM technologies.

CCU-CBM technologies take different approaches to achieve emissions reduction and utilization of CO_2.

The variability of technological approaches and the early stage of these emerging technologies creates the following challenges:

- Cement and concrete manufacturers are challenged to evaluate the viability of a growing number of new technologies through their own research laboratories.
- Designers lack consistent methodologies for assessing and validating the performance of concrete made with CCU-CBM technologies due to limited data availability and historical performance.
- There are no standard methodologies for quantifying and verifying emissions reduction claims from CCU-CBM, which limits the availability of information to decision-makers.

These uncertainties deter investment in and deployment of these technologies. Further technical validation is needed. Additional pilot and demonstration projects would provide opportunities for industry stakeholders to gain experience and collect data.

Deployment-Ready Solutions

TECHNOLOGY MATURITY

While it was widely recognized that CCU-CBM technologies will be an important contributor to the decarbonization of cement and concrete, they are generally at a low adoption readiness level and there are other carbon reduction strategies that are more immediately deployable and accessible.

Some of the other decarbonization approaches, such as clinker substitution, can be implemented as cost-neutral solutions for reducing emissions today. In some cases, these approaches offer cost benefits. Other strategies including fuel switching, renewal of facilities and equipment, and improvements in concrete mix designs are part of continual operations within the cement and concrete industry.

Industry players are deploying mature technologies that offer financial benefit. The use of alternative materials, is already challenging due to the decreasing availability of materials, often as a result of decarbonization efforts in the industrial sectors from which they are sourced The ability of existing deployment-ready solutions to offer continued emissions reductions will be limited, necessitating continued development of CCU-CBM technologies today.

These alternative approaches for reducing the carbon impact of concrete may also be more consistent with existing industry practices and supply chains, and the requirements of prevailing codes and standards. These factors reduce the time to receive approval and the overall adoption cycle, providing a further comparative advantage for investment. In some cases, these strategies have already been deployed in other nations, and could be introduced in Canada with changes to standards or through the introduction of additional incentives.

SCALE OF EMISSIONS

The scale of emissions arising from cement plants is extremely high, averaging more than 80,000 tonnes of CO_2 per year per plant. The volume of CO_2 generated by just one plant far exceeds what can meaningfully be utilized within the cement plant's local economy. Currently available CCU-CBM technologies focused on the utilization of CO_2 report capacities of hundreds of tonnes per year, and would need to be deployed at a much larger scale to utilize the CO_2 produced by just one cement plant. This results in a mismatch between the significant equipment costs and requirements to capture the high volume of CO_2 produced by a cement kiln versus the need to scale technologies capable of beneficially utilizing the captured CO_2.

Sourcing captured CO_2 is a current challenge for CCU-CBM technology providers, and available CO_2 may not be affordable due to the limited number of CO_2 capture sites, transportation costs, and purity requirements. Technology solutions that focus on capturing carbon at the cement kiln are being piloted that will have the capacity to capture much more significant volumes of emitted CO_2. Until the CCU-CBM technologies mature, the captured CO_2 can be sequestered in underground storage. This approach is only viable in areas of the country that have suitable geology and infrastructure in close proximity to operating cement kilns. As the maturity of CCU-CBM technologies advances, the quantity of CO_2 that can be utilized is expected to increase and the cost of these technologies will likely reduce, incentivizing adoption.

Codes and Standards

Codes, standards, and specifications play a crucial role in governing how concrete materials and products can be made. They provide direction on what materials can be used, how design or construction should occur, and a variety of other requirements. Generally, they define the minimum standards expected.

Codes vs. Standards

Codes: Codes provide direction on how structures or infrastructure will be designed and constructed. They may also define what materials may be used, how materials may be placed or handled, or other directives. Codes are overseen by legally established bodies with defined authority and jurisdiction. Failure to comply with prevailing codes and standards can have legal ramifications.

Standards: Standards are meant to define practices and approaches to ensure that a uniform approach is taken to promote quality and consistency. Standards are typically created and maintained by industry organizations in the design community. They represent best practices and are voluntary, though governments may mandate their own standards.

It is possible for CCU-CBM technologies to be used even if they are not specifically identified in standards that are recognized by the building codes, but it is perceived to be a higher risk.

In Canada, material standards for construction materials are largely developed through the Canadian Standards Association. There are a range of standards defined for cement and concrete, outlining testing requirements, expected design and construction practices, accepted materials, and other considerations. Concrete used in Canada must meet these standards.

For a technology to be vetted and considered by code or standards committees, it typically must be deployed and there must be sufficient data and evidence on its performance. But for technologies to be deployed, risk-averse stakeholders want assurance that they are compliant with the relevant codes and standards. The lack of direct reference or inclusion in the codes and standards is itself a barrier to adoption. This impasse means that CCU-CBM technologies can struggle to enter into the market.

RENEWAL CYCLES

Codes are typically renewed over a fifteen year cycle, and the committees that oversee codes are generally staffed by expert volunteers. Once published, it can take time before the latest versions of the codes are adopted and used in local standards and specifications. These local standards and specifications may operate on a different renewal cycle, which can further extend the time for adoption of new guidance, and they may override or alter guidance from the national standards. Obtaining recognition of new approaches and materials within the codes is therefore highly variable and can take a decade or longer. The long lead times and review requirements to achieve code changes are confusing, expensive, and time-consuming for innovators to complete.

