CONCRETE ZERO

Cement Association of Canada

Canada's cement and concrete industry action plan to net-zero

Cement Association of Canada

Contents

Executive Summary

The Cement Association of Canada is the voice of Canada's cement industry.[1] In this document, we lay out the steps that we—together with our members and partners in the concrete sector—will take to help Canada achieve its net-zero carbon goals as we continue to make concrete a versatile, durable, cost-effective, resilient, and essential construction material.

Concrete Zero shares the journey we have been on as an industry. We have already begun our transition to lower-carbon fuel sources, carbon-reduced cements, and clean technologies. Cement-based materials—including ready mixed, precast and masonry concrete—have also been implementing carbon reductions in their product composition and manufacturing processes. And the industry has been on the leading edge of transparently disclosing and verifying carbon reductions.[2] Our Action Plan lays the foundation for what we will do next and our role in delivering solutions to climate change.

What Net-Zero Means to Us

Net-zero is our shared commitment.
The operations and products of the entire industry are examined for opportunities to reduce CO_2 emissions, across the entire lifecycle, to zero. While carbon capture, use and storage are included in our actions to reach net-zero, the purchase of offsets is not, and nor have we accounted for avoided emissions that arise from the use of our products.

This Action Plan uses a 2020 baseline for cement production and emissions data as the most recent year that complete data was available at the time of our modelling. Year-over-year variability in production (and therefore also carbon emissions) is common and due to various cyclical market conditions. Implementation of this Action Plan will be managed on an ongoing basis, and we will report on our progress every five years which will allow us to account for year-over-year variabilities and demonstrate clear progress against our targets. All cement facilities meet consistent national regulatory reporting requirements and all grey cement producers also voluntarily report production and emissions data to the Global Cement and Concrete Association *Getting the Numbers Right* database.

We are well on our way towards our 2030 goal of reducing our CO_2 emissions by 40%, as we committed in the Roadmap to Net-Zero Carbon Concrete by 2050, a collaborative plan generated through partnership between industry and the Government of Canada. This Action Plan shows that greater emissions reductions are possible.

Our decarbonization pathways for the balance of the next 10 years are focused on eliminating the use of coal and petroleum coke as heat sources for clinker production, while increasing the use of lower-carbon and alternative fuels, including repurposing waste products as cleaner alternatives compared to virgin fossil fuels.

At the same time, we will reduce the volume of clinker used to produce cement—which will result in a 1.5 Mt CO_2 emissions reduction over the course of the decade. Increased use of supplementary cementitious materials or SCMs in the form of fly ash[3] and ground granulated blast-furnace slag will also play an important role in this decade, as will introducing ground limestone, recycled concrete fines, calcined clays, and other new promising materials.

We anticipate that Carbon Capture, Utilization and Storage (CCUS) will also come online, starting in Alberta.[4] Canada will begin to capture carbon in this decade—and part of that effort will be North America's first commercial deployment of a full-scale capture and storage project at a cement plant. CCUS projects are taking shape all over the world—buoyed by public support. Canada has also identified the important role that this technology will play in helping industries such as cement decarbonize.[5] In 2030, we estimate an annual reduction of 1.5 Mt CO_2 from CCUS projects that will be in operation, assuming the right combination of investment and policy supports.

Roadmap Vs. Action Plan

Together with Innovation, Science and Economic Development Canada, the Cement Association of Canada launched the Roadmap to Net-Zero Carbon Concrete by 2050 in the fall of 2022.[6] **This roadmap commits the sector to achieving reductions of 15 million tonnes of greenhouse gas (GHG) emissions cumulatively by 2030, followed by ongoing reductions of over 4 million tonnes annually from the production of cement and concrete in Canada.** This Action Plan is consistent with the commitments outlined in our collaboration with government. The Roadmap is focused on collaboration between industry and government to develop effective policies and programs that will help the cement and concrete industry achieve greater emissions reductions.

Between now and 2030, emissions reductions will also be found in the concrete production, design of structures, and construction phases through measures such as clean electrification and material use efficiency: that is, optimized use of concrete in construction applications.

Beyond 2030, clinker substitution will continue, even as we see rapid declines in supplies of supplementary cementitious materials like fly ash and slag thanks to broader changes in the decarbonization of electricity and the steel industry. After 2030, the use of innovative materials, natural pozzolans, and beneficiated waste and recovered materials will increase. In 2050, 4.8 Mt CO_2 in emissions reductions will be realized from the reduction of clinker in cement, and of cement in concrete compared to a business-as-usual scenario.

We also anticipate further widespread availability of low-carbon and alternative fuels that will help drive down emissions—including engineered biomass and green hydrogen. By 2050, 100% of our fuel mix will come from non-fossil-based sources.

CCUS will continue to be deployed at full-scale as storage space and related infrastructures expand beyond Alberta, and as concrete's potential as a storage solution for carbon is better understood and deployed. CCUS paired with a clean fuel source such as biomass, plus the carbon uptake of concrete over its lifespan could result in the delivery of carbon-negative concrete.[7]

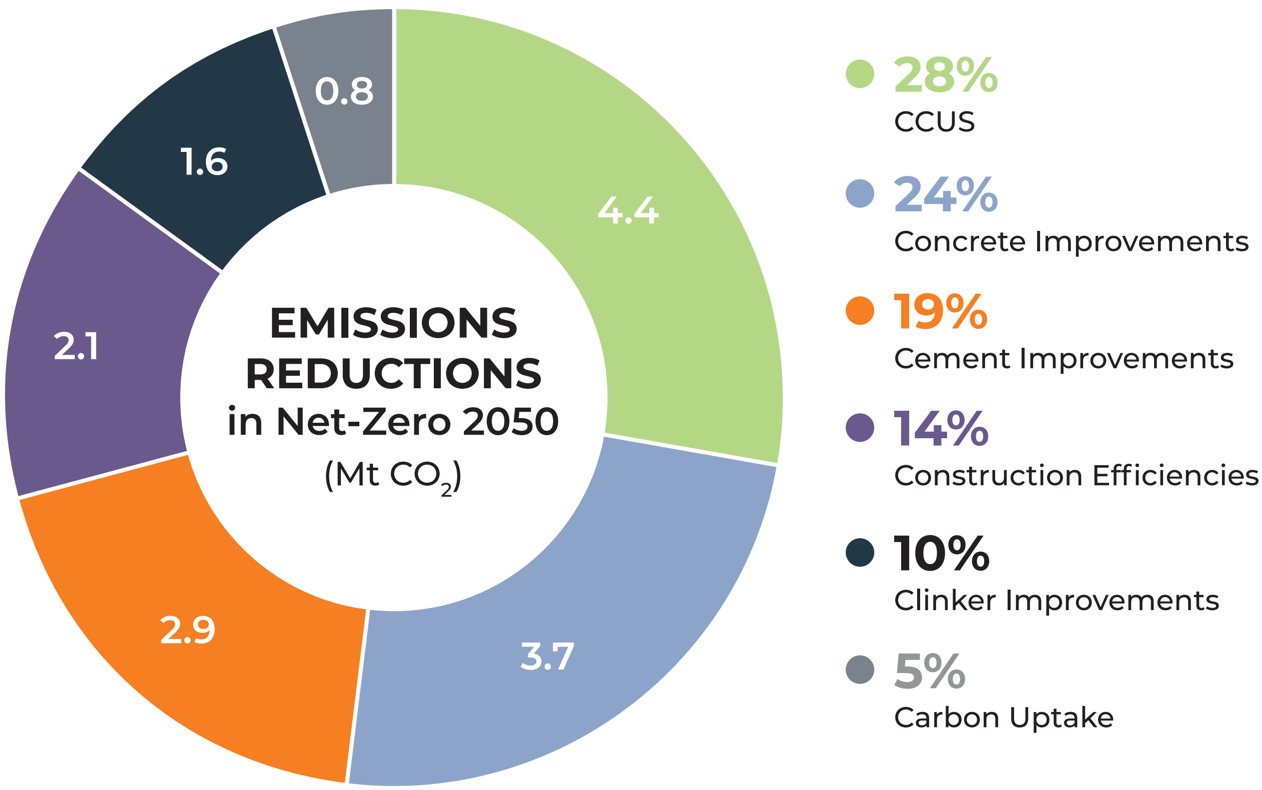
After 2030 is when we anticipate today's emerging technologies—such as zero-emission medium- and heavy-duty vehicles, green hydrogen, electrification of kilns, and carbon utilization technologies at commercial scale—to be at full-scale deployment. There is also an opportunity for alternative clinker and other alternative binder technologies to portland cements to play a role in emissions reductions, however, for now we do not account for these technologies in our modelling.

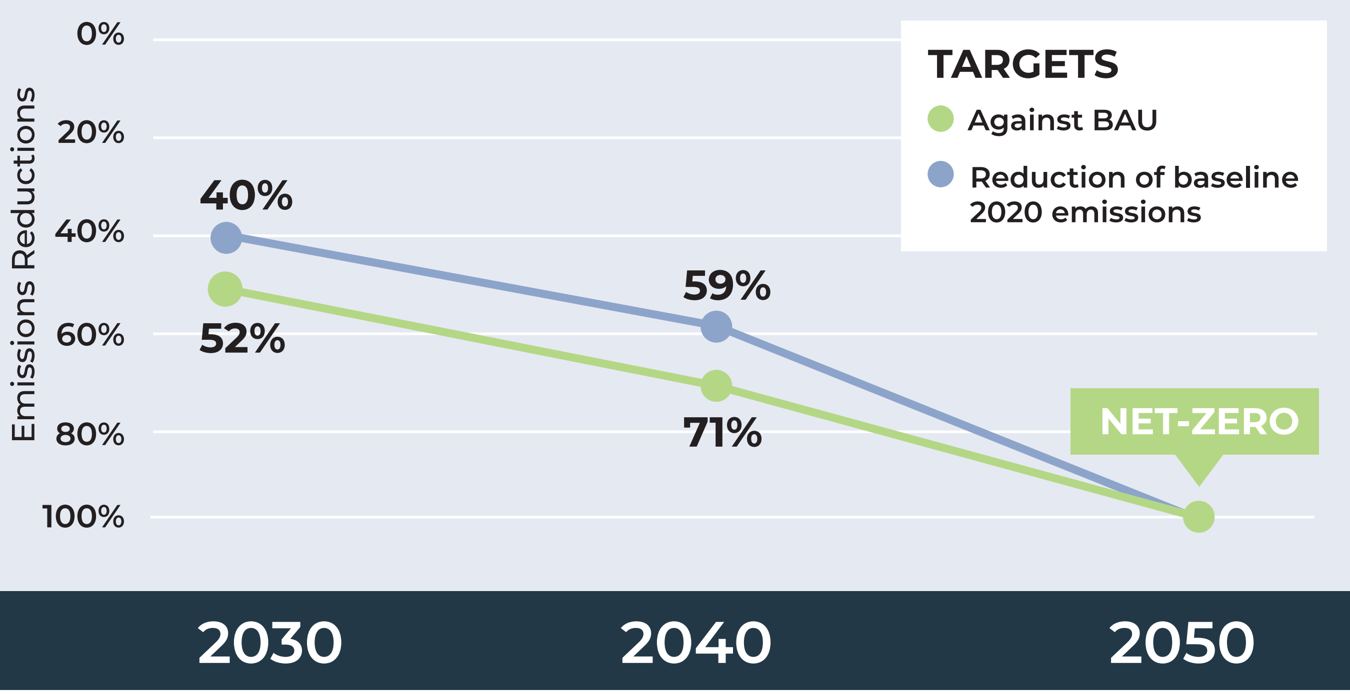
Our net-zero Action Plan is ambitious and cannot be achieved by industry effort alone. Working with governments at all levels, other industries, and colleagues in the design, architecture, and construction industry will be essential for success. Net-zero requires ambitious, determined, sustainable government policy—from regulations to financial programs, to supporting the growth of markets for emerging low-to-zero emission products; it thrives on research and demonstration of new technologies and products to bring them to market; it requires meaningful carbon reduction goals and associated metrics, and then meeting them with the best available approach while maintaining the safety, durability and versatility concrete is known for. Net-zero is also built on education and awareness—from transparency on achievable and timely reduction pathways to finding new and better ways to produce and build the things communities rely on. Tackling the challenge of net-zero requires change from the entire construction value-chain.

