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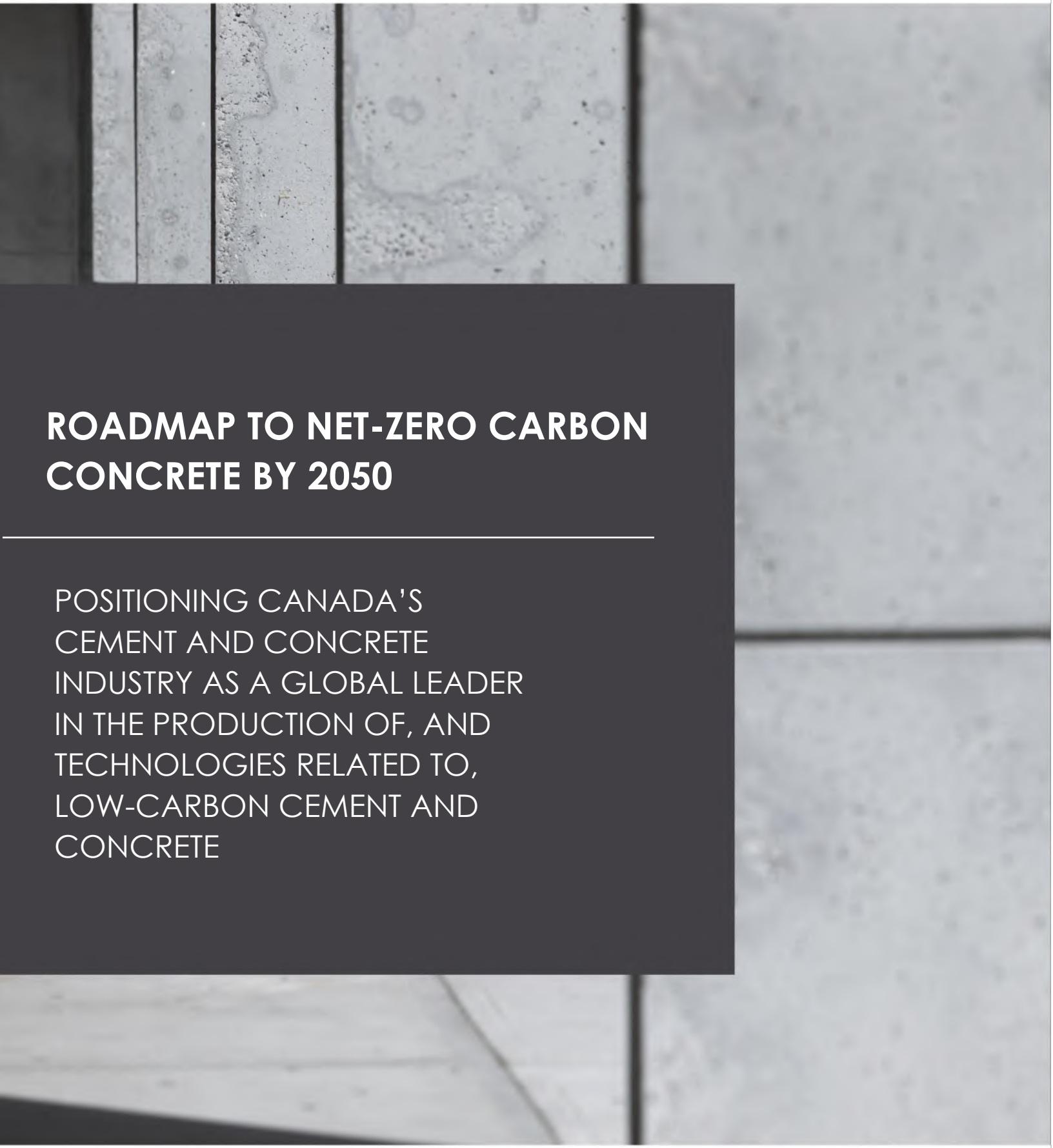

ROADMAP TO NET-ZERO CARBON CONCRETE BY 2050

POSITIONING CANADA'S CEMENT AND CONCRETE INDUSTRY AS A GLOBAL LEADER IN THE PRODUCTION OF, AND TECHNOLOGIES RELATED TO, LOW-CARBON CEMENT AND CONCRETE

Canada

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Web Services Centre
Innovation, Science and Economic Development Canada
C.D. Howe Building
235 Queen Street
Ottawa, ON K1A 0H5
Canada

Telephone (toll-free in Canada): 1-800-328-6189
Telephone (international): 613-954-5031
TTY (for hearing impaired): 1-866-694-8389
Business hours: 8:30 a.m. to 5:00 p.m. (Eastern Time)
Email: ISED@canada.ca

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Introduction

Concrete is an indispensable construction material used in the built environment (cement being the key binding component of concrete). Concrete is the second most consumed product on earth, after water, and is used in almost everything we build—from houses and cityscapes to dikes and dams to roads and bridges.

More than 1,100 ready mixed concrete, precast concrete, concrete pipe, and masonry plants are located across Canada. Collectively, the industry is responsible for approximately 158,000 direct and indirect jobs across the country while annually contributing $76 billion in direct, indirect and induced economic impact to the Canadian economy.

While Canadian production largely supports the Canadian market, exports of cement to the United States (U.S.) have increased from $840 million in 2016 to $1.1 billion in 2019. Given its performance characteristics and the broad availability of limestone, concrete (and therefore cement) is likely to remain the construction material of choice globally.

How concrete is made

Concrete is obtained by mixing cement (and possibly supplementary cementitious materials), fine and coarse aggregates (e.g, sand, gravel, recycled concrete) and water. Admixtures are added sometimes to confer specific properties. While cement makes up only a small percentage of the mix (12% by volume on average), it is generally responsible for more than 80% of the resulting carbon dioxide emissions. There are 3 principal concrete product categories: ready mixed concrete, precast concrete products and masonry units (concrete blocks).

In fact, concrete use is expected to continue to grow globally and in Canada, driven by population growth, urbanization, and economic development as well as the need to invest in new and retrofitted infrastructure to support climate objectives. In Canada, public spending on road construction and transportation infrastructure further bolsters a demand for cement. In this context, Canada will produce some 55 million tonnes of cement and 400 million tonnes of concrete over the next 5 years – filling enough concrete mixer trucks to circle the globe 4.5 times.

Against this backdrop of growing demand, the Government of Canada and the cement and concrete industry are progressing toward a sustainable market that aligns with the joint goal of reaching net-zero emissions by 2050.

Worldwide, cement manufacturing is a major source of greenhouse gas (GHG) emissions— cement production accounts for approximately 7% of GHGs globally.

Among global industrial emissions, cement accounted for about 26% in 2019[1].These emissions primarily come from the chemical process reactions needed to convert limestone into clinker, the precursor to cement, and from the fossil-fuel emissions generated to produce the high temperatures (approximately 1,450 degrees Celsius) required to achieve that process.

Likewise, cement production accounts for a significant share of Canada's current GHG emissions. Facility-level reporting through Canada's Greenhouse Gas Reporting Program listed 11.2 megatonnes (Mt) of carbon dioxide (CO_2) in 2019 for the cement manufacturing industry. This represents about 1.5% of Canada's emissions.

Decarbonizing Canada's cement and concrete sector is a priority. While that is a complex and multi-faceted challenge, it also presents Canadian industry with significant opportunities—both at home and abroad.

A nation-wide transformation of the Canadian cement and concrete sector will require significant levels of innovation and investment from manufacturers, the broader construction industry, and governments. Significant research and development to support emerging practices and technologies will be needed. High levels of investment in near-, mid-, and long-term industrial decarbonization projects such as transitioning large scale cement plants to lower emission energy sources and undertaking carbon capture, utilization and storage (CCUS) will be needed, too. The transformation will also require significant changes in design approaches, engineering, construction methodologies, and just as importantly, in the way that building materials and infrastructure are procured by all levels of government and the private sector.

The Government of Canada has a key role to play in supporting and driving decarbonization efforts. Policy support to achieve net-zero targets is needed from all levels of governments. An integrated policy and regulatory landscape will include these important parts:

- green procurement policies, related codes, standards and specifications, and training and education
- funding programs and other fiscal supports to spur innovation and investment
- concerted efforts to engage and inform stakeholders across the construction value chain

The growing urgency for rapid decarbonization to stay on track with a net-zero trajectory creates an acute demand for fiscal assistance and supports to attract near-term capital investment in major industrial decarbonization projects and for innovators translating research and pilot projects into commercial operations. This is particularly the case for the first few projects to adopt new technologies. Over time, technology costs will

[1] https://www.ic.gc.ca/eic/site/icgc.nsf/eng/07730.html

decline, low-carbon technologies will become more widely commercialized, and regulations will strengthen (including certainty on a rising price on carbon emissions). At that point, industry is expected to take on a greater share of the costs of decarbonization.