Defining Low-Carbon Materials

The Canadian market does not have uniform standards for defining low-carbon concrete materials. The primary tool that is used to quantify embodied carbon emissions in concrete materials is life cycle analysis reported through an Environmental Product Declaration.

While EPDs are widely accepted and viewed as a useful tool, there are current methodological limitations, including:

- **Limited Baseline Data:** There is an overall lack of data on the carbon impact of different concrete mixes across Canada. While some EPDs for concrete products are available in individual provinces, there is limited information in many areas of the country. Guidance exists for provincial concrete associations to develop EPDs, but there is a gap in awareness and use of this information. Some jurisdictions solely report industry averages. This variability makes it challenging to understand the true baseline carbon impact of concrete products in Canada.

Levels of Accuracy in EPD Data

Industry Average:
Composite data based on average input values from multiple individual production sites in a defined geographic area.

Plant-Specific:
Data on a single product from a specific manufacturer based on source materials and production processes used by the manufacturing facility.

Batch-Specific:
Data on an individual concrete mix design based on the actual material proportions.

- **Lack of Standardized Methodologies:** The rules that govern the creation of EPDs are not designed to enable comparative decision-making. Rules currently permit the use of estimated values or industry averages, though these rules are being updated to reduce how many assumptions can be used. This reflects that for many materials (including concrete), there can be limited source data, forcing practitioners to rely on average values. In practice, this means that EPDs can be created through different assumptions or approaches, limiting their value as a tool to support procurement.

- **Inability to Account for New Approaches:** Current EPD methodologies do not have a mechanism to account for the benefits of CO_2 that is utilized in the manufacturing of new concrete products. This lack of recognition limits the ability of CCU-CBM innovators to offer value to cement and concrete producers in terms of the reported carbon intensity of their products. There is also a lack of consensus on how to account for or attribute CO_2 that is captured in one area or by one industry and used at another. Clearer accounting rules for CO_2 are needed.

Limitations in current tools make it difficult to definitively attribute carbon benefits to CCU-CBM technologies. Development of consensus standards for what constitutes low-carbon cement and concrete would enable more informed and consistent procurement decisions.

Economics of CCU-CBM

CAPITAL COST REQUIREMENTS ARE HIGH

Existing operating cement facilities have long service lives, which may justify investment in retrofitting these facilities with carbon capture. Some CCU-CBM technologies have high capital investment requirements and long (or non-existent) payback periods however, making them difficult to justify based on current market dynamics. Fully-deployed carbon capture projects can cost more than $1 billion to implement and may cost more than the capital cost of the cement kiln itself. Limited demand for captured CO_2 means that this investment cannot likely be recouped, even with the projected increases to carbon taxes in Canada.

CO_2 utilization technologies are generally lower cost and may not require capital investment at all. To date however, utilization technologies have been deployed at later phases in the concrete production process after cement manufacturing has already occurred. This means that cement manufacturers have not directly received revenue from the adoption of utilization technologies, and this capital is therefore not available to subsidize carbon capture at the cement kilns.

UNCERTAIN POLICY ENVIRONMENT LIMITS INNOVATION

Approaches that require substantial capital investment are reliant on enabling policy and funding support. Political uncertainty is detrimental to continued innovation and adoption. Without consistent policy support, impactful CCU-CBM strategies with challenging economics are unlikely to proceed.

REGIONALIZATION OF PRODUCTION

While cement is traded and transported across borders, concrete products are typically locally produced. It is rare for concrete products to be transported long distances from where they are manufactured due to shipping costs that make them uncompetitive with local products. Ready mixed concrete specifically has a uniquely limited delivery range. This limits potential economies of scale that can be achieved and geographically restricts the availability of low-carbon technologies that are deployed at the concrete plant. Different geographies also use local materials to make cement and aggregates. Differences in the composition of these materials can mean that CCU-CBM technologies have to be tailored to the chemistry of local materials.

DEMAND FLUCTUATION

The construction market continually changes in response to market demand. Demand for lower-carbon concrete material options from cement and concrete producers will likely increase in general. Producers however have limited ability to predict future demand for their products and there is variability in local markets or geographies. As most concrete products are made and delivered in close proximity to sites where they will be used, there is limited scalability and reach for the deployment of some CCU-CBM technologies. The regional inconsistency in market demand can make it difficult to justify investment in new innovations.

ECONOMIC RISK

Performance failure of concrete materials can be very costly. Poorer-performing concrete could result in reduced service life, increased operations and maintenance costs, or reduced useful life of the material itself. Concrete that does not meet specified performance requirements must be removed from job sites at the cost of the contractor and concrete supplier. This can also disrupt project timelines, creating further costs and emissions.

The introduction of any new technology could create a level of new risk, and it is reasonable to be cautious. Some CCU-CBM technologies, such as carbon capture at the cement kiln, will not result in any changes to material products. Other CCU-CBM technologies must be evaluated to assess whether any performance changes will be expected to occur to limit potential new economic risks.