CONCRETE ZERO

Canada's cement and concrete industry is committed to doing our part to help Canada build a better, cleaner future. **Working together, we can deliver concrete zero.**

Our Road to Net-Zero





About the Cement Association of Canada

OUR MISSION

To create the optimal conditions for our industry to lead and thrive in a clean economy.

OUR VISION

A resilient and sustainable future with net-zero concrete.

OUR MEMBERS

Our five member companies operate 14 cement plants in five provinces:

They are “vertically integrated”, meaning they also own and operate aggregate and concrete businesses.

As key partners in the built-environment ecosystem, they, and their international parent companies work to deliver the best solutions for sustainable construction today and tomorrow.

As manufacturers, they’re also committed to greener manufacturing of cement and concrete products. Each are charting corporate roadmaps with verified science-based targets to net-zero by 2050, with interim targets for 2030 and 2040 and a progress review in 2025.[8] Other environmental considerations, including the protection and enhancement of biodiversity, water conservation, and air quality are also priorities.

Our member companies protect the health and safety of their employees, customers, and host communities and create a better quality of life across Canada.

Their commitment to diversity and inclusion happens through community investments, workplace practices and working constructively with Indigenous communities to build mutually beneficial relationships.

Our Concrete Sector Allies and Partners

We work closely with our partners to promote and advance the contribution of concrete and of concrete products and systems to create thriving, sustainable, climate-resilient communities.

We wish to thank the following organizations for their contributions to this report:

NATIONAL CONCRETE PRODUCERS ASSOCIATIONS

Canada Masonry Design Centre

Canadian Concrete Masonry Producers Association

Canadian Concrete Pipe and Precast Association

Canadian Precast/Prestressed Concrete Institute

Concrete Canada

Interlocking Concrete Pavement Institute

PROVINCIAL CONCRETE PRODUCERS ASSOCIATIONS

Association Béton Québec

Atlantic Concrete Association

Concrete Alberta

Concrete BC

Concrete Manitoba

Concrete Ontario

Concrete Saskatchewan

Masonry Council of Ontario

Ontario Concrete Pipe Association

Tubécon

We would especially like to acknowledge our international partners, **the Global Cement and Concrete Association** and **the Portland Cement Association**—we greatly value the ongoing collaboration.

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Introduction

The concrete industry will be one of the most important partners to help achieve a net-zero future for Canada. **Here's why:**

1 Canada will build its **future with concrete**

Concrete is the most widely used building material in the world. It has supported human progress since ancient times and will be essential to building our shared future. Homes and communities need concrete. It's necessary for roads, bridges and buildings, manufacturing, renewable energy generation, resource industries, food production, and many other sectors and activities that sustain Canada's quality of life. It is also a local material that creates great-paying jobs in nearly every municipality in the country.

Twice as much concrete is used than all other building materials combined. Concrete is durable and helps the built environment withstand the worst effects of climate change. Improving how it is made and used will have a profound impact on climate change mitigation and adaptation.

A net-zero climate-resilient world will, literally, rest on concrete.

2 Big industries can make a **big impact**

Concrete is one of the most highly consumed commodities globally, second only to water. The active ingredient of concrete is cement, the binding agent that holds it together. The cement sector is the world's third-largest industrial energy consumer and the second-largest industrial CO_2 emitter. It represents about 7% of CO_2 emissions globally. Based on Canada's National Inventory Report, cement manufacturing accounted for 9.7 Mt CO_2 in 2020, the baseline year for this report.[9] This represents about 1.4% of Canada's emissions. **Cutting our emissions will have a big impact.**

3 There is no **silver bullet**

There is no silver bullet, no one magic solution that will get us to zero. Rather, it will take many actions. In detailing our path forward, we have chosen a cautious approach; our Action Plan uses the carbon-reduction levers available today.[10] While our path to 2030 is clear, we need more research and development in clinker chemistries, carbon utilization technologies, materials innovation, and clean fuel sources like hydrogen to get us to net-zero by 2050.

Solving the challenge of reaching net-zero will require many actions, from changing the way we make cement to imagining new ways of designing and constructing our infrastructure.

4 We're ready to act and **ready to collaborate**

We are up for this challenge. Our Action Plan shows that emissions reductions (from our 2020 baseline) of 40% by 2030, 59% by 2040, and net-zero by 2050 are possible using today's technologies. As new technologies are developed and proven, these reductions could accelerate. We will be transparent and accountable—and will release progress reports at least every five years. Our Action Plan is about finding true net-zero, so we do not account for offset purchases to get us to zero.

Where economic and regulatory conditions stand in the way of our progress towards our emissions reduction goals, we will actively work to improve those conditions rather than use them as an excuse to delay action.

And finally, we will be a partner, working with governments across the country, members of the procurement, architecture, engineering and design community, and the construction sector to realize this goal.

Working together, we can deliver

CONCRETE ZERO

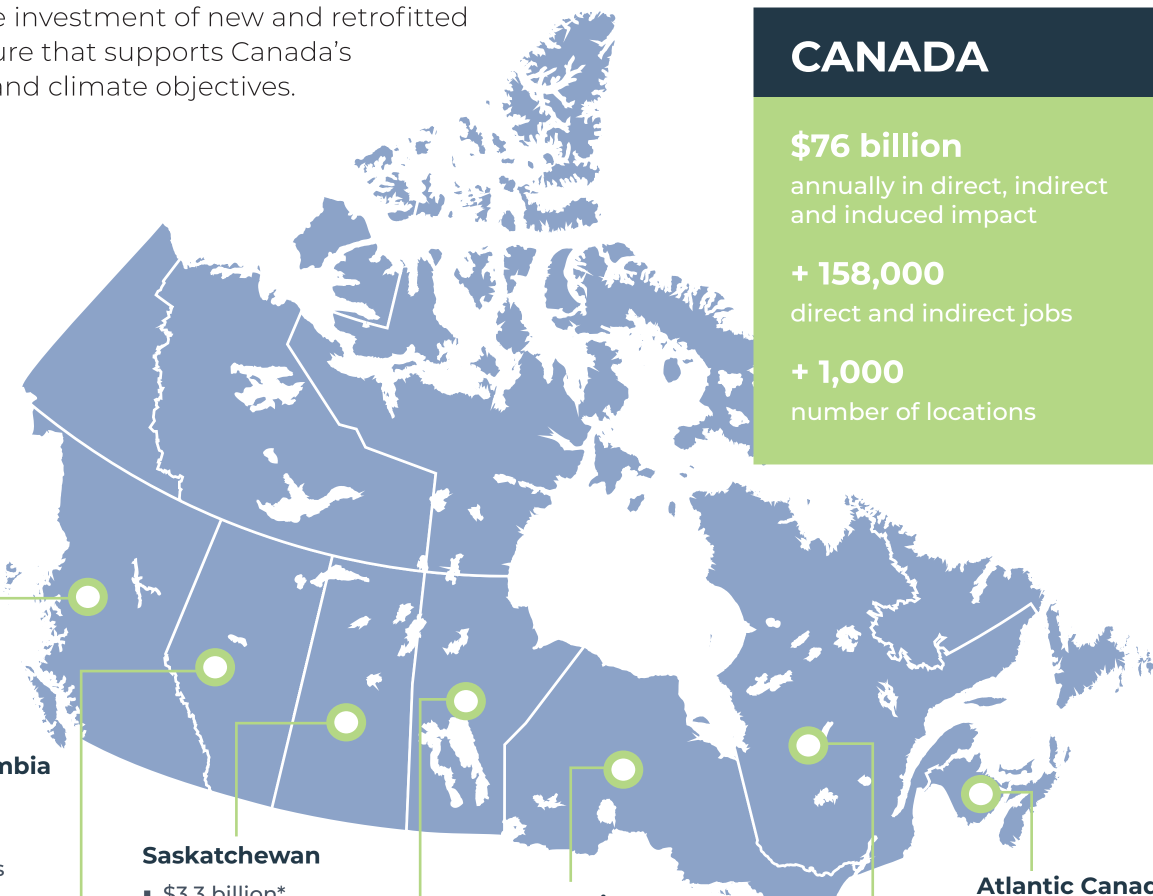
Canada's Cement Industry

Across Canada, there are **15 cement plants shipping cement to more than 1,100 associated facilities** that produce a variety of precast concrete products, ready mixed concrete, concrete pipe, and concrete masonry.

Collectively, the industry supports about 158,000 direct and indirect jobs across the country, and contributes $76 billion dollars in direct, indirect, and induced economic benefit to the Canadian economy.

While domestic cement production largely supports the Canadian market, exports to the United States have increased from $840M in 2016 to $1.1B in 2019. Global demand for cement and concrete is also expected to continue to grow. Our Action Plan anticipates modest growth of 1% per year in concrete production to support the investment of new and retrofitted infrastructure that supports Canada's economic and climate objectives.

Based on Canada's National Inventory Report, cement manufacturing accounted for 9.7 Mt CO_2 in 2020, or about 1.4% of Canada's total emissions. These emissions mostly come from the chemical process reactions needed to convert limestone into clinker, the precursor to cement (process emissions), and from the fossil-fuel emissions generated to produce the high temperatures (about 1,500 to 2,000 degrees Celsius) needed to achieve that process (combustion emissions).



CANADA

$76 billion
annually in direct, indirect and induced impact

+ 158,000
direct and indirect jobs

+ 1,000
number of locations

British Columbia
- $11 billion*
- 9,000 jobs**
- 134 locations

Alberta
- $16 billion*
- 34,000 jobs**
- 130 locations

Saskatchewan
- $3.3 billion*
- 6,800 jobs**
- 59 locations

Manitoba
- $2.6 billion*
- 5,400 jobs**
- 64 locations

Ontario
- $26 billion*
- 54,000 jobs**
- 358 locations

Quebec
- $13 billion*
- 27,000 jobs**
- 218 locations

Atlantic Canada
- $4.3 billion*
- 9,000 jobs**
- 29 locations

*Annually in direct, indirect and induced impact | **Direct and indirect jobs

Concrete is Essential to Society

Concrete is the world's most used building material for a reason. It is abundant, locally available, and can be used in innumerable ways. Concrete's remarkable properties make it a solution for both limiting the scope and combating the effects of climate change.

These are just a few of the performance benefits of concrete:

AVAILABLE

Concrete's universal availability means that this cost-effective building material can be used by various types of communities equally.