Government and industry collaboration through innovation hubs, R&D, demonstration projects, codes and standards, and skills development will further support the cement and concrete industry's push toward net-zero by 2050.

The development of the **Roadmap to Net-Zero Carbon Concrete** and **Action Plan to 2030** documents was spearheaded by a joint industry-government working group, co-led by the Cement Association of Canada and Innovation, Science and Economic Development Canada. This working group was comprised of key players from the federal government departments, representatives of the Canadian cement and concrete industry, and environmental organizations. [See Annex 1]

Through this partnership, Canada's cement and concrete industry has committed to reducing more than 15 megatonnes (Mt) of GHGs cumulatively by 2030. Thereafter, ongoing annual reductions of more than 4 Mt from the production of cement and concrete in Canada will occur on the road to net-zero concrete by 2050[2].

To achieve these targeted reductions, the Government of Canada and the Cement Association of Canada developed an **Action Plan to 2030** with specific measures centered on achieving three main outcomes:

1. **drive Canadian market development** by creating the market conditions needed for the industry to adapt to a net-zero economy
2. **drive innovation and transition within industry** throughout the full value chain by increasing support for the development and deployment of low-carbon technologies
3. **position Canada as a world leader in the production, adoption and export of low-carbon cement and concrete products and technologies** through the pursuit of new export opportunities and international collaboration

This roadmap aligns with Canada's newly announced 2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy. This is an ambitious plan to fight climate change while bringing sustainable, lasting economic prosperity to Canada, which charts a credible path to emissions that are 40% lower than 2005 levels by 2030.

This comprehensive roadmap is designed to be evergreen and reflects levels of ambition to guide emissions reduction efforts in each sector, including the buildings and construction sector. Progress on the action plan will be monitored and reported on

[2] GHG emissions reductions estimates were provided by the Cement Association of Canada (CAC) and reflect actions that the Canadian cement and concrete industry will undertake to reduce their emissions by 2030.

annually via a Steering Committee that will be formed of voluntary members consisting of two co-chairs as well as representatives from both industry and government. [See Annex 2]

Canada has the right conditions to become a world-leading producer and exporter of low-carbon cement and concrete products and systems, as well as related clean technologies and services. It has a modern regulatory environment and clean electricity advantages, coupled with a suite of Canadian innovations providing low-carbon commercialized solutions. Increased adoption of low-carbon cement and concrete will further drive the Government of Canada's commitment to clean growth and lead to financial, environmental and health benefits for all Canadians.

Opportunities to Decarbonize Cement and Concrete in Canada

Canada's cement and concrete industry is committed to achieving net-zero carbon across the entire value chain by 2050. There is currently no single process, product or technology that can, independently, achieve that net zero goal. There are, however, a menu of technologies, processes, and products that support decarbonization.

Over the last 30 years, the industry has invested in production improvements to reduce its consumption of raw materials and energy use and decrease the resulting industrial CO_2 emissions. The industry has also widely increased the adoption of cement substitutes, often called supplementary cementitious materials (SCMs) frequently derived from the waste products of other industries (e.g. steel slag). The industry has also increased the use of admixtures to both improve the physical properties and the environmental performance of concrete. Lower-carbon cement and concrete are featured and have been promoted by manufacturers across Canada.

Ongoing actions in the drive to net-zero are focused on the entire value chain, starting at the cement plant, and extending through the life cycle of the built environment to incorporate the circular economy. Key phases of this life cycle include the:

- production of clinker
- manufacture and shipment of cement
- production of concrete
- construction, use and decommissioning of the asset
- carbonation of concrete (concrete as a carbon sink) while in use and at end- of-life.

In the present to near-term, the cement and concrete sector is focused on optimizing clinker substitutes, reducing reliance on fossil fuels by switching to lower-carbon

alternatives, increasing use of recycled materials contributing to the circular economy, promoting market uptake of low-carbon cements and concretes, and maximizing efficiency in concrete design and construction.

In the longer term, priority actions include, continuing to deploy clinker substitutes and alternative clinker technologies. Actions also include harnessing new energy sources such as biogenically-derived fuels, clean hydrogen and electricity, and utilizing innovations to maximize concrete's ability to sequester carbon via a variety of carbon mineralization approaches.

Other solutions such as CCUS can provide near-term benefits with first-in-kind projects and longer-term benefits through full-scale deployment across the industry.

Concrete is an essential building material that has and will continue to play a critical role in cost-effective, safe, durable and climate resilient buildings and infrastructure. Prioritizing actions to achieve net-zero will create lasting benefits. These benefits include:

- retaining and strengthening Canada's cement and concrete industry through the global transition to a clean economy
- reducing embodied carbon emissions in the built environment
- developing and deploying innovative technologies that could both help other sectors decarbonize and support clean technology jobs and exports

Clinker and cement

The production of clinker is the most energy-intensive process in the overall production of concrete. Clinker is an intermediate precursor to cement, and its production is a major source of CO_2 in relation to cement. It is produced in a series of complex chemical reactions that ultimately transforms calcium carbonate in limestone to calcium oxides and calcium silicates. This process is responsible for more than 60% of the CO_2 emissions from cement manufacturing. The remaining CO_2 emissions, just under 40%, come largely from the energy combustion required to heat that process (other smaller sources of emissions include electricity use and on-site transportation and related equipment). Clinker is blended (and inter-ground) with different proportions of gypsum and unprocessed limestone to produce cement.

Solutions required to decarbonize clinker and cement production include reducing clinker volumes, increasing the use of alternative fuels, using clean electricity, improving energy efficiency, and conducting CCUS.

Reducing clinker volumes

Increasing the volume of decarbonated raw materials – particularly those that can be sourced locally and are not transported over long distances— to replace some of the limestone in the kiln reduces total emissions from the production of clinker. Decarbonated materials such as fine gradation materials from recycled concrete do not emit CO_2 when heated because they have already had the CO_2 removed. Globally, reducing clinker volumes is forecast to provide a 2% reduction in total emissions from the sector.

Additionally, there are other approaches to clinker reduction that can catalyze further carbon reductions. Specifically, there are a range of clays, natural pozzolans, and industrial by-products (e.g., fly ash, blast furnace slag) that, due to the lack of carbonates in their chemistry, can be utilized to reduce clinker ratio.

Canada's industry has already made progress in this area, with some cement producers committing targets of more than 30% clinker substitution, or a 0.70 clinker ratio, using alternative SCMs by 2030. A key challenge to overcome is the accelerated testing, standardization, and acceptance of novel cements in the market. These could be overcome with targeted R&D supports, the expedited development of related codes and standards, and procurement programs that increase opportunities to validate and promote innovations, including early-stage demonstration programs in low-risk environments.

Increased use of alternative fuels

Cement production requires significant high temperature levels that can currently only be achieved through combustion.[3] Using low-emitting clean fuel sources instead of traditional high-emitting, fossil fuel-based energy sources reduce GHG emissions from the combustion process. Lower-carbon fuels include materials recovered from the waste stream, particularly biomass; however, these still generally require some mixing with traditional fossil fuels to achieve the required conditions in the cement kiln. Beyond 2030, the benefits of biomass-based fuels as well as emerging fuels such as hydrogen are expected to enable cement manufacturers to significantly decarbonize their fuel supply.

Transitioning away from fossil fuel use is one of the key opportunities for the cement industry. Over the last several years, cement plants across Canada have already been investing in systems to allow for the use of alternative fuels, including waste-based fuels, urban generated wood-wastes, and other end-of-life waster products that may be difficult to recycle. This includes the construction of alternative fuel processing equipment, on-site storage buildings, feed systems, combustion control systems as well as associated supply contracts with the private and public sector. The cement industry continues to work across Canada with public waste authorities at the local government

[3] There is research underway on the potential for application of electric plasma arc technology in cement production, but this is in its very early stages.

level. Some challenges continue to be faced because of readily available, inexpensive landfill disposal that competes directly with the cement industry for these same waste materials.