Public Policy and Procurement

CONSISTENCY IN PROCUREMENT

As procurement of concrete is conducted by all levels of government through varying agencies, coordinated procurement using similar language and requirements will be essential to driving adoption of CCU-CBM technologies. Varying standards would create additional inefficiencies and costs for compliance for cement and concrete producers, hindering innovation. Adoption of common methodologies and standards for low-carbon procurement across all levels of government would incentivize deployment of CCU-CBM technologies and reduce adoption risk. Governments must also ensure that procurement guidance is followed and implemented during project execution.

DEMONSTRATION PROJECTS

Government-led projects are also well-suited to serve as demonstration projects. Some forms of public infrastructure are lower risk applications (e.g., sidewalks, curbs, and gutters, etc.) where there is limited concern for life-safety risk. The size and scale of these projects would also accommodate early-stage innovators that may only be able to supply limited quantities of material.

PROCUREMENT GUIDANCE

Procurement agents are specialized experts that do not have experience or technical knowledge on CCU-CBM technologies or concrete materials. These agents will require clear guidance on how to integrate considerations for lower-carbon products into their purchasing decisions in order to facilitate adoption of CCU-CBM technologies.

PREDICTABLE DEMAND

Government-directed procurement of concrete made with CCU-CBM technologies offers one of the only tools to overcome the cost barriers to use of low-carbon concrete materials. Government procurement could introduce requirements for lower-carbon cement and concrete or prescribe its use within certain projects. As governments are responsible for 50 percent or more of all concrete procured, strong commitments in procurement would accelerate production capacity for lower-carbon concrete materials. The public sector is best positioned to provide stable demand signals and to provide certainty for cement and concrete producers to invest in CCU-CBM technologies through procurement policies. Committing to targeted reductions in emissions for major projects will drive demand for these technologies as suppliers seek out market-ready solutions that can help them meet the prescribed targets. Targets should be realistic but ambitious, and will need to become more stringent over time.

Low-Carbon Procurement by the Government of Canada

Through the Treasury Board's Standard on Embodied Carbon in Construction, the federal government of Canada directs all new major construction projects to use concrete that achieves a 10% reduction in embodied carbon emissions in comparison to regional averages.

Closing and Next Steps

CCU-CBM technologies are a necessary component for achieving net-zero cement and concrete in Canada. The research and perspectives summarized in this report describes the current state of CCU-CBM technology adoption in Canada and outlines the potential opportunity of these technologies in achieving carbon emissions reductions in the building and construction sector.

The Burying Carbon in Buildings project will continue to build on this research by exploring further topics and completing further actions under the following themes:

TECHNICAL RESEARCH

Research underway at the University of Toronto will contribute to advancing the state of knowledge on CCU-CBM technologies in Canada. The following topics are being investigated:

- The effects of CCU-CBM technologies and techniques on the physical properties and performance characteristics of concrete materials.
- Methodologies for modeling and quantifying embodied carbon emissions for concrete materials using CCU-CBM technologies.
- Evaluating naturally occurring CO_2 uptake by concrete materials in different geographic regions across Canada.

INDUSTRY AND EXPERT CONSULTATION

Additional consultation will be conducted with expert stakeholders to solicit feedback and to share findings on the following topics:

- Priorities and approaches to effective public policy development.
- Review of code and standard cycles and opportunities for advancing consideration of CCU-CBM technologies with or without specific reference in the codes and standards.
- Guidance for the assessment of environmental impacts associated with CCU-CBM technologies.

INFORMING PROCUREMENT

Guidance will be developed on effective specification and procurement of concrete materials utilizing CCU-CBM technologies. This report will be targeted toward the design, construction, and development industry to support the use of CCU-CBM technologies. The report is expected to describe the responsibilities of all project partners involved in the construction of buildings and infrastructure (e.g., architects, structural engineers, concrete suppliers, and general contractors). This will be the final outcome of the Burying Carbon in Buildings project.

Appendix A: Acknowledgements

The document was developed with the assistance of a diverse advisory panel that provided feedback through review of draft documents and discussion. The members of the advisory panel are listed below.

Advisory Panel

Adam Auer	*Cement Association of Canada*
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Anya Barkan	*Multiplex*
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Sarah Petrevan	*Cement Association of Canada*
Oscar Valdes	*Entuitive*

In addition to the advisory panel, a group of thought leaders were invited to participate in interviews as part of the development of this document. The additional stakeholders that contributed their expertise are listed below.

Stakeholders Consulted

Lisa Bate	*CarbonCure Technologies*
Jack Boland	*City of Toronto*
Travis Butler	*Butler Brothers Concrete*
Rob Cooney	*Treasury Board of Canada*
Jamie Gray-Donald	*Quadreal*
Navisa Jain	*EllisDon*
Lee Hodgkinson	*Dream*
Cindy McLaughlin	*CarbonBuilt*
Na'im Merchant	*Carbon Removal Canada*
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Chris Severson-Baker	*Pembina Institute*
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Chris Stern	*CarbiCrete*
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