RESILIENT

Concrete can withstand the pressures climate change puts on our communities. In a crisis event, properly designed concrete infrastructure is more likely to stay intact compared to other building systems, reducing loss of life and helping quicker community recovery. Concrete passively heats and cools buildings, which reduces energy consumption and mitigates health impacts and other risks of extreme heat.

DURABLE

Concrete infrastructure lasts longer and requires less maintenance than other building systems. Concrete buildings are long-lasting and can be re-used, adapted, and re-purposed.

VERSATILE

Concrete is an exceedingly versatile material that gives structural designers enormous freedom to deploy new ideas that improve environmental performance and quality of life, while also allowing infinite aesthetic design possibilities to create beautiful structures.

CIRCULAR

Making and using cement and concrete offers many options for reusing and recycling. This includes using industrial by-products as raw materials for making cement, as additives to concrete, and for heating kilns with alternative fuels. There is a growing opportunity to recycle and reuse ground concrete, reducing the need for virgin materials and maximizing the carbon uptake of concrete.

The 5 C's Explained

This Action Plan is organized based on the cement and concrete value chain, identifying at each stage where emissions reductions will come from.

CLINKER

The primary ingredient in cement

Clinker is the primary ingredient of cement. Clinker is produced by heating limestone, clay, and other minerals to about 1500°C-2000°C in a rotary kiln system. At these temperatures, the elements that comprise the raw minerals recombine to form crystals that dissolve and then harden when mixed with water. Clinker is the base binder material used to produce cements.

CEMENT

A mineral binder

Cement is the active ingredient of concrete and comprises between 10 and 15% of the concrete's mix. It is manufactured by finely grinding clinker and gypsum together. Other materials can be added to produce cements with specific qualities, e.g., limestone is added to produce portland-limestone cement.

CONCRETE

A critical construction material

Concrete is a castable, stone-like, composite building material that is composed of fine and coarse aggregates (i.e., sand and gravel) that are bound together with water and cement that hardens over time.

CONSTRUCTION

Designing and building

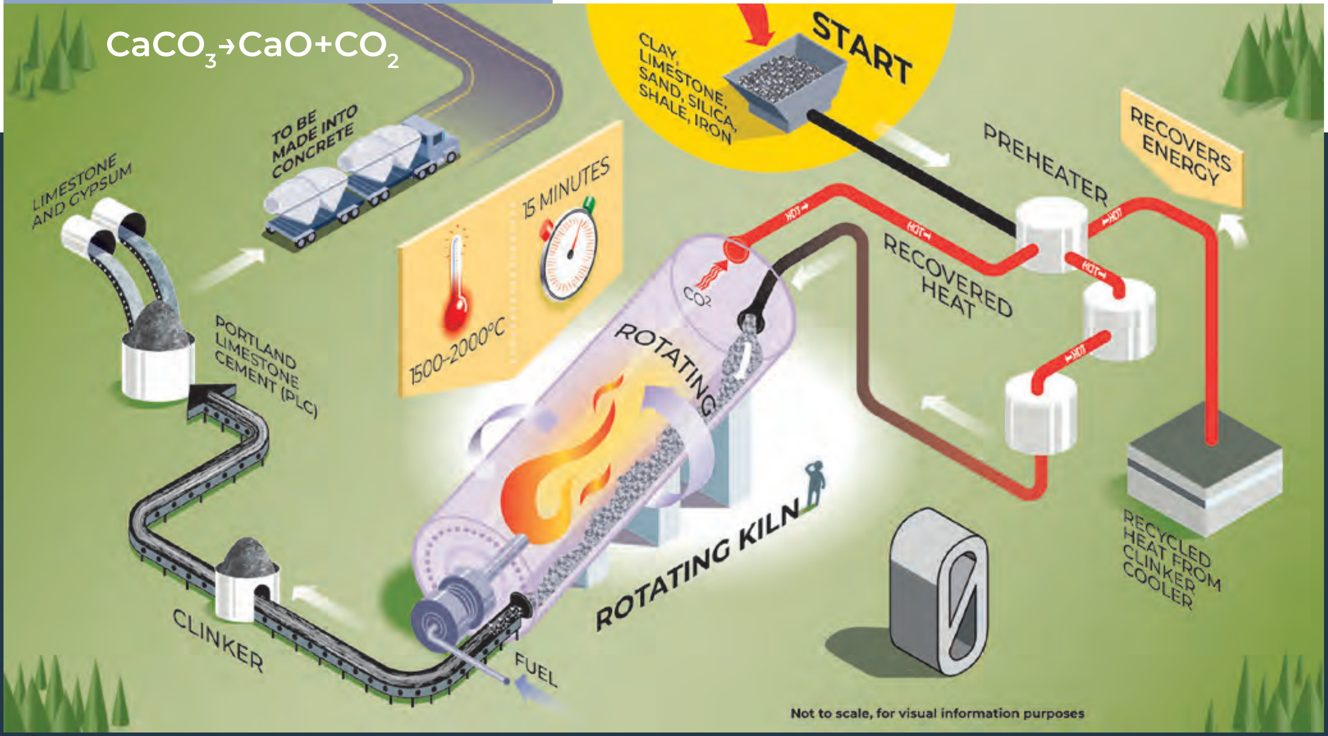
Architects, engineers, and the construction industry are all users of concrete products, whether it's in roads, buildings, or bridges. Finding efficiency in the way concrete is used, both in design and construction, can help reduce emissions.

CARBON UPTAKE

Concrete is a CO_2 sink

Over time, CO_2 in the atmosphere reacts with the calcium hydroxide in concrete to form calcium carbonate—a reversal of the chemical process that occurs when making the cement used in concrete. This reduces the whole-life CO_2 footprint of both the cement and the concrete for which it (the cement) is used.

How cement is made



Net-Zero
Across the Cement and Concrete Value Chain

EMISSIONS REDUCTIONS
($Mt\ CO_2$)

2030	2040	2050
0.9	1.2	1.6

Clinker

Clinker is the foundational component of cement, the key ingredient that gives cement its binding properties. It is also the most GHG-intensive component of cement and, by extension, concrete.

Clinker is made by heating limestone and minerals to very high temperatures (~1,500 degrees Celsius) in a rotary kiln. This process generates CO_2 in two distinct ways:

- About **one-third** of total clinker emissions come from the combustion of fossil fuels, traditionally coal and petroleum coke, to generate heat in the kiln.
- About **two-thirds** come from what are referred to as "process emissions," in this case the decarbonization of limestone ($CaCO_3$) to produce lime (CaO) which drives the chemical reactions that produce clinker.

Clinker is then finely inter-ground with gypsum, limestone, and other raw materials to make cements with a variety of different properties.

2020 BASELINE

In 2020, Cement Association of Canada member companies produced about **11.4 million tonnes** of clinker at an average carbon intensity of **833 kg CO_2 per tonne** of clinker for a total **9.5 Mt CO_2 emissions**.

ACTION PLAN

We will eliminate the use of virgin fossil fuels, lower the proportion of clinker in cement, and aggressively pursue CCUS technologies.

How we'll reduce emissions

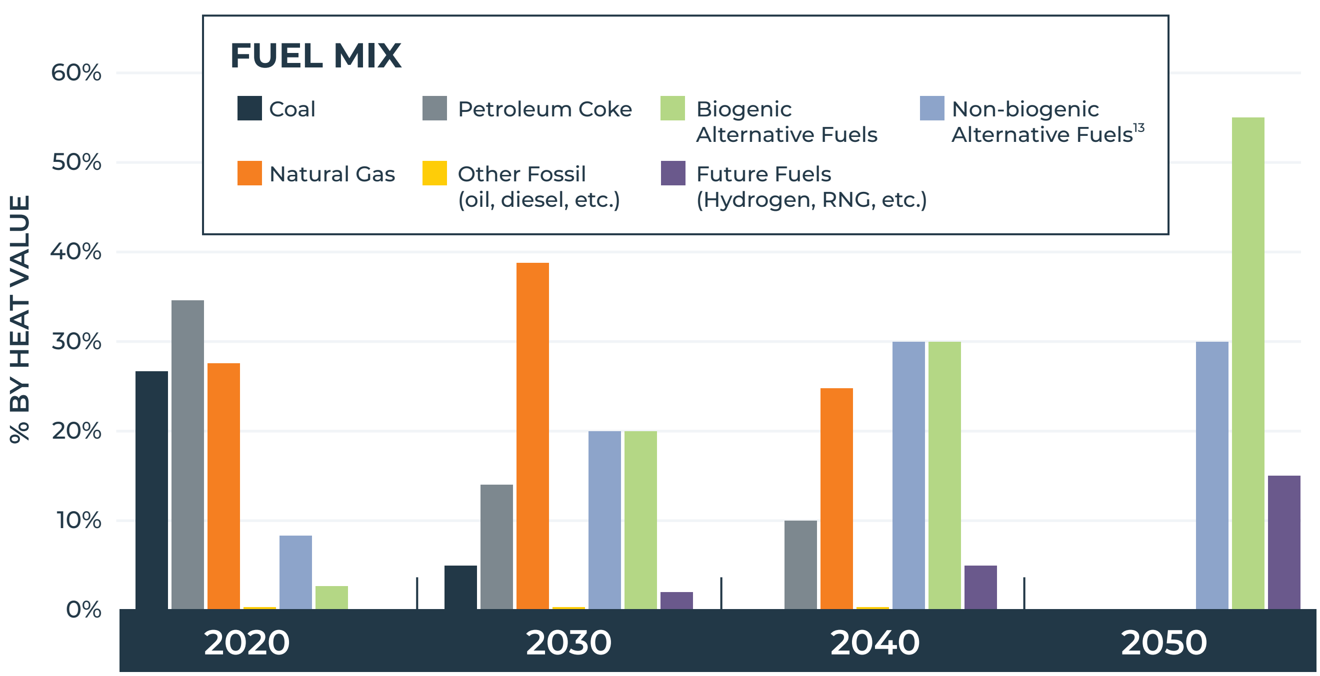
1 Replacing Fossil Fuels

In Canada, the heat needed to drive clinker production is derived primarily from fossil fuels—mainly coal, petroleum coke and natural gas. However, cement kilns are also ideally suited to use a variety of alternative heat sources.[11] These include biomass and waste-derived fuels that can significantly reduce combustion emissions. This has the added benefit of keeping such materials out of landfills and avoiding GHG emissions from landfill decomposition.[12]

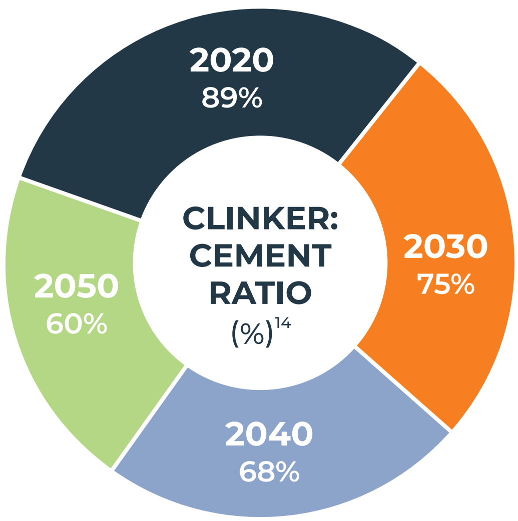
Canadian cement manufacturers have increased their use of lower-carbon fuels. Still, the fuel substitution rate in 2020 was less than 10%, well below a comparative European average of more than 40%. This is largely because provincial policy barriers make it difficult to obtain permits to use non-fossil-based fuels. Further, because landfills are accessible and low-cost, there is limited market incentive for waste producers to divert biomass and other materials that could be used to produce energy for cement production. The cement industry has worked closely with provincial regulators to address these barriers. Many have recently demonstrated resolve in opening the door to deeper investment in fuel substitution in Canada. To meet our net-zero commitments, we will retreat from fossil fuels, starting with coal and petroleum coke, while increasing reliance on lower-carbon alternatives. By 2030, we aim for an average substitution rate of 40%, half of which would be comprised of biomass. As higher-quality biomass fuels (e.g., biochar) and other low- or zero-carbon fuels (e.g., zero-emissions hydrogen) become commercially and economically available, we aim to eliminate virgin fossil fuels entirely by 2050.