Using clean electricity and improving energy efficiency

There are numerous energy efficiency measures that could be considered at cement plants. These measures vary in terms of the capital investment required and include doing electrical retrofits such as upgrading motors to variable frequency drives and improving milling operations (e.g., switching from ball mill to vertical roller mill grinders). Grid-based decarbonization, site-specific renewable energy production and the electrification of mobile equipment also represent decarbonization opportunities.

Employing carbon capture, utilization and storage (CCUS)

Climate models have shown that CCUS technologies play a key mitigation role in the decarbonization of cement and concrete. Carbon capture technology can mitigate both the combustion and process emissions that are released in clinker production. Near-term opportunities to sequester large-scale emissions are primarily in storing captured CO_2 in geologic formations. However, a variety of different technologies focus on utilizing captured CO_2 in cement and concrete production, including injecting CO_2 into un-cured concrete. The technologies also focus on manufacturing SCMs and synthetic aggregates from waste products, which can then be used to sequester carbon in concrete products.[4]

Increasingly, second-generation CCUS technologies such as calcium looping and chemical looping are also being explored for potential integration within the cement industry as more efficient, less toxic alternatives to current post-combustion capture processes (such as amine scrubbing). These processes, together comprising high-temperature looping cycles, are 2 of the most promising second generation CCUS technologies that are expected to be ready to be deployed post-2040. They benefit from high efficiency as well as reactors that are available at scale and are essentially off-the-shelf.[5] Calcium looping and chemical looping are promising not only for cement manufacturing but for other industrial processes as well, such as including iron and steel production and steam generation.[6] Additionally, CO_2-embedded SCMs that can reduce the clinker factor in blended cements offer significant CO_2 equivalent (CO_2e) reductions

[4] These carbon conversion technologies (or carbon tech) are a potential way of shifting carbon from being a problem to a valuable revenue-generating feedstock. Interest in carbon tech is a market opportunity that is expected to grow to $1 trillion annually by 2030. Within this market backdrop, Canada is uniquely positioned to be a global leader in the growing carbon tech sector as it has leading academic research centres and scale-up facilities specializing in CCUS in Alberta, British Columbia, Ontario, Quebec, and Saskatchewan.

[5] Paul Fennell and Ben Anthony (editors), "1 – Calcium and chemical looping technology: An introduction," *Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO2) Capture* (Sawston, United Kingdom: Woodhead Publishing, 2015).

[6] *Ibid.*

relative to conventional portland limestone cement production (between 20% and 40% CO_2e reductions).[7]

Concrete and construction

Concrete plays a major role in the built environment, providing a versatile, strong and resilient material with many indispensable uses. The use of concrete in the built environment has 4 phases— design, construction, use, and end-of-life—each with the opportunity for emissions reductions.

Solutions required to decarbonize concrete production and its use in construction include concrete mix optimization, concrete manufacturing and transportation, and the optimization of design and construction.

Concrete Mix Optimization

The use of supplementary cementitious materials (SCMs) can replace, on average, 30% or more of the cement required to produce concrete. This will reduce GHG emissions while still producing concrete with the same or superior quality, strength and durability of that made purely of cement. The concrete industry has been offering lower carbon intensity concrete products, including concrete made with portland limestone cement (PLC) or blended cement for several years, and efforts continue to be made to transition customers to these products. Challenges remain in some markets, particularly with governments that have traditionally been slower to adopt lower-carbon products. The cement and concrete industries continue to work together with local concrete producers, provincial Concrete Associations and government officials to move towards wide acceptance of these products in a variety of uses.

At the cement plant or the concrete plant, fly ash, ground granulated blast surface slag, ground limestone and other materials can be added to deliver concretes with reduced CO_2 emissions. As the energy and steel industries transition away from their use of coal and other fossil fuels, the availability of virgin fly ash and slag will decline. They will be replaced by fly ash and slag recovered from landfills, higher proportions of unprocessed ground limestone, calcinated clay and perhaps other novel materials. The cement sector is focused on research and development in this area and has invested heavily in securing alternative sources of fly ash that will allow for continued reduction in the GHG intensity of cement and concrete products.

As well, the use of admixtures is currently common in concrete production, generally to improve performance and the efficiency of making concrete. However, these admixtures currently represent only 1% of total concrete material. New admixture chemistries are an opportunity to increase their use in concrete and the role they play in reducing concrete's carbon footprint while maintaining and improving concrete's performance.

[7] Aecon Group Inc, "Aecon Pilots Low Carbon Concrete at Innovation and Training Centre," (May 31, 2022).

Concrete manufacturing and transportation

Mixing and delivering concrete requires energy, and shifting the energy needs of concrete production facilities to clean electricity and other low-carbon sources of energy will result in emissions reduction. In addition, concrete and concrete products, while manufactured locally, must still be transported to the jobsite. This results in diesel fuel emissions. Switching to zero-emissions fleets will also result in a reduction of CO_2 emissions.

Optimization of design and construction

Optimization in the design phase of a project takes a whole life-cycle approach—every aspect through each stage of construction should be assessed for opportunity. Just as we have done for energy efficiency, we must make material efficiency a design priority.

Advances in building codes, standards, and design processes can limit overdesign in materials and structures, while still accommodating flexibility to meet project specific performance and other requirements.

Optimized construction means zero waste on the job site and zero returned concrete. A new emerging technology called additive manufacturing (also referred to as 3D printing), reduces the need for construction tools and, hence, construction waste while reducing construction time. This method of concrete construction has the potential to change the way cementitious materials are used to create infrastructure components. Another consideration vis-à-vis optimization is the integration of sensors into formwork. While mainly about optimizing project timelines, sensors can also reduce the need to overdesign concrete mixes for a certain early strength (i.e., less cement can be added, thusly reducing emissions).

Designing for longevity, adaptive re-use and deconstruction also play important roles in minimizing waste and reducing the need for virgin materials. Where returned and demolished concrete does exist, technologies that utilize the unreacted calcium oxide within that material to capture CO_2 should be given access over conventional recycling to maximize its decarbonization potential. Finally, more is being learned about the capacity of concrete to naturally reabsorb CO_2 (i.e. “concrete carbonation") that was released in the cement-making calcination process. Research suggests that more than 20% of the process emissions from cement used in concrete could be reabsorbed over the life of concrete in the built environment. The way we design concrete infrastructure (e.g., exposed concrete designs) and the way end-of-life concrete is handled and processed can help enhance these natural processes. More R&D is required to understand how to influence and optimize this characteristic of concrete as well as how carbonation rates are impacted by emerging mineralization technologies, such as CO_2 injection.

There are existing opportunities to reduce emissions in cement and concrete. These include the use of SCMs, fuel switching, concrete mix optimization, concrete manufacturing and transportation, and the optimization of design and construction.

Industry estimates that up to 20% to 30% of concrete's embodied carbon could be avoided through the optimization of these solutions. Additional reductions can be achieved through efficiency in the design and use of concrete during construction as well as through establishing policies to favour low-carbon materials and products in procurement.

Greening Policy Levers

Codes and standards

Codes and standards provide a key lever for setting mandatory minimum requirements governing infrastructure assets. Their evolution is essential to ensure that we evolve building practices in consideration of changing climate conditions, and drive made-in-Canada innovation for low-carbon materials and approaches. Action is required to de-risk and raise awareness of innovative solutions that are less familiar to designers and builders who tend to lean towards tried-and-true methods that deliver projects on time and on budget.

Once climate-smart codes and performance-based standards are adopted by authorities with regulatory jurisdiction, they become mandatory and raise the minimum bar for the consideration of low-carbon and resilient approaches in infrastructure procurement, design, construction, operation and retrofit. Voluntary standards can also be used in public sector procurement and funding criteria, or by industry leaders in their efforts to de-risk and integrate new low-carbon technologies and materials into design and construction.

By integrating both low-carbon performance and operational and embodied carbon considerations into building and infrastructure design, guides, codes and standards we can close the critical research, regulatory and technology gaps in order to de-risk low-carbon materials and approaches and grow and transform Canada's construction sector to align with an innovative, low-carbon economy.

Using codes and standards in tandem with other policy levers, including federal funding program eligibility requirements regarding the use of low-carbon materials, can provide certainty to industry regarding the federal vision for the construction sector's low-carbon pathway and ultimately promote low-carbon market transformation.

Prioritizing performance-based, low-carbon requirements will create the flexibility needed to catalyze innovation within industry, positioning Canada as a world-leading supplier of low-carbon building materials.

Procurement

Green procurement is a powerful lever to drive the decarbonization of construction materials. Government infrastructure projects consume approximately 40 percent of the cement produced globally. By requiring increasingly lower carbon materials in procurement and adopting performance-based project requirements, they incentivize innovation. Governments can also carve out projects to demonstrate new to market

products and processes. Long term commitments to buy lower carbon materials provide market signals that can be leveraged by industry for investment in decarbonization. In the Greening Government Strategy, the Government of Canada has committed to requiring the disclosure of embodied carbon in structural materials in major construction projects starting in 2022, and a 30% reduction in that embodied carbon starting in 2025. In addition, Government of Canada has committed to introduce a new Buy Clean Strategy to support and prioritize the use of made-in-Canada low-carbon products in Canadian infrastructure projects. These measures are important levers to further strengthen Canada's capacity to produce low-carbon cement and concrete products and solutions.

Given its immense buying power, the Federal Government has a leading role to play in helping to lower GHG emissions. In this respect, adopting effective green procurement policies can help lead by example, encouraging key industries to reach their own net-zero goals and promoting clean innovation across the economy. In addition to supporting the private sector, stronger efforts will also be needed from the Federal Government to encourage and support adoption of green procurement policies at the provincial and municipal level.

Carbon reporting

As existing technologies are improved and new ones are developed to help the cement and concrete industry achieve carbon neutrality, there needs to be equal advancement in the quantification and reporting of carbon emissions. Advancing carbon emission reporting can be achieved by supporting the continuous development of life-cycle inventory datasets and environmental product declarations (EPDs). Ensuring that all manufacturing sectors are developing life-cycle inventories and EPDs in a consistent and harmonized way will enable a level playing field to compare the carbon emissions of improved and new technologies.

Canadian clean technologies and innovations

The need for research, development, and innovation to support the cement and concrete industry's pathway to net-zero by 2050 cannot be understated. New technologies will need to be deployed and technological challenges will need to be solved to support decarbonization in the industry.

Significant R&D to support emerging practices and technologies will be needed, as will high levels of investment in near-, mid-, and long-term industrial decarbonization projects. For example, this could involve transitioning large-scale plants to lower emission energy sources like biogenic fuels, clean hydrogen and electricity and the full deployment at scale of CCUS. These are important solutions for the industry that are still being piloted, and Canada has a role to play in the R&D for these solutions.

Research and innovation must also be undertaken to significantly change construction methodologies and change the way that building materials and infrastructure are procured by all levels of government and the private sector. There are several near-term research and innovation actions that could be advanced by 2022/2023 to help the Canadian cement and concrete industry meet their net-zero targets. This includes a topic review and gap analysis of the Canadian cement and concrete industry to identify priority areas for action. Secondly, the establishment of robust research and development approaches and innovation and funding models will be critical tools to achieving net-zero within the industry. For example, the establishment of a research, development and demonstration program could reduce risk for both new and existing technology developers could complement the market pull and help sustain and grow a greener cement and concrete industry in Canada.

> *"Continuous innovation has been the driving force behind the CO_2 reductions the industry has achieved over the last decades."*
>
> *Global Cement and Concrete Association, 2021*

Small and medium enterprises have and will continue to play an important role in supporting innovation in the industry. Canada is home to global leading technology entrepreneurs who are advancing commercial-ready technologies to further reduce emissions from cement and concrete. Solutions required to achieve net-zero include harnessing technologies such as:

- curing concrete with CO_2
- mineralizing carbon within concrete
- advancing carbon capture
- producing carbon treated concrete additives
- leveraging artificial intelligence to track and monitor concrete levels

The Government of Canada has a range of programs and policies in place to support Canadian clean technology companies, including support for industrial decarbonization (i.e. CCUS) and transformation:

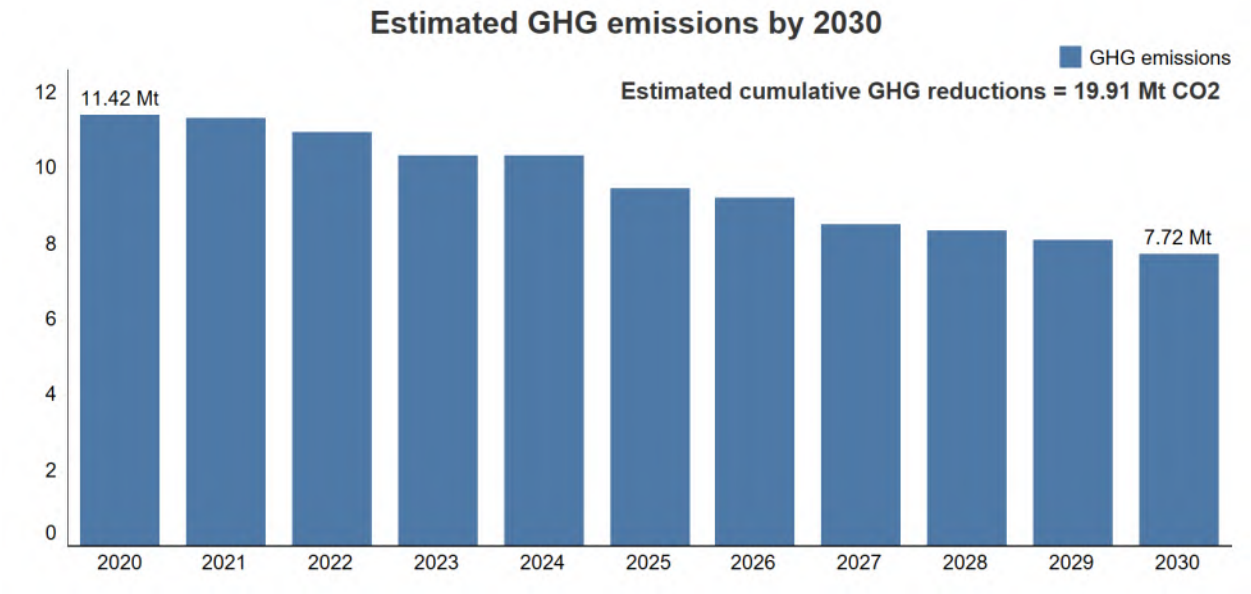
- The Strategic Innovation Fund - Net Zero Accelerator (SIF-NZA), announced the Healthy Environment and Healthy Economy plan in 2020. This $8 billion initiative is expediting decarbonization projects with large emitters, scaling up clean technology and accelerating Canada's industrial transformation across all sectors.
- The Clean Growth Hub is the federal focal point for clean technology. The Hub brings together departments and agencies to help clean tech developers and users navigate federal programs, enhance program coordination, and track the

outcomes of federal investments in clean technology. Clients range from young clean tech innovators with high potential for disruption to large adopters in high-emitting industries facing growing pressures to decarbonize.

- Sustainable Development Technology Canada (SDTC) is a federal foundation that assists Canadian companies to develop and deploy clean technology solutions that address climate change, clean air, clean water and clean soil. Through funding and by utilizing their knowledge ecosystem, SDTC helps move technologies from demonstration closer to commercialization while growing the Canadian economy.
- Support for CCUS projects: The Government of Canada recognizes that CCUS provides an important pathway to emissions reductions in many industrial sectors. Through Natural Resources Canada's Office of Energy Research and Development, the government is investing $319 million (over more than 7 years) into R&D and demonstrations to advance the commercial viability of CCUS technologies. These funds will support businesses, academia, non-profit organizations, government, and federal laboratories on the path to net-zero emissions by 2050. The Government also announced a specific investment tax credit for CCUS projects to further encourage investment in decarbonization technologies that would reduce emissions of greenhouse gases. The CCUS tax credit would apply for eligible expenditures incurred starting on January 1, 2022.
- The NRC has been at the forefront of supporting the construction sector in advancing low-carbon building materials. The NRC has recently received funding to create a Platform to Decarbonize the Construction Sector at Scale in support of the development and adoption of low-carbon construction solutions, tools and technologies. Specifically, the NRC will develop new carbon-based requirements and implement them through standards, specifications, guidelines, and publications such as the Canadian National Master Construction Specification (NMS), and the National Model Codes. It will also focus R&D and innovation capacity to address knowledge and data gaps in the development, identification and specification of low-carbon materials, products, services and practices (e.g. Life Cycle Assessment), as well as increase construction sector productivity through digitalization.