2 Clinker Substitution

The most effective way to reduce total direct clinker emissions is to use less of it. This is done first by substituting clinker with other lower-carbon binding agents in cement, lowering what is referred to as the "clinker/cement ratio." Second, by deploying concrete mixes that take advantage of lower-carbon supplementary cementitious materials (SCMs). This reduces the amount of clinker needed to produce high quality concrete. For limited applications, it is possible to eliminate the need for clinker in the final concrete product (e.g., concrete blocks). These strategies are described in more detail in the following "Cement" and "Concrete" sections.



Using concrete more efficiently, as described in the "Construction" section (see page 26) can also help reduce total clinker emissions. To do this, we'll need to undertake aggressive R&D, as well as work to update codes and standards, and specifications to enable an increase in clinker substitution (see the "Cement" section on page 21). Education and awareness across the procurement, architecture and engineering community of these new lower-clinker cements will provide certainty of performance, while government policy and incentives will play a meaningful role in supporting market uptake (e.g., "Buy Clean" policies).



3 | Carbon Capture

Carbon Capture, Utilization and Storage (CCUS) offers a solution to both combustion and process emissions. Commercial-scale carbon capture and storage systems can capture greater than 90%-95% of CO_2 emitted from a cement kiln. Detail on the value of CCUS is in the "Enabling Measures" section (see page 30).

4 | Thermal Efficiency

Producers have realized substantial gains in thermal efficiency in recent decades by replacing older kiln technologies with more modern designs. Challenges around installing a new kiln line, including lengthy and uncertain permitting processes and substantial capital investments, may dissipate over time as carbon pricing signals strengthen. We will track gains in thermal efficiency as the industry transitions to higher biomass-based alternative fuels, with modest improvements from higher-quality engineered biomass and other low-carbon fuels as they become available.

5 | Decarbonated Raw Materials

Decarbonated raw materials are a source of calcium oxide that does not contribute to process emissions, but instead can help reduce process emissions. Decarbonated materials like metallurgical slags, incinerator bottom ash, and recycled concrete fines do not emit CO_2 when heated because they have already had the CO_2 removed. This is a strategy that is highly site-specific and supply constrained. We predict only modest reductions from decarbonated materials, but our model will be updated as new sources of economically accessible decarbonated materials are identified.

6 | Novel Clinker Chemistries

With an eye to achieving net-zero emissions by 2050, research and development is emerging around the development of new clinker chemistries. Alternative clinkers such as reactive Belite-rich portland cement (RBPC) clinkers, Belite-Ye'elimite-Ferrite (BYF), Carbonatable Calcium Silicate clinkers (CCSC), and Magnesium Oxides derived from Magnesium Silicates (MOMS), are being studied, with careful attention to their verifiable carbon emission reduction potential.[15]

There are several challenges with these new, emerging chemistries: maintaining durability and quality is of prime importance as is market acceptance and scalability—that is the ability to reliably produce at the volume needed for the marketplace. New chemistries may also face market adoption challenges as concrete made from novel clinkers may behave differently and require significant education and adaptation by concrete placers and finishers and other construction industry actors. We will monitor how these chemistries develop over time and model their potential impacts as they become more commercially available.

EMISSIONS REDUCTIONS
($Mt\ CO_2$)

2030	2040	2050
1.5	2.2	2.9

Cement

The most energy-intensive phase of the concrete value chain occurs at the cement plant. Cement is produced when clinker, gypsum, and limestone are interground in ball or vertical mills.

Blended cements can be produced by adding other active materials to the grinding process or blending those materials into cement after grinding. Cement production is energy- and carbon-intensive, due to the temperatures needed to produce clinker and related process emissions (see Clinker section on page 18). However, energy use can be optimized to help reduce emissions.

2020 BASELINE

In 2020, Canadian cement manufacturers produced about **12.7 million tonnes** of cement at an average carbon intensity of **744 kg CO_2 per tonne** of cement for a total of **9.5 Mt CO_2**. These emissions are generated from clinker production, with electricity emissions from cement production reported separately.

ACTION PLAN

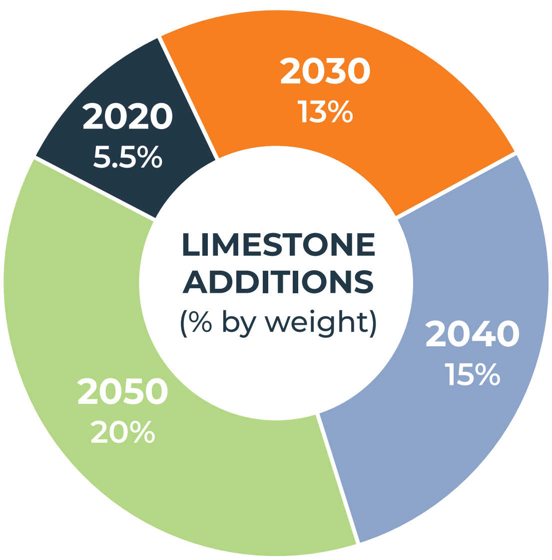
We will lower clinker content in cement while still producing a durable, resilient product. Along with the clinker improvements noted earlier, this will reduce the overall carbon intensity of cement.

How we'll reduce emissions

1 | New Cement Blends

Portland-limestone cement (PLC)

Portland-limestone cement (PLC) is a portland cement product with a higher proportion of unprocessed (i.e., non-kiln fired) limestone than normal (traditional) portland cement. PLC performance is equivalent to traditional portland cement, but reduces the carbon footprint by up to 10%. In Canada, PLC has been adopted by the Canadian Standards Association (CSA A23.1/ A23.2) and is referenced in the National Building Code. Accelerating widespread adoption across the country will reduce clinker consumption and lower Canada's greenhouse gas emissions by up to 1 Mt annually.



Supplementary Cementitious Materials (SCMs)

Supplementary Cementitious Materials or SCMs are used as a partial replacement of clinker in cement or (more commonly in Canada) as a partial replacement for cement in concrete (see the "Concrete" section on page 23). Today, the most used SCMs in Canada are ground granulated blast furnace slag (a by-product of steel production), fly ash (a by-product of coal-fired electricity production), and natural pozzolans such as volcanic ash, certain shales, and calcined clay. Fly ash and slag are industrial by-products that have historically been landfilled and forgotten.

As the energy and steel industries transition away from their use of coal and other fossil fuels, the availability of virgin fly ash and blast furnace slag will decline. They will be replaced by materials recovered from landfills, higher proportions of unprocessed ground limestone, calcined clay, and other new materials.[16] 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.

Inter-grinding or blending SCMs with clinker to produce "blended cements" lowers clinker content and provides other environmental benefits by using materials that would otherwise be considered waste.[17] Blended cements can also improve workability, durability, and strength. Blended cements consume less energy in production and can use less water at the construction site.

	2030	2040	2050
Blended Cements (% of market)	25%	35%	50%
SCM in Blended Cement (%)	20%	20%	20%
CO_2 Burden of SCMs (Mt CO_2)	0.09	0.1	0.2

EMISSIONS REDUCTIONS
(Mt CO_2)

2030	2040	2050
0.4	1.0	1.5

Concrete

As an essential building material, concrete must be produced to ensure quality and performance while reducing emissions.

The concrete that is used at construction sites is made by mixing cement with water, sand, and gravel (aggregates). There are an almost limitless number of concrete formulations. Concrete can be made for any application to meet the needs of engineers, contractors, infrastructure design, owners, and more.

2020 BASELINE

Our model implies that based on the volume of cement production, in 2020, Canadian concrete manufacturers produced about **43 million cubic metres (m^3)** of concrete.[18] This is at an average carbon intensity of **269 kg CO_2/m^3** for total CO_2 emissions of **11.5Mt**. We estimate growth in concrete production to be 1% per year through the duration of our Action Plan.

ACTION PLAN

We will optimize concrete products by working with governments and industry partners to develop specifications that use the “right concrete for the job”—maximizing emissions reductions while preserving the strength, durability and other essential properties concrete is known for. We will power all concrete production with non-emitting, clean energy.

How we'll reduce emissions

1 | Concrete Mix Optimization

In many applications, using supplementary cementitious materials (SCMs) can replace some of the cement needed to produce concrete, resulting in significant GHG reductions. However, the percentage of SCMs that can be used varies significantly (higher or lower) depending on the application because of factors such as speed of strength gain, particularly in periods of colder weather.

Concrete admixtures are natural or manufactured chemicals or additives added during concrete mixing to enhance specific properties of the fresh or hardened concrete, like workability, durability, or early and final strength. Almost all concrete mixes use some sort of admixture. Admixtures have a very low carbon footprint and represent only one per cent or less of the concrete materials. They also can dramatically improve concrete performance. Admixtures improve workability for concrete placement and finishing operations, but they can also significantly reduce the environmental footprint of concrete by reducing the amount of cement needed to reach a specified level of performance.

The concrete industry has been offering lower-carbon-intensity concrete products, including concrete made with portland-limestone cement (PLC), blended cements, SCMs and admixtures for decades. The industry continues to work hard to transition customers to these products. However, some markets are still challenging, particularly where governments have traditionally been slower to adopt lower-carbon concrete products for public infrastructure projects.[19]

We will continue to work with local concrete producers, provincial concrete associations, and governments to move towards wide acceptance of these products in a variety of uses by adopting performance-based specifications instead of utilizing prescriptive specifications that often require a minimum cement content and maximum amount of SCMs.

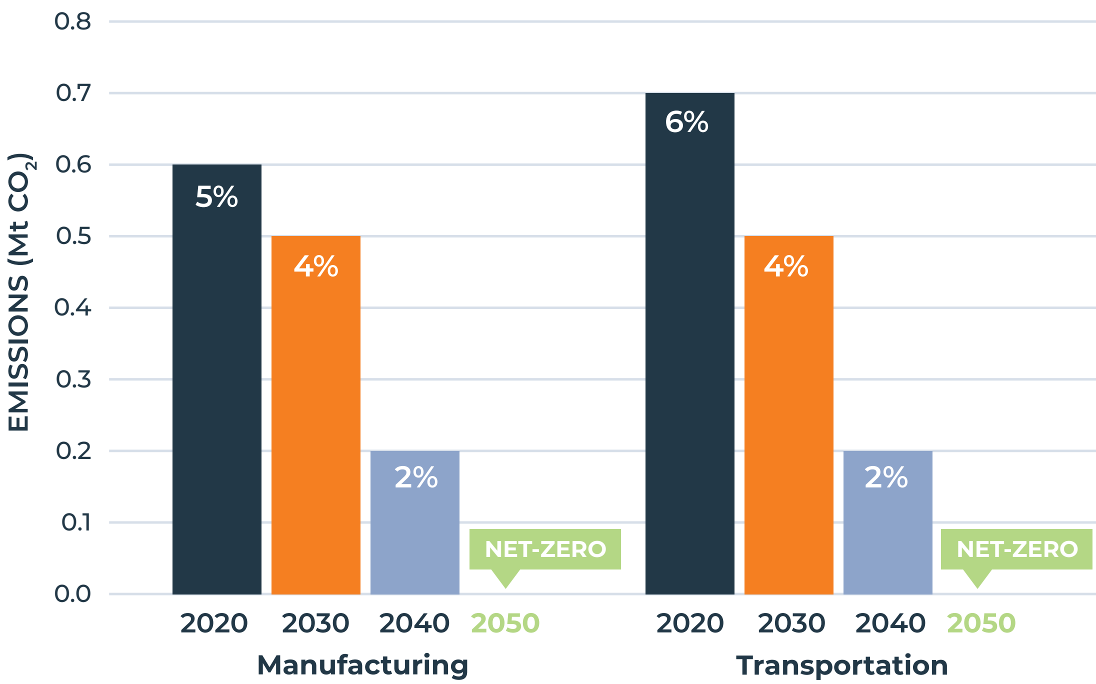
Avoided Emissions

Concrete use and production can lead to significant avoided emissions. For example, waste biomass used to replace fossil fuels in cement kilns also avoids methane emissions from the decomposition of that biomass in landfills. Concrete's albedo—meaning the amount of energy reflected by a surface—in combination with thermal mass can help reduce operational energy related emissions in buildings by increasing energy efficiency and helping to shift energy demand to off-peak times when the grid is cleaner. Concrete pavements can improve the fuel efficiency of vehicles, leading to reduced emissions from cars and trucks. While these emissions have been described and validated in a variety of academic studies, we have chosen to exclude them from our Action Plan and focus on our direct footprint.

2 Powering Concrete with Clean Energy

Shifting the energy needs of concrete production facilities to clean electricity and other low-carbon sources of energy will reduce emissions. Today, electricity consumption accounts for about 5% of the total CO_2 footprint of concrete (7.5% when including electricity emissions from the manufacture of the cement used in concrete).[20]

Delivering concrete also needs energy, whether it's a concrete mixer truck ready to pour concrete, or a truck delivering a pre-cast concrete product to a job site. While the transition to cleaner heavy-duty vehicles will take time, industrial vehicle manufacturers have made a lot of progress in powering these vehicles with clean hydrogen, electricity, and other lower-carbon fuels.



EMISSIONS REDUCTIONS
($Mt\ CO_2$)

2030	2040	2050
1.0	1.6	2.1

Construction

There are opportunities to reduce and avoid the volume of emissions associated with concrete use through design and construction.

This means not overusing concrete and using the lowest carbon option available on the market that meets the requirements of the given application without compromising durability and safety. Achieving emissions reductions in construction is outside of the direct control of the cement and concrete industry and requires a shared commitment to achieving net-zero, together.

2020 BASELINE

We do not have an emissions reduction baseline for construction, however our net-zero model assumes a business-as-usual scenario, where without material efficiency gains, **concrete consumption grows 1% per year** from **43 million m^3** in 2020 to almost **58 million m^3** in 2050.

ACTION PLAN

We will pursue policies and collaborations that incentivize and support the construction industry to obtain the right amount of concrete needed for a project, avoiding overdesign and ordering more concrete for a job than what is needed.

How we'll reduce emissions

1 | Optimization in Design

Optimization in the design phase of a project takes a whole life-cycle approach, and 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 being flexible enough to meet project-specific performance and other requirements.

Structural systems can also be optimized by considering the size, shape, and spacing of structural components. This includes how and where those components are connected to transfer loads most efficiently. Examples include bubble and waffle deck structures and vaulted flooring systems. Taking a whole life-cycle approach to design can maximize emissions reductions. While a higher-strength concrete needs higher cement contents, in some applications these higher strengths may mean the overall structural system can be designed with a lower carbon footprint because the overall system has been optimized.

2 | Waste Reduction

Optimized construction means zero waste on the job site and zero returned concrete. Concrete and cement are not only products to be produced, but crucial components in a circular economy.

	2030	2040	2050
Savings from Material Efficiency (millions m^3 of concrete)	3.6	5.9	7.9
CO_2 Reduced at the Construction Stage (in year concrete produced) (Mt CO_2)	0.7	0.9	0.8

EMISSIONS REDUCTIONS
($Mt\ CO_2$)

2030	2040	2050
1.2	1.0	0.8

Carbon Uptake

Concrete naturally sequesters CO_2 from the atmosphere, permanently capturing it in a process known as carbon uptake (or recarbonation).

This natural carbon uptake effect has been known to occur since the first modern uses of concrete, but it has only more recently been studied and quantified in detail.

ACTION PLAN

We will factor in the carbon uptake properties of concrete in our net-zero modelling, using the best available, verified data.

How concrete absorbs CO_2

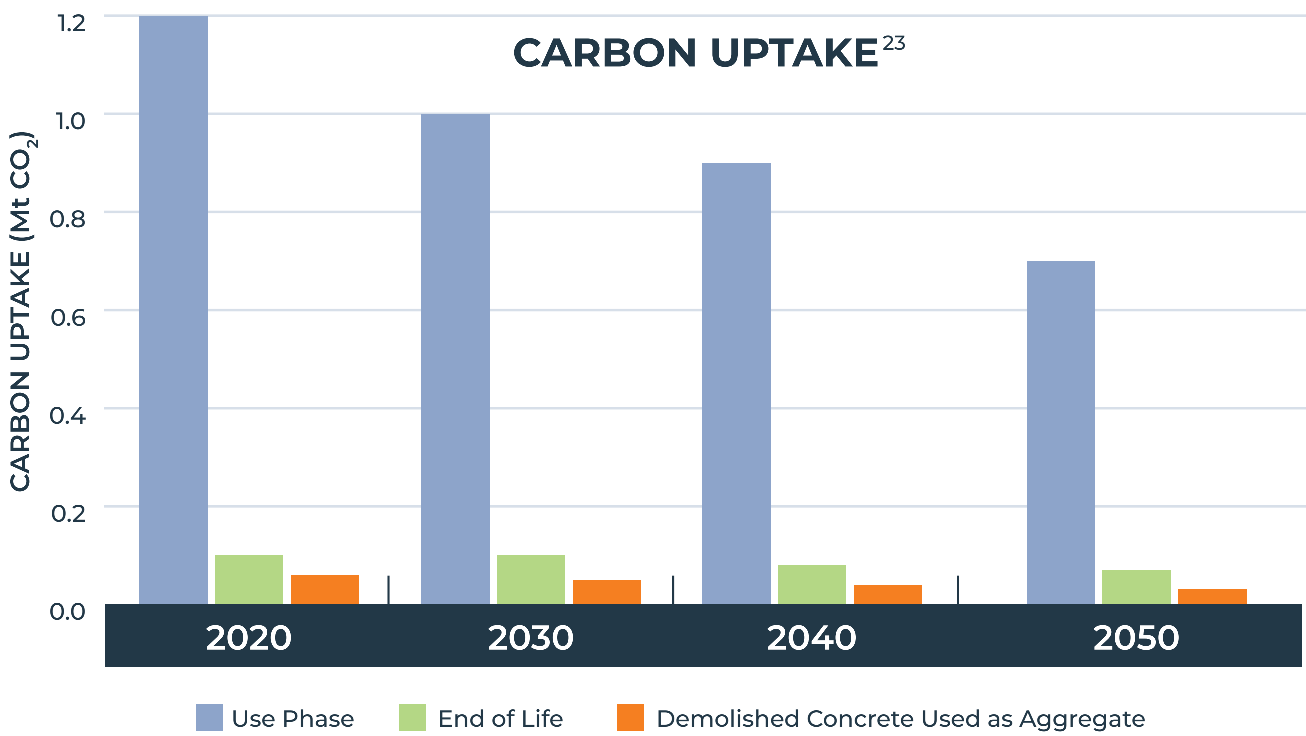
Research conducted at IVL, the Swedish Environmental Research Institute, finds an average of 20% of the CO_2 calcination emissions (i.e., process emissions from clinker production) can be permanently sequestered when a concrete structure has been built. Another 2% of calcination emissions can be permanently sequestered when the concrete structure is demolished. Another 1% of calcination emissions are considered permanently sequestered if the demolished concrete is reused as an aggregate.

The rate of CO_2 uptake depends on many conditions, but rates of CO_2 uptake are greatest when the surface-to-volume ratio is high, like when concrete has been crushed and exposed to air. During the design phase of a project, a good strategy to maximize CO_2 uptake is for architects and engineers to ask to use exposed concrete wherever possible.

Permanently sequestering CO_2 using concrete as a carbon sink directly reduces the CO_2 within the life cycle of concrete. Carbon uptake also occurs when recycling concrete aggregate, as more concrete surface is exposed to air.[21] There are also several rapidly emerging and scaling innovations focused on maximizing concrete's carbon uptake advantage.

This Action Plan assumes the IVL percentages of carbon uptake. However, a number of other studies, including core sampling from existing concrete structures across North America, are being undertaken.[22]

We will revise carbon uptake estimates (up or down) as further field evidence is collected. We will also pay attention to developing technologies focused on concrete's carbon storage potential, with a view to include these innovations in our Action Plan as technologies are deployed and emissions reductions are verified.



Enabling Measures

The solutions detailed in our Action Plan are vital to Canada's cement and concrete industry meeting our net-zero goal. They also require partnerships and collaborative approaches to realize their potential.

How we'll reduce emissions

1 | Carbon Capture, Utilization and Storage (CCUS)

ACTION PLAN

We will continue to collaborate with governments in all regions of the country on the necessary programs and policies to unlock this important carbon-reducing technology. Future CCUS development will need to focus on both the storage and the utilization aspects of these technologies, because storage may not be a viable solution to reduce emissions in all regions.

The scale-up of Carbon Capture, Utilisation and Storage (CCUS) is vital to the cement and concrete industry reaching net-zero both within Canada and globally. In their foundational report, *Net Zero By 2050: A Roadmap for the Global Energy Sector*, the International Energy Agency defines CCUS as an essential 'pathway' for heavy industry to reduce GHG emissions to avoid catastrophic climate change. The report calls for an unprecedented rate of CCUS development and deployment as part of a broader energy system transition to achieve the scale of GHG mitigation needed, including expanding global CCUS capacity from 40 Mt per year in 2020, to more than 7,600 Mt per year by 2050.

That's why CCUS is a vital part of our Action Plan—we don't get to zero without it. Deploying carbon capture and storage technology at full scale during cement manufacturing could eliminate process and combustion emissions almost entirely. Today, there is no other technology or process that can eliminate process emissions. CCUS, together with bioenergy, clean fuels, and carbon uptake, could result in the future delivery of carbon-negative concrete for our world.

This Action Plan considers CCUS emissions reductions in two ways: 1) the carbon emissions reduction needs for CCUS, once all other measures have run their course, and 2) emissions reductions from planned or announced CCUS projects.