Canada's *Roadmap to Net-Zero Carbon Concrete* begins by mapping out key new actions, initiatives and policies needed to advance decarbonization of the sector through to 2030. At the same time, the roadmap doubles down on existing commitments related to decarbonization of the construction sector, including cement and concrete. Additionally, the roadmap charts the course for critical R&D and longer-term action needed to achieve net-zero by 2050, including having industry increase investments in CCUS projects that will largely come online post-2030.

Figure 1: Estimated reductions potential against 2019 baseline[8]



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GHG emissions (Mt)	11.42	11.32	10.97	10.32	10.32	9.47	9.22	8.52	8.34	8.09	7.72

Estimated cumulative GHG reductions from 2019 level between 2020 and 2030 are 19.91 Mt.

CO_2 = carbon dioxide; GHG = greenhouse gas; Mt = megatonne.

* These are concrete-related emissions, including both cement emissions and other concrete-specific emissions.

** 2019 baseline emissions of 11.42 Mt of CO_2.

Source: Cement Association of Canada.

[7] Cement Association of Canada

Full implementation of Canada's *Roadmap to Net-Zero Carbon Concrete* is projected to reduce over 15 Mt of GHGs cumulatively by 2030, with ongoing reductions of more than 4 Mt annually[9]. These estimates are based on the following core activities:

- increasing the adoption of blended cements products and systems, such as the existing portland limestone cement and blended portland limestone cement, which will reduce clinker consumption and decrease emissions
- substituting fossil fuels with alternative sources of energy to lower emissions optimizing concrete mixes for construction projects and improving the energy efficiency of cement and concrete manufacturing operations
- moving design and construction towards performance-based materials and systems while improving material use efficiency
- employing CCUS technologies to avoid the release of emissions

Action Plan to 2030

As a first step, this roadmap includes the near-term **Action Plan to 2030**, which intends to address immediate efforts and includes a plan for R&D to get to 2050 targets. The action plan is centred on 3 overarching priority areas that must be advanced as the industry transitions to net-zero. The goals of these priority areas are to:

1. **drive Canadian market development**
2. **drive innovation and transition within industry**
3. **position Canada as a world leader in the production, adoption and export of low-carbon cement and concrete products and technologies**.

Annex 3 provides a detailed overview of actions to be undertaken to address these priority areas.

Priority area #1: Drive Canadian market development

Create the commercial and regulatory conditions needed for the concrete market to quickly adapt to a net-zero and circular economy while driving towards Canada's 2030 and 2050 GHG reduction targets.

Prioritizing consensus-based changes to building codes and standards to regulate building life-cycle carbon will drive demand for low-carbon materials and design. Deploying that knowledge to the construction community will ***create the commercial and regulatory conditions needed*** *for the concrete market to quickly adapt to a net-*

[9] GHG emissions reductions estimates were provided by the Cement Association of Canada (CAC) and reflect actions that the Canadian cement and concrete industry will undertake to reduce their emissions by 2030.

zero and circular economy while driving towards Canada's 2030 and 2050 GHG reduction targets.

Further action and awareness campaigns for senior decision-makers are needed to integrate low-carbon performance into building and infrastructure design, guides and codes. Ultimately—ultimately this will close filling the critical research, regulatory and technology gaps in order needed to de-risk low-carbon materials and approaches and grow and transform Canada's construction sector to align with an innovative, low-carbon economy.

To **drive Canadian market development**, industry and the Federal Government will:

- support innovation, technology and R&D strategies and policies to achieve net-zero carbon concrete in Canada by 2050
- work collaboratively on developing green procurement policies
- advance the availability and quality of relevant data including through regularly updating and disclosing embodied carbon data and life-cycle inventory data of low-carbon cement and concrete products
- accelerate codes and standards development cycles to secure rapid deployment of low-carbon cement and concrete, with particular focus on exploring performance-based designs
- update the National Master Specification (NMS) to recognize existing lower-carbon cement solutions and continue to use the NMS to help build market-wide awareness of, and confidence in, cement and concrete innovations as new standards are approved
- launch a coordinated professional development initiative for public and private sector buyers, designers and builders and support continuing education of the architecture, engineering and construction community to ensure existing provisions in codes, standards and specifications are fully utilized, and new low-carbon provisions are well-communicated and understood

Priority area #2: Drive innovation and transition within industry

Drive innovation and industrial transition along the full concrete value chain (cement manufacturing, aggregate production, concrete manufacturing, construction processes including carbon capture, carbon utilization and mineralization, end of life/recycling and, carbon storage).

The road to net-zero has challenges for the cement and concrete sector and decarbonization will need to occur along the full concrete value chain.

The Government of Canada is already making significant investments to drive innovation and industrial decarbonization. For example, since 2017, $5.2 billion has been invested in the Strategic Innovation Fund (SIF), a program that supports large-scale, transformative projects that promote the long-term competitiveness of Canadian industries, clean growth, and the advancement of Canada's strategic technological advantage. A priority area for SIF is the Net-Zero Accelerator (NZA), a multi-billion-dollar initiative that funds projects to help decarbonize heavy industry, support clean technologies and accelerate domestic greenhouse gas emissions reductions by 2030, while creating pathways to net-zero by 2050. SIF also recently launched an Industrial Decarbonization Team (IDT) to facilitate and support the development and financing of transformative projects in Canada's industrial sectors. The IDT aims to help Canada in achieving its 2030 and 2050 emission reduction targets, while building a more competitive and low-carbon economy for Canada.

However, further action is needed do ***drive innovation and transition along the value chain*****:** Specifically, industry and government will:

- work with domestic and international stakeholders to identify and support R&D and deployment activities, and foster collaborations with academia to ensure Canada maintains its global leadership in low-carbon cement and concrete solutions;
- assess gaps and implications for Canada's future circular and net-zero cement and concrete sectors considering some existing solutions rely on industrial by-products that will be less available over time while sector demand continues to rise
- identify and develop new technological solutions to reduce the carbon intensity of the concrete industry, including the use of novel SCMs and admixtures, as well as low-carbon cement production
- promote the procurement of proven new-to-market technologies in demonstration projects in low-risk infrastructure
- promote the use of voluntary standards as a mechanism to promote innovation in the construction sector

Priority area #3: Position Canadian industry as a global leader

Position the Canadian concrete industry as a global leader in the low-carbon building materials sector through the pursuit of new export opportunities and international collaboration and advocacy on emerging policy trends

Global markets are increasingly prioritizing net-zero targets and large investments by other countries to establish new and retrofitted infrastructure that supports climate

objectives. This presents a significant opportunity for Canada to capitalize on its expertise in producing low-carbon concrete and pursue new export opportunities.

While concrete itself is rarely exported, cement products enjoy considerable international trade. Some 40% of cement products manufactured in Canada are exported to the U.S. Currently, only minimal amounts are exported to non-U.S. markets. However, as the global imperative for net-zero takes root in international markets, the demand for low-carbon cement and concrete related systems and technologies presents a potentially significant market for Canadian companies.

To successfully position Canada as a global leader in the low-carbon building materials sector, it will be important to undertake 2 tasks. First, identify priority international markets for low-carbon cement concrete products, systems and technologies, and then develop a comprehensive market development strategy to successfully support Canadian exporters in key markets.

The pursuit of international opportunities will also require attention to a variety of emerging trade policy instruments that may be increasingly applied as countries consider measures designed to meet their international climate commitments and other objectives. Such measures will vary greatly across the globe, both in terms of approach and speed of implementation, and it will be important to ensure that Canadian exporters can continue to access international markets considering such measures.

The European Union (EU) has recently taken an important step forward on a Carbon Border Adjustment Mechanism (CBAM) that is designed to stem carbon leakage from countries without a carbon price. It has released a legislative proposal that would result in the application of a carbon tariff on imports of carbon-intensive goods such as iron and steel, cement, fertilizers, aluminium, and electricity[10] as part of the European Green Deal. Following the EU's announcement, other countries such as the U.S. and Canada are also considering similar regimes. International coordination will be necessary in the development of CBAM regimes, including the establishment of a baseline/benchmark for reliable data and methodologies to account for embodied emissions in traded products subject to such measures, including cement. That said, the development of CBAMs offers potential benefits to Canada's cement and concrete manufacturers as they shift towards low-carbon products. Supporting development of the low-carbon concrete industry in Canada should future-proof it in the face of CBAMs in domestic and foreign markets.

Additionally, the rise of protectionism in key markets such as the U.S. as manifested through Buy America demonstrates a U.S. commitment to an "America first" investment policy on their domestic infrastructure. Although cement is currently exempt from Buy

[10] Tim Gore, "The proposal for a Carbon Border Adjustment Mechanism fails the ambition and equity tests," *The EU's Fit-for-55 package: The European Green Deal's fitness test* (Brussels, Belgium: Heinrich-Böll-Stiftung, September 2021).

America, ongoing monitoring and advocacy will be necessary to preserve access to the U.S. market.

The U.S typically relies on a large amount of Canadian cement. Globally, it imports more than 16 million tonnes of cement annually, with nearly 6 million tonnes (or 35%) of that being imported from Canada. In 2021, both the Governments of Canada and the U.S. announced that they will both introduce buy clean strategies. Alignment of these approaches could assist in further market penetration in the U.S. as well as defend what Canada is already exporting.

To **position Canada as a global leader in the low-carbon carbon building materials sector,** industry and government will work with key trading partners to:

- identify priority international markets for low-carbon cement and concrete products, systems and technologies
- work on coordinated assessment of key technologies, such as CCUS, and low-carbon fuels
- ensure the alignment of robust and transparent carbon accounting methodologies and verification procedures
- pursue Canada-US synergies on approaches to the development of buy clean strategies
- identify opportunities for international collaboration in the development of CBAM measures

Enabling policy

The Government of Canada also plays a critical role in creating the enabling conditions to incentivize and catalyze the decarbonization of major industrial sectors, such as cement and concrete, and stimulate private investment in clean technologies. The Government of Canada has a significant role to play in regulating private sector companies that operate within its borders.

For example, codes, standards and procurement policy are arguably the most significant federal levers to incentivizing and fostering the enabling conditions for decarbonization within industry. Using these tools, the Government of Canada has the capacity to create the commercial and regulatory conditions needed for the concrete market to quickly adapt to net-zero, while driving toward Canada's 2030 and 2050 GHG reductions targets.

The Government of Canada is taking important steps to fully implement climate mitigation, adaptation and resilience as core considerations in the development of Canada's codes and standards system for construction and building materials. Advancing this work will enable the industry's ability to bring low-carbon solutions to market and will enable (or require) project designers to integrate climate adaptation and resilience considerations into infrastructure projects.

Using codes and standards in tandem with other policy levers, including federal funding program eligibility requirements and procurement policy, can provide certainty to industry on the federal vision for the construction sector's low-carbon pathway. This promotes low-carbon market transformation.

Other key enabling policies include enhancing certainty around carbon pricing. Currently, the federal carbon price in Canada is set at $50 per tonne of CO_2e and applies in all provinces and territories using the federal backstop. The federal carbon price is set to gradually increase to $170 in 2030. As per the commitment in the 2030 *Emissions Reduction Plan*, in order to enhance long-term certainty, and support the uptake of near or net-zero emissions technology prior to 2030, the Government of Canada will explore measures that help provide greater confidence in the future price of carbon pollution.

The Government of Canada is also exploring border carbon adjustments as a potential policy tool that could complement domestic carbon pollution pricing to allow for greater ambition and stringency. Such a policy can support determined carbon pollution pricing by leveling the playing field between domestic producers and their international competitors.

In addition, investment approaches such as carbon contracts for difference could be employed—enshrining future price levels in contracts between the government and low-carbon project investors, and thereby de-risking private sector low-carbon investments. As per the Emissions Reduction Plan, carbon contracts for difference and carbon pricing are important mechanisms to de-risk emissions reductions in the cement and concrete industry.

There are also smaller-scale policies that the Government of Canada could put in place to help catalyze further emissions reductions within the domestic cement and concrete industry. For example, the government could consider mandating zero-emission heavy-duty vehicles (zero emissions being achieved through electrification, hydrogen or other technologies) to transport cement and concrete products.

Action Plan to 2050

Technology deployment:

Building on measures identified in the Action Plan to 2030, achieving net-zero by 2050 will depend on the adoption of a number of key technologies in the sector—most notably, CCUS. Only about one-third of emissions from cement manufacturing results from the combustion of fossil fuels. The remaining two-thirds (more than 60%) is almost entirely process emissions that result when limestone, the primary mineral input in cement manufacturing, is converted to lime by the high temperatures in the cement kiln. While combustion emissions can be managed through fuel switching and efficiency gains, without CCUS, the process emissions in cement manufacturing are effectively irreducible.

> *"Deployment of carbon capture technology at full scale during cement manufacturing could fully eliminate process emissions and potentially result in the future delivery of carbon negative concrete for our world."*
>
> *Global Cement and Concrete Association, 2021*

There are other smaller and less expensive technology options for cement—including new heat exchangers and digital solutions for energy efficiency—that incrementally reduce emissions. However, there are no known largescale or breakthrough technologies that fully address CO_2 emissions at their production point, other than CCUS. Canada is already a global leader in CCUS expertise, technologies and infrastructure. By 2030, Canada will have the foundation for larger-scale deployment of CCUS technologies, including an enhanced capability and business case, government regulatory and fiscal supports, and a larger ecosystem of CCUS related infrastructure, including CO_2 transportation hubs. But to achieve our net -zero by 2050 ambitions, the deployment of carbon capture technology at full scale is essential.

The Government of Canada and the Canadian cement and concrete industry recognize the critical role that CCUS plays in the decarbonization of Canada's industrial sectors. Notably, *A Healthy Environment and a Healthy Economy: Canada's Strengthened Climate Plan to Create Jobs and Support People, Communities and the Planet (2020)* identified CCUS as a priority technology to help meet our domestic climate targets. The plan also underscored the need for CCUS to lower its costs before it can be fully commercialized. To address this challenge, the Government of Canada has undertaken a number of initiatives to support CCUS. This includes the creation of the Strategic Innovation Fund's Net-Zero Accelerator; and ongoing investments in R&D and demonstrations to advance the commercial viability of CCUS technologies.

Most recently, the 2030 Emissions Reductions Plan also announced a commitment to develop a comprehensive CCUS strategy to guide the development and deployment of CCUS technologies to mitigate GHG emissions from a range of industrial sectors in Canada, including cement.

Furthermore, Budget 2022 introduced an investment tax credit to incentivize the proliferation of CCUS technologies to reduce emissions in high-emitting sectors, including cement. Starting in 2022, the investment tax credit will be available to CCUS projects to the extent that they permanently store captured CO_2 through an eligible use. Eligible CO_2 uses include dedicated geological storage and storage of CO_2 in concrete—an important point to emphasize as this means that Canadian companies that work in storing carbon in concrete are also supported by this tax credit.

Concrete can be part of the decarbonization strategy for all industries given its potential to store CO_2. Using synthetic carbonate aggregates, CO_2 injection and CO_2 curing could turn the 400 million tonnes of concrete used in Canada over the next 5 years to a reservoir for storing nearly 200 million tonnes of CO_2 from across industries.

Alongside the release of Canada's CCUS strategy, the investment tax credit is a major federal tool to help guide and support the large-scale deployment of CCUS technology across Canada's many industrial sectors, including cement and concrete. This will help Canada meet its 2050 targets.

Both government and industry expect that CCUS will continue to be deployed at full-scale to virtually eliminate all process emissions from the manufacturing of cement. However, in addition to the continued deployment of CCUS, there are a number of additional smaller-scale commercial and/or soon-to-be-ready (by 2030) technology options that are expected to help contribute to the decarbonization of the cement and concrete sector.

Beyond 2030, certain existing low-carbon solutions will continue to see increased adoption by industry. For example, clinker substitution is expected to rise, lowering process emissions in cement manufacturing. Despite the fact that the industry will see rapid declines in the supply of both fly ash and slag, due to broader changes in energy, the availability of other materials such as ground limestone and calcined clay will increase.

There will also be room for further use of alternative fuels to drive down the industry's CO_2 emissions. This will involve the industry moving beyond natural gas as an alternative fuel to pursue *lower* low-carbon sources such as purpose-grown biomass. It is also possible that alternatives to portland clinker cements may play a role in decarbonization, but we recognize the comparatively minimal contribution to emissions reductions.

Finally, new technologies such as hydrogen and electrification of kilns could help power cement and concrete production beyond 2040. However, further R&D is needed to unleash these technologies for commercial adoption. Ultimately, alongside full-scale deployment of CCUS, these smaller-scale commercial and/or soon-to-be-ready technology options are positioned to deliver carbon negative concrete by 2050.