	2030	2040	2050
Emissions Remaining for CCUS (Mt CO_2)	7.6	6.1	4.4
Emissions Reduced via planned or announced CCUS projects (Mt CO_2)	1.5	2.0	2.0

2 Research and Development

ACTION PLAN

We will work with governments to create a collaborative research and development agenda to support manufacturing improvements and the way that building materials and infrastructure are procured and used by all levels of government and the private sector.

Research and development are vital to achieving the Action Plan pathway to net-zero. This includes deploying new technologies and solving technological challenges to support decarbonization. This means 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 first commercial deployment of CCUS at scale.

ACTION PLAN

We will work with the codes, standards and specifications community to integrate low-carbon performance, operational and embodied carbon considerations into building and infrastructure design, guides, codes and standards, and specifications. We will continue to work with governments, and the engineering and design community to advocate for the adoption of performance-based specifications to allow for the greatest carbon emissions reduction possible depending on the project. We will advocate to close research, regulatory and technology gaps to de-risk low-carbon materials and approaches and grow and transform Canada's construction sector to align with an innovative, low-carbon economy.

Codes, standards and specifications set mandatory minimum requirements for infrastructure assets and have developed to ensure safety. They must evolve to ensure that building practices consider a changing climate and to drive made-in-Canada innovation for low-carbon materials and approaches, in addition to safety. This means "de-risking" and raising awareness of innovative solutions among designers and builders, who often favour tried-and-true methods for delivering projects on time and on budget.

Once climate-smart codes and performance-based standards become mandatory, the bar is higher for 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 to help de-risk and integrate new low-carbon technologies and materials into design and construction. While many codes, standards and specifications indicate that they are performance-based, there are many residual "prescriptive requirements" remaining from past practices that limit carbon reductions. The specification of minimum cement contents and the limiting of the use of supplementary cementing materials are two examples that often prevent carbon reduction in concrete products.

ACTION PLAN

We will advocate and support the necessary education for requiring increasingly lower-carbon materials in public procurement and adoption of performance-based project requirements to spur innovation. We will collaborate with governments to build opportunities for education and knowledge-sharing on how to specify increasingly lower-carbon concrete mixes—this includes carving out projects to demonstrate new-to-market products and processes through applied research rebates, insurance premium or tax credits.

Public procurement can help decarbonize construction materials. Government infrastructure projects consume about 40 percent of the cement produced around the world. Long-term commitments to buy lower-carbon materials gives market signals that can be leveraged by industry for investment in decarbonization.

The Government of Canada requires the disclosure of embodied carbon in structural materials in major construction projects since 2022 and will require a 30% reduction in that embodied carbon starting in 2025. The first embodied carbon disclosure and reduction requirement is for ready-mixed concrete and came into effect Jan 1, 2023—a measure our industry advocated for and helped design.

The federal government has also committed to introduce a new Buy Clean Strategy to support and prioritize using low-carbon materials and products in Canadian infrastructure projects. These will help improve our ability to produce low-carbon cement and concrete products. In addition to supporting the private sector, the federal government will need to do more to influence green procurement policies at the provincial and municipal level, where most of the infrastructure is procured.[24]

Buy Clean

Buy Clean is a procurement policy approach that supports both climate and economic policy objectives by incorporating low-carbon construction purchasing requirements to address greenhouse gas emissions from construction materials in government purchasing. Canada's cement industry is committed to achieving Buy Clean in Canada and has taken a leadership role to realize it. Cement and concrete are the first industry to produce regionally-specific life-cycle inventory data to support transparency in low-carbon decision making, and concrete is the first material with a requirement under the Government of Canada's Standard on Embodied Carbon in Construction.

ACTION PLAN

We will work across the cement and concrete value chain to improve data collection. We will also work with governments, life-cycle analysis (LCA) experts and others to develop a robust system of carbon accounting that is transparent, avoids double-counting, and includes performance metrics.

Canada's cement and concrete industry is on the leading edge of carbon accounting and disclosure. Both sectors fully embraced regionally-specific industry-wide average Environmental Product Declarations (EPDs) as a way of quantifying and confirming industry improvements in carbon reduction. All cement facilities in Canada have also published facility-specific EPDs and an increasing number of concrete producers have as well.

However, our Action Plan exposes many important data gaps (e.g., detailed data on the volumes of concrete and concrete mixes used in different categories of infrastructure).

This is a challenge our industry will tackle as we aim to improve our modeling and reporting on our net-zero Action Plan.

Much significant work remains to be done to improve the availability, quality, consistency, and comparability of carbon data across the cement and concrete value chain, and equally across the value chain of other construction products, such as steel and wood. These limit our ability to establish material- and project-level benchmarks to increase market confidence in carbon reduction strategies.

Achieving Concrete Zero

Our net-zero Action Plan is an ambitious roadmap for achieving net-zero by 2050, but it cannot be achieved by industry action alone.

Partnerships and collaboration will be essential. The following list of recommendations are focused on specific, enabling actions that will minimize the challenges faced by the cement and concrete industry and unlock its full potential to meet its goals.

Actions from governments

1

Government policy must be **ambitious, predictable, and durable**.

To achieve net-zero, industry needs clear policy signals that align programs and incentives that enable a successful business case for industry investment in innovative carbon-reducing technologies and material efficiency strategies. A durable, predictable carbon price is a necessary foundation that must be paired with regulations and funding programs to support the decarbonization of supply and the scale-up of increasingly low-carbon to net-zero products. Policies and programs designed for industry should account for factors including industry investment cycles, technology readiness, energy intensity, and carbon leakage among other sector-specific considerations. Carbon Border Adjustment Mechanisms (CBAMs) are vital to protect energy-intensive, trade-exposed industries from facing unfair competition from jurisdictions without carbon pricing in place.

Governments must also continually review permitting rules to ensure protection of the public good, which includes supporting the updating of industrial practices to enable emissions reductions. This includes supporting critical investments in infrastructure to switch plants from coal to natural gas and other alternative fuels, expanding the use of renewable energy and storage at industrial facilities, enabling the supply of clean fuels, charging networks for zero-emission medium and heavy-duty vehicles, and CCUS transportation and storage infrastructure. Regulatory modernization, where needed and applicable, is also necessary. Unintended consequences from regulations can affect major carbon reduction pathways across industry. This includes better coordination and understanding of the interactions and impacts of policies across different departments and levels of government.

2

Government funding programs focused on supporting the **deployment of near- and net-zero emission industrial technologies**.

Various finance mechanisms could be used, like direct grants, tax credits, low-interest and concessional loans, and blended finance instruments. Equally important are targeted, specialized supports like contracts for difference to address the unique challenges and risks facing the first full-scale commercial deployment of near- or net-zero carbon technologies, including CCUS.

3

Continued government **investments in clean energy infrastructure**.

Many of the best ways to reduce emissions available to the industrial sector will need significant new investments in energy, transportation, and carbon reduction infrastructure. Switching from coal to alternative fuels, like green hydrogen fired kilns, will need greater fuel production capacity and better delivery for industrial use. Switching from fossil-fuel generated electricity to clean electricity may require investment in new supply, grid, transmission, distribution, and other upgrades. Transitioning industrial fleets to zero-emissions vehicles requires clean fuel supply, charging sites and supporting infrastructure. Implementing CCUS needs a national plan for regional networks of CO_2 pipelines to connect generators to utilization technologies and sequestration sites, particularly outside of traditional oil and gas corridors. At the same time, the expansion of all this infrastructure will also require a reliable supply of low-carbon concrete and other materials. All of these will require government support and incentives, particularly during the initial stages of implementation while markets are developing.

4

Government **support for research, development, and demonstration**.

Increased support for R&D and innovation through collaborative projects with the cement and concrete value chain, enabled by public funding and risk sharing investment mechanisms is needed. This work must focus equally on technology and materials innovation with the goal of targeted demonstrations with early adopters to show value and accelerate deployment at scale of low-carbon solutions. This could be achieved through innovation hubs that involve actors along the cement and concrete value chain, innovators in clean technology, innovators in materials, and government.

5

Accelerated adoption of low-carbon concretes through **codes, standards, specifications, and public procurement**.

Every public dollar spent on infrastructure should help Canada prevent, reduce, and withstand climate change.

Changes to codes, standards, specifications, and public procurement will accelerate the production and adoption of low-carbon cements and concrete products across the market. Ambitious standards for energy performance of buildings that are demanding and sophisticated enough to account for embodied carbon will also be essential to reducing emissions in the built environment. Finally, governments must adopt material/technology neutrality and CO_2 lifecycle performance in construction regulations, codes and standards, specifications, and carbon accounting methodologies, as well as in public procurement, to deliver outcomes focused on greater emissions reductions over time.

Actions from both governments and the private sector

6

Policies that create differentiated markets for **near- and net-zero emissions material production**.

Canada's cement and concrete industry is up to the challenge of producing increasingly lower-carbon cements and concretes on the path to net-zero by 2050. As industry produces those materials, demand must also be stimulated for lower-carbon (scaling towards near- or net-zero materials) to grow the market and support viable business cases for private investment in net-zero technologies and manufacturing.

Essential to this are government programs and policies like carbon contracts for difference, codes, standards and specifications, and green/low-carbon procurement. In the private sector, this includes making embodied carbon a performance metric and increasing commitment to purchase near- or net-zero construction materials.

7

Make net-zero an **essential design parameter in all infrastructure projects**.

Net-zero requires action at all stages of the cement and concrete value chain. Governments and the private sector must collaborate and work within their own supply chains to ensure that reduction of CO_2 emissions becomes an equal design parameter alongside quality, cost, speed, and specific project client requirements. Solutions could include shifting to a whole-building Lifecycle Analysis (LCA) approach that considers both operational and embodied carbon as a norm for all infrastructure projects.

8

Adopt **performance-based standards for all building materials**.

While lower-carbon cement and concrete materials are readily available in many of Canada's markets today, the uptake of these materials has been limited by overly restrictive or arbitrarily prescriptive procurement policies in both the private and public sector.

By moving to performance-based material and design standards, high-performance, lower carbon cement and concrete products like portland-limestone cements, fly ash, slag, and other SCMs and admixtures can enable the greatest emissions reduction possible for the application, while maintaining the strength, durability, resiliency, and versatility that concrete is known for.

Actions from the cement and concrete industry

9

Continue to **build collaborative partnerships** along the value chain.

Canada's cement industry must continue its work to build stronger partnerships among the cement and concrete industry value chain and with the procurement, architecture, engineering, design, and construction community. Working together, all partners must tackle systemic barriers to optimizing concrete design and construction and prioritizing CO_2 performance in procurement, design, and construction.

10

Increase **education, awareness, and dialogue** in communities across Canada.

The cement and concrete industry must enhance our work with communities to educate, build awareness and exchange in meaningful dialogue on the steps being taken at a local level to reduce emissions. This includes exchanging ideas on waste diversion, and lower-carbon fuel sources. This will be essential for understanding the role heavy industry plays in good public health stewardship.

A Call to Action

It's no exaggeration to say that human civilization is built on a foundation of concrete. However, the irony is not lost on the people working in our industry that the very material that has enabled civilization to advance so far has also played a role in the climate crisis that now threatens our world—and our way of life here in Canada.