On the Federal side, other major developments to drive industrial decarbonization include Budget 2022's announcement of the establishment of a Canada Growth Fund to attract substantial private sector investment to help meet important national economic policy goals. This includes:

- reducing emissions and contributing to achieving Canada's climate goals
- diversifying Canada's economy and bolstering exports by investing in the growth of low-carbon industries and new technologies across new and traditional sectors of Canada's industrial base
- supporting the restructuring of critical supply chains in areas important to Canada's future prosperity

Budget 2022 also announced the intent to increase the impact of the Canada Infrastructure Bank (CIB), broadening its role to allow it to invest in private sector-led infrastructure projects that will accelerate Canada's transition to a low-carbon economy. This will allow the CIB to invest in CCUS, clean fuel production and hydrogen production, among other areas.

Collaborations, research and development:

Moving toward net-zero carbon cement and concrete by 2050 will also necessitate additional R&D and collaboration between experts. As a first step, industry and the federal government will continue their partnership to promote research consortia to validate and optimize promising novel technologies. This includes investigating novel materials and feedstocks, exploring novel activation processes for non limestone-derived cementitious materials and researching novel cement chemistries.

Further research and development are also required for newer technologies that are still being piloted, but could be commercially viable by 2050. This includes transitioning large scale plants to lower emission energy sources like biogenic fuels, clean hydrogen and electricity.

Other areas of future R&D could include:

- exploring the longer-term climate resilience of built infrastructure with conventional and novel technologies and materials
- geological surveying of mine tailings and other materials as feedstocks for the cement and concrete industries.

Conclusion

Decarbonizing Canada's cement and concrete sector is a top priority. While it is a complex and multi-faceted challenge, it also presents Canadian industry with significant opportunities—both at home and abroad. This roadmap charts the course to net-zero carbon concrete by 2050, outlining a suite of time-bound measures and actions for industry and government to take to support rapid decarbonization of the sector. The actions proposed within this roadmap fall within three broad themes: (1) driving Canadian market development; (2) driving innovation and transition within industry; and (3) positioning Canadian industry as a global leader.

This roadmap was developed in recognition that decarbonization of the cement and concrete industry requires ongoing effort that necessitates strong and sustained action, and continued partnership between industry and government. In recognition of this, the Roadmap includes a robust governance and monitoring structure to ensure continued progress and implementation of the actions proposed herein.

Canada has the enabling tools and conditions to become a world-leading producer and exporter of low-carbon cement and concrete products, systems and related clean technologies and services; with its modern regulatory environment, clean electricity advantages and suite of home-grown low-carbon commercial innovations. Ultimately, increased adoption of low-carbon cement and concrete will further drive the Government of Canada's commitment to clean growth and lead to financial, environmental, and health benefits for all Canadians.

Glossary

Admixture: A chemical additive to concrete that is used to modify the properties of concrete in its freshly mixed, setting, or hardened states.

Binder: A material that acts to bond materials in concrete together. Examples include cement, fly ash, slag, silica fume, etc.

Biogenic fuels: Combustible organic matter produced by living organisms, but not fossilized or derived from fossil resources.

Carbon Border Adjustment Mechanisms (CBAM): A policy that seeks to reduce the risk of carbon leakage by putting a carbon price on imports of certain goods.

Carbon leakage: A situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints, and therefore "leaking" carbon emissions from one country to another, potentially leading to a net increase in global emissions.

Carbon capture, utilization and storage (CCUS): A process that captures carbon dioxide emissions and either reuses or stores it so it will not enter the atmosphere.

Carbon neutral: When greenhouse gas emissions are equally balanced so they are equal to the emissions removed.

Cementitious material: One of the principal ingredients that make up the concrete mixture. There are two types of cementitious materials: hydraulic cement and supplementary cementitious materials (SCMs).

Circular economy: an approach of retaining and recovering as much value as possible from resources by reusing, repairing, refurbishing, remanufacturing, repurposing, or recycling products and materials.

Clinker: A nodular material produced in the kilning stage during the production of cement. Clinker as the active ingredient in cement when ground with other materials.

Embodied carbon: Carbon dioxide emitted during the manufacture, transport and construction of building materials together with end-of-life emissions.

Environmental Product Declarations (EPDs): An independently verified and registered document that communicates transparent and comparable information about the lifecycle environmental impact of a product.

Net-zero carbon: A situation when the sum total of all asset- or product-related greenhouse gas (GHG) emissions, both operational and embodied, over its lifecycle including disposal equals zero.

Overdesign: Increasing cement in concrete as opposed to designing for the specific needs of the construction project and therefore reducing unnecessary overproduction and emissions.

Pozzolan: A siliceous and aluminous material that, in the presence of moisture, chemically reacts with calcium hydroxide to form compounds possessing cementitious properties. Examples include calcined kaolinite clays, fly ash, volcanic ash and silica fume.

Process emissions: The emissions from industrial processes involving chemical or physical transformations other than fuel combustion.

Supplementary cementitious material (SCM): Materials that, when used in conjunction with Portland cement, Portland limestone cement or blended cements, contribute to the properties of hardened concrete through hydraulic and/or pozzolanic activity.

Annex 1: Process and Participants

An industry-government working group oversaw development of the Roadmap. Led by the Cement Association of Canada and Innovation, Science and Economic Development Canada , this working group comprised several key federal departments and agencies, industry leaders and environmental and Indigenous organizations.

Participating organizations included members of government, the cement and concrete sector, the technology and energy sector, and environmental institutions:

Government

- Innovation, Science and Economic Development Canada
- National Research Council of Canada
- Standards Council of Canada
- Infrastructure Canada
- Treasury Board of Canada Secretariat
- Environment and Climate Change Canada
- Natural Resources Canada

Cement and concrete sector

- Cement Association of Canada
- Ash Grove Cement, A CRH Company
- Canadian Precast Prestressed Concrete Institute
- Concrete Ontario (Ready Mixed Concrete Association of Ontario)
- Lafarge Canada
- Lehigh Hanson, Heidelberg Cement Group
- St Marys Cement, A Votorantim Cimentos Company

Technology and energy sector

- Blue Planet Systems
- Carbon Upcycling Technologies
- CarbonCure
- Pond Technologies
- Solidia Technologies
- Svante

Environmental institutions

- Canada Green Building Council
- Clean Energy Canada

In addition, 6 technical committees consisting of industry and government experts were established to help identify and prioritize key actions required by industry and government partners to create the roadmap. These included technical committees on:

1. building knowledge and opportunities for low-carbon products
2. strengthening Canada's low-emissions supply chain
3. supporting global and domestic market development
4. driving innovation through codes and standards
5. supporting Canadian research and innovation
6. identifying strategic pilot projects.

In addition to these working group and technical committee consultations, the secretariat hosted a summit in late November 2021. It brought together technical experts and innovators to discuss opportunities for Canadian cement companies in the low-carbon economy, as well as regulatory and procurement barriers for adoption of low-carbon products and systems. The following common themes were heard from all stakeholders in this forum:

- the importance of CCUS in reducing carbon emissions
- the need for policy makers and investors to lead the charge on change
- the necessity of educating all players of the supply chain to support changes and increase confidence in the field for the application of greener solutions
- the importance of finding solutions to bring new technology to code quickly and making such changes at national, provincial and municipal levels
- the fact that procurement will be a major piece in achieving reductions targets and needs to be driven by the federal government while applying pressure to the private sector

Annex 2: Monitoring, governance and reporting

Introduction

Government and industry recognize the importance of accountability for the activities laid out in this joint action plan. Ongoing monitoring and reporting to the Minister of Innovation, Science and Industry and to stakeholders will be a priority as we collectively move toward our 2050 net-zero goal.

The joint announcement between the Government of Canada and the Cement Association of Canada, in May 2021, outlined the priority outcomes from the establishment of the net-zero carbon concrete action plan. These outcomes include providing a regular report to Canadians on the progress toward key milestones, in addition to an annual GHG reductions report.

Outcomes

- Drive development of actions outlined in the Roadmap
- Ensure timely implementation of developed actions
- Develop an annual public-facing document to report against established deliverables, including reporting on GHG reductions.

Steering committee

A steering committee will be formed of voluntary members and will consist of 2 co - chairs as well as representatives from both industry and government. This overarching committee will meet 4 times a year and will hear from the implementation committees at each meeting to monitor progress, provide consensus-based direction, and guide timelines for actions.

The steering committee will be supported by a secretariat that is responsible for setting agendas, disseminating documents, and gathering and producing reports for internal briefings and public-facing reports.