As people with families that we love, as Canadians, and as professionals proudly working in cement and concrete, we are determined to rise to the challenge that this moment presents. We believe that our industry—which is filled with innovative, resourceful, and hard-working individuals—can and will play a central role in helping Canada achieve its net-zero goals.

We also know that we cannot do it alone. It will take all of us—governments at all levels, industries and businesses of all kinds, our concrete sector allies and partners, and citizens, visionaries, and entrepreneurs from every part of Canada—working together to achieve this important goal.

Every journey begins with a single step, and **Concrete Zero** is ours.

Glossary

Albedo: A measure of the fraction of solar energy reflected by a surface or object often expressed as a percentage. Lighter color surfaces reflect solar energy and have a high albedo, while darker surfaces absorb solar energy and have a low albedo.

Absolute gross carbon emissions: The total quantity of greenhouse gas emissions.

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

Biomass: An energy source made of material that comes from previously living organisms, such as wood residue, paper products, or organic household waste.

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

Biogenic content: The amount of renewable, organic material in a fuel.

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

Blast furnace slag: A by-product of steel manufacturing that can be used as a supplementary cementing material.

Calcination: The heating of solids to a high temperature for the purpose of removing volatile substances, oxidizing a portion of mass, or rendering them friable. Calcination, therefore, is sometimes considered a process of purification. In the case of cement, limestone is calcined to produce lime, which is then used to make clinker.

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, 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 them so they will not enter the atmosphere.

Carbon offset: A carbon offset is a credit for emissions reductions given to one party that can be sold to another party to compensate for its emissions. Carbon offsets are typically measured in tonnes of CO_2-equivalents and are bought and sold through international brokers, online retailers and trading platforms.

Carbon neutral: When greenhouse gas emissions are equally balanced, they are equal to the emissions removed. Carbon neutrality is a generic term, scientifically valid when considered comprehensive and on a global level: it corresponds to a worldwide equilibrium between anthropogenic emissions and anthropogenic absorption. As such, an organization, product, or service cannot be carbon neutral by itself, but can contribute to global carbon neutrality.

Carbonation: Otherwise known as recarbonation or carbon uptake, it is a natural process, occurring when concrete reacts with CO_2 in the air. The exact amount of CO_2 that concrete can reabsorb has a maximum of 100% of that emitted during the calcination of limestone in the cement manufacturing process. (These are known as process CO_2 emissions and are the cause of approximately two thirds of the embodied CO_2 of cement.) The actual amount of carbon uptake will depend on a range of parameters including the resistance class, exposure conditions, thickness of the concrete element, recycling scenario and secondary use.

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 cement kiln during the production of cement. Clinker is the primary and active ingredient in cement when ground with other materials.

Clinker ratio: The ratio of clinker to cement.

Combustion emissions: The emissions released from the fuels combusted to heat the cement kiln.

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.

Fly ash: A by-product of burning coal to generate electricity that is used as a supplementary cementitious material.

Grey cement: The active ingredient of concrete and comprises between 10 and 15% of the concrete's mass. It is manufactured by finely grinding clinker and gypsum together. Other materials can be added to produce cements with specific qualities, e.g., limestone is added to produce portland-limestone cement.

Green hydrogen: When the energy used to produce hydrogen by electrolysis comes from clean, renewable energy sources.

Net-zero carbon emissions: A situation when the sum 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.

Petroleum coke (petcoke): A by-product from oil refining that is sometimes used as fuel in cement manufacturing.

Portland-limestone cement: Cement obtained by inter-grinding limestone with portland cement clinker, as defined in CSA A3001.

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 materials (SCMs): 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.

Virgin materials: Materials such as rocks, concrete, or aggregate, that are being used for the first time.

White cement: is a portland cement that differs from gray cement chiefly in colour. The manufacturing process is controlled so that the finished product will be white. White cement is used primarily for architectural purposes such as precast curtain walls and facing panels, terrazzo surfaces, stucco, cement paint, tile grout, and decorative concrete.

Appendix: Concrete Zero by the Numbers

Our Action Plan, *Concrete Zero* details how Canada's cement and concrete industry plans to achieve net-zero concrete by 2050. This plan covers the five member companies of the Cement Association of Canada, and their associated facilities. It was developed with our allies in the concrete industry. The emissions data contained in *Concrete Zero* vary slightly from those in Canada's National Inventory Report, because this Plan only pertains to members of the Cement Association of Canada (i.e., 14 of the 15 cement manufacturing facilities in the country) and because of slightly different scopes and accounting methods.

As noted in this report, the availability of data across the cement, concrete and construction value chain has many constraints, which we will work to improve over time. This report shares the best data and modelling available to us and shows our commitment to transparency.

All cement facilities meet consistent national regulatory reporting requirements and all grey cement producers also voluntarily report production and emissions data to the Global Cement and Concrete Association *Getting the Numbers Right* database. We therefore based the modeling in this Action Plan on baseline (2020) cement production and emissions data from these reports (this includes total clinker and cement production, calcination (process), and combustion emissions, as well as energy consumption and composition). Based on these real-world values, we designed a model that estimates concrete production parameters, in consultation with concrete producers and considering data reported in EPDs. We also worked to align our assumptions as much as possible with those adopted in the U.S. Portland Cement Association Net-Zero Roadmap, as we share both members and an integrated market.

Our modeling was developed thoughtfully with input from our members and allies across the cement and concrete value chain and represents a consensus on the solutions available to drive our sector toward net-zero. It also represents a shared commitment to continue our internal collaboration to continuously improve the quality and scope of our data to further refine our modeling and support continuous improvement in transparency and reporting.

Concrete Zero takes a cautious approach and focuses on the carbon-reduction solutions available today, more specifically those with a Technology Readiness Level of 6 or higher.[25] While our path to 2030 is clear, we know that we need more research and development in clinker chemistries, carbon utilization technologies, materials innovation, and clean fuel sources like hydrogen, to enable us to reach net-zero by 2050. Future updates to this Plan will reflect the realities of innovations as technologies are proven, available, and verifiable in their emissions reductions. *Concrete Zero* does not include the purchase of offsets to achieve net-zero.

We have chosen 2020 as the baseline year for our Action Plan. While this year is "typical" in terms of production, it is important to note that the industry is subject to market cycles and other economic variables (e.g., extent of public investment in infrastructure) which can result in significant year-over-year fluctuations in production, and therefore also emissions.

As we report on our progress, we will include both intensity and absolute emissions to better account for these fluctuations and to offer a better picture of our progress toward net-zero. Overall, we have accounted for modest growth of 1% per year of concrete to support the investment of new and retrofitted infrastructure to support Canada's economic and climate objectives. This growth is offset somewhat by predicted material efficiency gains in construction. Importantly, our model predicts a decline in the production of clinker, which is the carbon-intensive constituent ingredient in cement.

Concrete Zero exposes important data gaps for the cement and concrete industry, for example, detailed data on the volumes of concrete and concrete mixes used in different categories of infrastructure. This is a challenge our industry will tackle as we aim to improve our modeling and reporting on this Action Plan.

We will release an update of this report no less than every five years to demonstrate our progress.

Summary

	2020	2030	2040	2050
BAU Emissions (Mt CO_2)	**11.5**[26]	**12.7**	**14.1**	**15.5**
Clinker Improvements (Mt CO_2)		0.9	1.2	1.6
Cement Improvements (Mt CO_2)		1.5	2.2	2.9
Concrete Improvements (Mt CO_2)		0.5	2.0	3.7
Construction Efficiencies (Mt CO_2)		1.0	1.6	2.1
Carbonation (Mt CO_2)		1.2	1.0	0.8
CCUS (Mt CO_2)		1.5	2.0	4.4
Net Emissions (Mt CO_2)		**6.1**	**4.1**	**(0)**

Reductions against 2020 and BAU

2030

- 6.6 Mt CO_2 52% against BAU
- 5.4 Mt CO_2 or 40% reduction of baseline 2020 emissions

2040

- 9.9 Mt CO_2 or 71% against BAU
- 7.4 Mt CO_2 or 59% reduction of baseline 2020 emissions

2050

- Net-zero

Breakdowns

Clinker

	2020	2030	2040	2050
CLINKER PRODUCTION & EMISSIONS				
Clinker Production (Metric Tonnes)	11.4	9.5	8.4	7.0
Net Increase in CaO from Decarbonated Raw Materials (%)	-	1.0%	2.0%	3.0%
Absolute Gross Clinker Emissions (Mt CO_2)	9.5	7.0	5.8	4.2
▪ Process Emissions (Mt CO_2)	6.0	5.0	4.4	3.6
▪ Combustion Emissions (Mt CO_2)	3.4	2.0	1.4	0.6
FUEL MIX (% by heat value)				
Coal	26.7%	5.0%	0.0%	0.0%
Petroleum Coke	34.6%	14.0%	10.0%	0.0%
Natural Gas	27.6%	38.8%	24.8%	0.0%
Other Fossil (oil, diesel, etc.)	0.2%	0.2%	0.2%	0.0%
Non-biogenic Alternative Fuels	8.3%	20.0%	30.0%	30.0%
Biogenic Alternative Fuels	2.7%	20.0%	30.0%	55.0%
Future Fuels (Hydrogen, RNG, etc.)	0.0%	2.0%	5.0%	15.0%
CLINKER EMISSIONS REDUCTIONS AGAINST 2020				
Decarbonated Materials (Mt CO_2)		0.05	0.9	0.11
Fuel Mix (Mt CO_2)		0.8	1.1	1.5
Total Absolute Gross Clinker Reductions (Mt CO_2)		**0.9**	**1.0**	**1.2**

Assumptions

- Volume of clinker production is based on the assumed market demand for concrete, which is based on 2020 data, with a 1% increase per year.
- Emissions are calculated using 2020 baseline calcination intensity of 533kg of CO_2 per tonne of clinker.
- Calculated combustion emissions include kiln and non-kiln fuels (i.e., on-site transportation fuels).
- Our fuel calculations are based on the assumed intensity values in the table at right, which have been derived from the Global Cement and Concrete Association's Cement CO_2 and Energy Protocol, which is the CO_2 and Energy Accounting and Reporting Standard for the cement industry.

Fuel Intensity Values

	(Kg CO_2/GJ)
Coal	96.0
Petroleum Coke	92.8
Natural Gas	56.1
Other Fossil	75.0
Alternative Fuels	85.0
Biogenic Fuels	0
Future Fuels	0

Cement

	2020	2030	2040	2050
CEMENT PRODUCTION & EMISSIONS				
Implied Cement Production (Metric Tonnes)	12.7	12.7	12.3	11.7
Absolute Gross Cement Emissions (Mt CO_2)	9.5	7.1	5.9	4.4
Clinker: Cement Ratio (%)	89%	75%	68%	60%
CEMENT PRODUCTION				
Limestone Additions (% by weight)	5.5%	13.0%	15.0%	20.0%
BLENDED CEMENTS				
Blended Cements (% of market)		25%	35%	50%
SCM in Blended Cement (%)		20%	20%	20%
CO_2 Burden of SCMs (Mt CO_2)		0.09	0.1	0.2
CEMENT EMISSIONS REDUCTIONS AGAINST 2020 (excluding clinker reductions noted above)				
Total Absolute Gross Reductions from Cement Improvements ($MtCO_2$)		**1.5**	**2.2**	**2.9**

Assumptions

- Volume of cement production is based on the assumed market demand for concrete, which is based on 2020 data, with a 1% increase per year.
- There is no accounting for imports or exports in cement production.
- Absolute gross emissions from cement include clinker and SCMs.
- Assumed CO_2 intensity for SCMs is the value of slag at 147kg CO_2/Mt.[27] Note that we have applied slag values for all SCMs, which overestimates emissions as other common SCMs such as fly ash are much lower in CO_2 intensity (closer to 5 kgCO_2/Mt).
- Clinker-to-cement ratios include adjustments for blended cements.
- Scope 2 electricity CO_2 emissions account for a small fraction of total cement emissions (~0.3 megatonnes in 2020). Our Action Plan reports these emissions but does not integrate them into our gross calculations. Instead, it is assumed that these emissions will decline to zero by 2050, as per Canada's commitments to decarbonize its national grid. Similarly, no reductions have been attributed to any on-site renewable electricity production.