Implementation committees

Implementation committees will be established based on the main action areas outlined in the roadmap, meeting semi-monthly or monthly and reporting to the steering committee. Voluntary membership will consist of representation from industry and government and include relevant individuals to develop and implement actions items identified in the roadmap under each action area. Each implementation committee will be supported by a secretariat that is responsible for setting agendas, developing documents and liaising with secretariats from other committees.

Reporting

The steering committee will publish an annual public-facing report that assesses progress of the implementation of the roadmap against committed deliverables. In order to reduce the burden on reporting, the secretariat will work with other horizontal reporting requirements to ensure alignment in reporting results.

Annex 3: Action plan details

Driving Canadian market development

Create the commercial and regulatory conditions needed for the concrete market to quickly adapt to a net-zero and circular economy while driving towards Canada's 2030 and 2050 GHG reduction targets.

1. Develop an R&D strategy
   - Identify new-to-market low-carbon concrete products and systems technologies ready to be demonstrated in pilot projects
   - Release guidance and peer reviewed case studies of projects that have used low-carbon concrete and highlight existing barriers to the uptake of low-carbon products and systems, and identify the necessity for solutions to remove these barriers
   - Conduct a review to list and describe Canadian and non-Canadian best-practice models for R&D and innovation from diverse sectors in order to determine the most effective collaborative approach for Canadian cement and concrete industries and government. Conduct an assessment of common themes and gaps among existing cement and concrete decarbonization roadmaps
   - Develop weighted screening criteria to prioritize of RD&D topics and proof of concept projects from an environmental, Canadian and construction industry perspective
   - Publish advice on performance and the availability of low-carbon concrete products and systems across all regions
   - Develop actions to support, focus and enable collaborative R&D to help industry develop low-carbon, and net-zero carbon concrete by 2050.

2. Advance green procurement policies
   - 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
   - Introduce a new Buy Clean Strategy to support and prioritize the use of made-in-Canada low-carbon products in Canadian infrastructure projects

- Develop and implement green procurement standards and mechanisms to support the procurement of low-carbon materials and projects. Implement this approach for Government of Canada procurement and explore the potential for applying performance and reporting requirements to reduce the carbon footprint of structural materials including concrete for federal infrastructure projects
- Engage with provinces and territories to promote the development of sub-federal buy clean policies and approaches to using lower carbon concrete and other structural materials
- Conduct whole building (or asset) LCA by 2025 at the latest for major federal buildings and infrastructure projects

3. Develop life cycle assessment (LCA) tools
- Develop national and industry standards for the measurement and use of low-carbon concrete, supported by implementation of the NRC Platform research agenda
- Evaluate the potential of harmonizing LCA life-cycle reporting
- Translate LCA guidance into national standards
- Support industry to use whole building LCA and performance-based design to achieve lowest carbon projects

4. Advance embodied carbon data and benchmarking
- Complete the funding, collection and analysis of regionalized lifecycle inventory data for Canadian cement and concrete and establish regionalized carbon intensity baselines for cement and concrete
- Develop a national LCA/LCI database for construction materials to hold the LCI data and work with industry to enable LCA tools to connect to the database
- Make carbon footprint data and benchmarks available to industry to develop regionally specific EPDs to support low-carbon procurement and design
- Publish advice on performance and the availability of low-carbon concrete products and systems across all regions

5. Accelerate codes and standards development cycles
- Include performance-based design practices in standards relevant to cement and concrete
- Revise the NMS to become a vehicle for the innovation and adoption of low-carbon performance-based approaches that use cement and concrete
- Develop provisions for carbon emissions that could be included in the National Model Codes
- Work to accelerate standards development cycles and their reference in codes to secure more rapid deployment of low-carbon cements and concretes
- Continue to support the evolution of the building codes to include broader definitions of performance

6. Support training and education

- Launch a coordinated professional development initiative for public and private sector buyers, designers and builders focused on accelerating market acceptance of performance proven low-carbon cement and concrete solutions
- Support continuing education of the AEC community to ensure existing provisions in codes, standards and specifications (e.g.: NMS) are fully utilized, and new low-carbon provisions are well-communicated and understood
- Explore opportunities to support municipalities and Indigenous communities to increase the adoption of low-carbon concrete in their infrastructure projects

7. Establish a joint industry-Government of Canada "low-carbon market development task force" to perform the following functions:

- identify capital intensive strategic and lighthouse projects and prioritize decarbonization projects and related capital needs for near, mid and long-term investments in net-zero cement and concrete, to support the cement and concrete sector's net-zero ambition and 2030 reductions potential of 15Mt or more;
- identify priority international markets for low-carbon concrete products, systems and technologies, and pursue trade diversification opportunities;
- systemic integration of industry representation in and coordination with Government of Canada efforts on initiatives such as: the United States' Green Procurement memorandum of understanding; the United Nations Industrial Deep Decarbonisation Initiative; and the Carbon Border Adjustment Mechanism;
- increase alignment of codes and standards with export jurisdictions;
- continued monitoring of international cement and concrete roadmaps and strategies;
- coordinated assessment of key technology collaboration efforts, particularly those related to the development of core CCUS, zero-carbon fuels and related infrastructure; and
- identify the routes of influence to get low-carbon products and systems to market.

Driving innovation and transition within industry

Drive innovation and industrial transition along the full concrete value chain (cement manufacturing, aggregate production, concrete manufacturing, construction processes including carbon capture, carbon utilization and mineralization, end of life/recycling and, carbon storage).

1. Support industry-government collaboration on low-carbon materials and systems

2. Identify and support R&D and deployment activities

- Advance and implement an R&D agenda, focused on the development, demonstration and commercialization of low-carbon cement and concrete solutions

- Identify key obstacles (e.g.: building codes and specifications) to the use of portland limestone cement, by region, and provide direct feedback

3. Implement an investment tax credit to incentivize and attract capital investment in CCUS technology development

4. Launch and implement a CCUS strategy for Canada, with federal actions that will support the deployment of CCUS in industries including in cement and concrete

5. Conduct research gap analysis of Canada's low-carbon cement and concrete supply chain

- Complete a study on gaps, solutions and implications for the low-carbon cement and concrete supply chain and make recommendations for future actions
- Release the National Research Council of Canada report *Strategies for Low-Carbon Concrete: Primer for Federal Government Procurement* to help organizations better understand the strategies available to reduce the embodied carbon content of concrete in their construction projects
- Conduct research to identify limiting factors to moving toward low-carbon (including identifying key barriers and opportunities for low-carbon cement and concrete products, low-carbon design and construction, and innovations) and to chart a path forward and update activities as market needs change

6. Promote the procurement of proven new-to-market technologies

- Support new-to-market low-carbon cement and concrete innovations with testing, standards and certification
- Develop a bridging technical specification to incorporate low-carbon innovations into industry standards and to facilitate the transition of research into a commercial reality, and transition this technical specification into a National Standard of Canada
- Develop guidance for applying a climate lens to the development of industry standards

7. Map and prioritize near, mid and long-term key decarbonization projects across the cement and concrete value chain, including an assessment of the capital requirements for full adoption

8. Develop a carbon contract for difference to enshrine future price levels in contracts between the Government of Canada and low-carbon project investors, thereby de-risking private sector low-carbon investments

9. Conduct proactive outreach with industry to build awareness of existing federal support programs (e.g., Innovative Solutions Canada, Global Innovation Clusters)

10. Change the revision and errata update for national codes to a formal update to facilitate faster adoption by provinces and territories, and make codes more dynamic

11. Transfer relevant optional normative language annexes to the main body of standards in a timely manner

Positioning Canadian industry as a global leader

Position the Canadian concrete industry as a global leader in the low-carbon building materials sector through the pursuit of new export opportunities and international collaboration and advocacy on emerging policy trends

1. Create a market development strategy that identifies priority international markets for low-carbon concrete products, systems and technologies

2. Pursue opportunities to work with the United States, and other trading partners as well as global forums including the Clean Energy Ministerial and the Global Cement and Concrete Association on the coordinated assessment of key technologies such as CCUS and low-carbon fuels, and on alignment of carbon accounting methodologies and verification procedures

3. Align with the United States and other trading partners on approaches to the development of buy clean strategies, including alignment on data, codes and standards.

AEC = architecture, engineering and construction; CCUS = carbon capture, utilization and storage; EPD = Environmental Product Declaration; LCA = life-cycle assessment; LCA^2 = Low-carbon assets through life cycle assessment initiative ; LCI = life-cycle inventory; MT = metric ton; NMS = National Master Specification; R&D = research and development; RD&D = research, design and development.