External Electricity	2020	2030	2040	2050
Total Electricity Use (MWh)	1,832,219	1,832,219	1,832,219	1,832,219
Production Weighted National Average Grid Carbon Intensity (Kg CO_2 / MWh)	165	70	30	1.2
Total Electricity Emissions (Mt CO_2)	0.3	0.1	0.05	0.02

Concrete

	2020	2030	2040	2050
CONCRETE PRODUCTION & EMISSIONS				
Total Gross Concrete Emissions (Mt CO_2)	11.5	8.8	7.1	5.2
▪ Gross Cement Emissions (Mt CO_2)	9.5	7.1	5.9	4.4
▪ Emissions from SCMs (Mt CO_2)	0.3	0.3	0.4	0.5
CEMENT EMISSIONS				
Cement Content in Concrete (Kg/m³)	297	291	266	236
Cement-Related Emissions in Concrete (Kg CO_2/m³)	221	163	128	89
Emissions Reductions from Reducing Cement in Concrete (Mt CO_2)		0.1	1.0	2.2
NON-CEMENT EMISSIONS				
Manufacturing Emissions %	5%	4%	2%	0%
Manufacturing Emissions (Mt CO_2)	0.6	0.5	0.2	0
Transportation Emissions %	6%	4%	2%	0%
Transportation Emissions (Mt CO_2)	0.7	0.5	0.2	0
CONCRETE EMISSIONS REDUCTIONS AGAINST 2020				
Non-cement CO_2 Reductions from Concrete Phase (Mt CO_2)		**0.4**	**1.0**	**1.5**
CO2 Reductions from Reducing Cement in Concrete (Mt CO_2)		0.1	1.0	2.2
Total Gross Emissions Reductions from the Concrete Manufacturing Phase (Mt CO_2)		0.5	2.0	3.7

Assumptions

- Concrete production flows from assumed market demand of 1% growth per year.
- Novel technologies, such as carbon-negative engineered aggregates, are not considered as the technology readiness level (TRL) is deemed too low at this point in time.
- Assumed CO_2 intensity for SCMs is the value of slag at 147kg CO_2/Mt.[28] Note that we have applied slag values for all SCMs, which overestimates emissions as other common SCMs such as fly ash are much lower in CO_2 intensity (closer to 5 kgCO_2/Mt).
- Electricity emissions are assumed to decline in keeping with Canada's commitment to decarbonise the grid by 2050.
- All cement produced is assumed consumed. Emissions reductions from cement improvements are accounted for in Cement and Clinker.

Construction

	2020	2030	2040	2050
Implied Concrete Production and Installation (millions of m^3)	42.8	47.3	52.2	57.7
Returned Concrete (%)	6%	3%	2%	1%
Optimization in Design (%)		5%	8%	10%
Savings from Material Efficiency (millions m^3 of concrete)		3.6	5.9	7.9
CO_2 Reduced at the Construction Stage (in year concrete produced) (Mt CO_2)		0.7	0.9	0.8
Total Gross CO_2 Reductions from Installed Concrete in Construction		**1.0**	**1.6**	**2.1**

Assumptions

- CO_2 reductions account for cement and concrete mix improvements (we are not duplicating).
- Material efficiency is based on reducing volume of concrete for same functional performance: optimize column spacing, voided slabs, etc.

Carbon Uptake

	2020	2030	2040	2050
CEMENT PROCESS & CONCRETE EMISSIONS				
Cement Process Emissions (Mt CO_2)	6.0	5.0	4.4	3.6
Gross Concrete Emissions (Mt CO_2)	11.5	8.8	7.1	5.2
CARBON UPTAKE (Mt CO_2)				
Use Phase	1.2	1.0	0.9	0.7
End of Life	0.1	0.1	0.08	0.07
Demolished Concrete Used as Aggregate	0.06	0.05	0.04	0.03
EMISSIONS REDUCTIONS				
CO_2 Reductions from Carbonation (Mt CO_2)	**1.4**	**1.2**	**1.0**	**0.8**
Gross Concrete Emissions after Carbonation (Mt CO_2)	**10.1**	**7.6**	**6.1**	**4.4**

Assumptions

- Percentages from Tier 1 IVL Calculation
- Calcination emissions derived from clinker and cement calculations on pages 46 and 47.
- Scope 2 emissions are not included in this table, but their relative importance is small, approximately 300,000 tonnes in 2020, and we assume full grid decarbonization by 2050.

Carbon Capture, Utilization and Storage (CCUS)

	2030	2040	2050
Emissions Remaining for CCUS (Mt CO_2)	7.6	6.1	4.4
Emissions Reduced via CCUS projects (Mt CO_2)	1.5	2.0	2.0
Net Need for CCUS (Mt CO_2)	**6.1**	**4.1**	**2.4**

Assumptions

- "CCUS projects" refers to projects that are currently planned and/or announced. Emissions reductions attributed to them are projected, and numbers will be updated over time as data improves.
- "CCUS projects" includes projected Scope 2 emissions.
- Emissions remaining refers the opportunity for CCUS projects to reduce emissions once all other carbon reduction measures have run their full course.

Endnotes

1 This report uses "Canada's cement industry" to refer to the five members of the Cement Association of Canada, and thus our numbers deviate slightly from the National Inventory Report, which covers 6 companies and a total of 15 cement plants in Canada. This Action Plan is specifically focused on "grey cement", and therefore excludes production and emissions from one facility in Canada which exclusively produces "white cement." Regardless, the broader industry commitment to net-zero remains consistent across all members.

2 This has been achieved through regionally-specific Environmental Product Declarations (EPDs) for cement and concrete as well as Type III facility-specific EPDs for cement and an increasing number of concrete producers.

3 This includes harvested fly ash which is ash that was not used as it was produced but was instead deposited in landfills or impoundments for disposal.

4 This is due to the existing physical and regulatory infrastructure in Alberta. There has been storage identified in Saskatchewan, however there are no cement plants in that province.

5 https://natural-resources.canada.ca/climate-change/canadas-green-future/carbon-capture-utilization-and-storage-strategy/23721

6 https://ised-isde.canada.ca/site/clean-growth-hub/en/roadmap-net-zero-carbon-concrete-2050?auHash=wPlhRBhz47OUROIkYSDbRr5u1r3SsZKvzke3n2KpJ-M

7 https://www.ivl.se/projektwebbar/co2-concrete-uptake.html

8 Apart from Federal White Cement, a manufacturer of specialty architectural cements with unique manufacturing needs.

9 The National Inventory Report covers all cement facilities in Canada; however, this Action Plan only applies to the members of the Cement Association of Canada, who account for all but one facility in Canada.

10 Specifically, our Action Plan only accounts for technologies above TRL-6 (Technology Readiness Level 6) as we anticipate their implementation in future years in this plan. We have not included technologies with TRLs below 6. For an understanding of TRL levels, please see: https://iea.imgix.net/1ad3e6c7-e13d-4257-b293-3db136482a8b/TechnologyreadinesslevelscaleappliedbytheIEA.

11 The intense heat and long residence time (i.e., the amount of time the fuels react in the kiln) generate a highly efficient combustion environment where materials otherwise not suitable for combustion can be combusted safely with no measurable impact on non-GHG air emissions and without the production of bottom ash that would be the case in an incinerator, for example.

12 Some studies suggest avoided landfill emissions are significant, perhaps as high as three times the direct reduction in combustion emissions. However, there remain challenges in consistently quantifying avoided emissions from landfill and as such, they are not currently accounted for in our Action Plan.

13 Assumed carbon intensity of plastic, this could improve over time.

14 Includes adjustment for blended cements.

15 For further reading see: https://doi.org/10.1016/j.cemconres.2017.02.002, and Antunes M, Santos RL, Pereira J, Rocha P, Horta RB, Colaço R. Alternative Clinker Technologies for Reducing Carbon Emissions in Cement Industry: A Critical Review. Materials (Basel). 2021 Dec 28;15(1):209. doi: 10.3390/ma15010209. PMID: 35009355; PMCID: PMC8746203.

16 This could include the alternative binders being worked on by the American Concrete institute, see ACI ITG10 for further information.

17 Some SCMs such as fly ash and slag carry a CO_2 burden from their production, and we have accounted for this in our modelling.

18 At the time of publishing this document, actual data on concrete production is unreliable. Therefore, we have estimated total concrete production based on the amount of cement produced that year. We are committed to addressing this data gap (among others) in future iterations of our Action Plan.

19 It is estimated that all three levels of government in Canada are collectively responsible for approximately 30% of all concrete consumption and therefore have a strong influence on the demand for low-carbon solutions.

20 Offsite Scope 2 electricity emissions for cement are reported separately in appendix. While it is difficult to attain precise number on electricity consumption at concrete facilities, our Action Plan makes a country-wide assumption of the emissions burden from electricity and applies it to our model.

21 It is worth noting that utilizing recycled concrete aggregate also avoids some of the energy, emissions, and natural resource depletion that normally occurs with mining and processing aggregates – contributing to a circular approach.

22 One of which is being led by the Canada Green Building Council, titled, *"Burying Carbon in Buildings: Advancing Carbon Capture and Utilization in Cementitious Building Materials."* As found at: https://www.cagbc.org/news-resources/cagbc-news/cagbc-u-of-t-to-receive-1-7-million-contribution-for-carbon-capture-study/

23 Note that Scope 2 emissions are not included in this table, but their relative importance is small, approximately 300,000 tonnes in 2020, and we assume full grid decarbonization by 2050.

24 Federal purchasing makes up just 4% of all public spending and less than 1% of all infrastructure spending in Canada, as found in https://cleanenergycanada.org/wp-content/uploads/2022/10/CEC-MoneyTalks-Final-Web.

25 For an understanding of TRL levels, please see: https://iea.imgix.net/1ad3e6c7-e13d-4257-b293-3db136482a8b/TechnologyreadinesslevelscaleappliedbytheIEA.

26 This number differs from the National Inventory Report because the NIR is limited to capturing direct cement production emissions, whereas we have considered carbon emissions from the broader value chain including concrete, fuels used in transport between facilities, etc.

27 As per the Environmental Product Declaration for slag cement as found at: https://www.slagcement.org/_files/ugd/7a9259_077074050db442d2a001cd2d2fdc2afc.pdf

28 As per the Environmental Product Declaration for slag cement as found at: https://www.slagcement.org/_files/ugd/7a9259_077074050db442d2a001cd2d2fdc2afc.pdf

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