Global Cement and Concrete Association

CONCRETE FUTURE

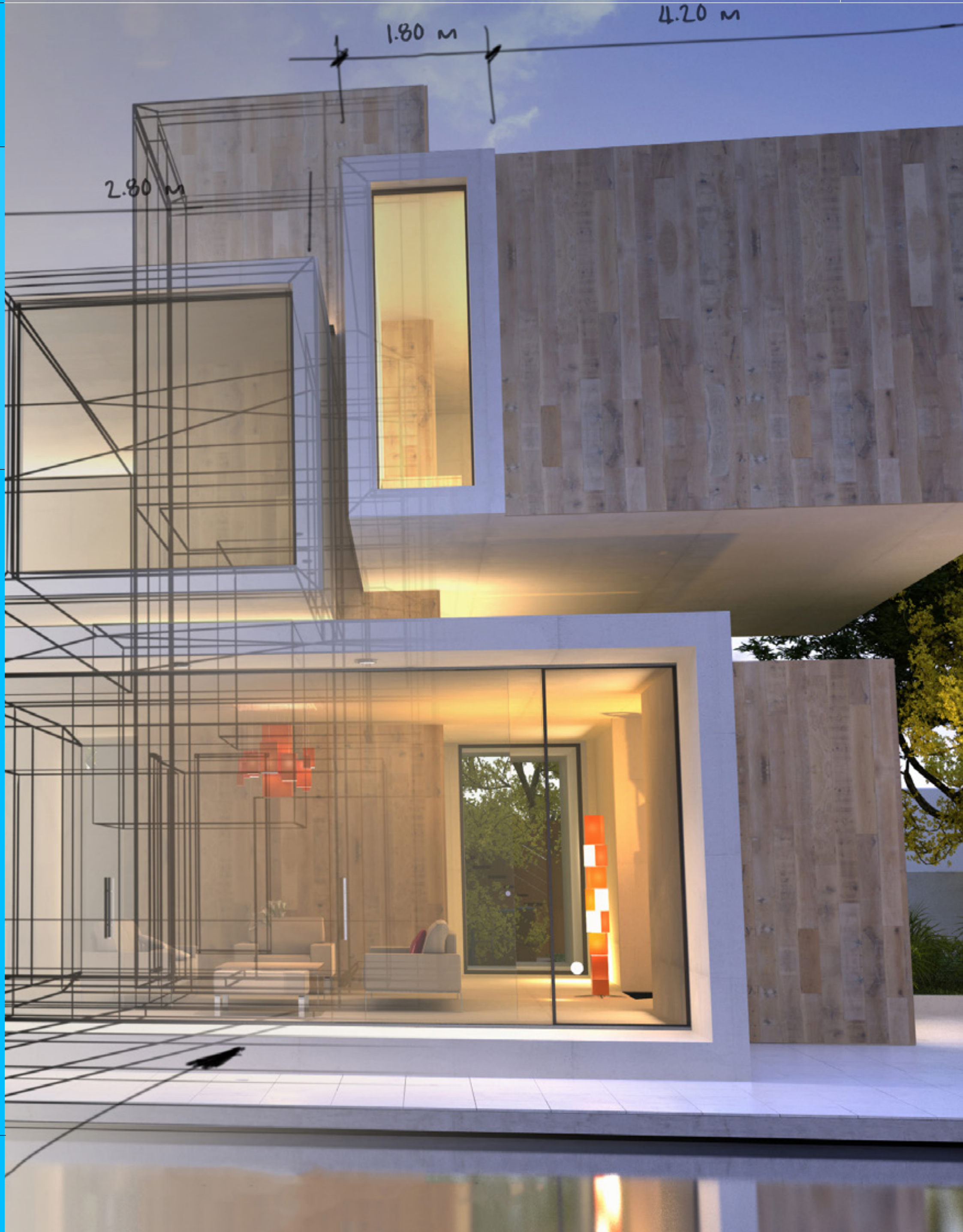
The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete

ROADMAP FULL DOCUMENT

CONCRETE FUTURE

CONTENTS

OVERVIEW



OUR CONCRETE FUTURE

Our ‘Concrete Future’ sets out the positive vision for how the cement and concrete industry will play a major role in building the sustainable world of tomorrow. Over the past 100 years, concrete has revolutionised the global built environment. It is the vital building material that has shaped our modern world. As we face the important challenges for future generations, addressing the need for sustainable communities and prosperity, including key infrastructure, homes, clean water and providing resilient communities as our climate changes, as well as supporting the transition to low carbon energy concrete, we are working towards building a brighter world.

Our Concrete Future highlights the commitment of our essential global industry, envisioning a net zero world and our contribution towards it, as well as the comprehensive work to decarbonise already underway.

Today, our member companies are already involved in a circular economy revolution, touching every part of the lifecycle of our product – the manufacture of cement, the cleaner energy we are already using, as well as the more efficient use, reuse and recycling of concrete.

Our concrete net zero future can be achieved on known technologies, but we are not resting, we are striving to innovate at every stage of the whole life of concrete. Each company is embarking on exciting technological pathways, but through the strength of collaboration we hope to make the journey more streamlined. We are proud of our two world-class global innovation programmes under our Innovandi platform.

To build the Concrete Future requires the collective action of all our member companies, but we cannot achieve it alone. It also requires the input, support and action of others. We call on policymakers, governments, investors, researchers, innovators, customers, end users and financial institutions, to play their part. Here we outline the collective endeavour which will guide us to a net zero future for society's critical building material and for the world.

OUR COMMITMENT AND PATHWAY TO BUILDING A NET ZERO WORLD

The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete is the collective commitment of the world's leading cement and concrete companies to fully contribute to building the sustainable world of tomorrow.

Our roadmap sets out a net zero pathway to help limit global warming to 1.5ºC. The sector is committed to producing net zero concrete by 2050 and is committed to acting now.

The industry has already made progress with proportionate[01] reductions of CO_2 emissions in cement production of 20% over the last three decades. **This roadmap highlights a significant acceleration of decarbonisation measures achieving the same reduction in only a decade. It outlines a proportionate[01] reduction in CO_2 emissions of 25% associated with concrete by 2030** from today (2020) as a key milestone on the way to achieving full decarbonisation by the mid-century. The roadmap actions between now and 2030 will prevent almost 5 billion tonnes of CO_2 emissions from entering the atmosphere compared to a business-as-usual scenario.

Our roadmap represents a decisive moment for our industry and the world, demonstrating that it is possible, and setting out an achievable net zero pathway for the world's most used human-made material. GCCA members pledge to achieve the roadmap aims, contributing in line with their position in the cement and concrete value chain.

The roadmap sets out the levers and milestones needed to achieve net zero across the whole lifecycle from cradle to cradle. It highlights the actions from the industry already underway and those it will undertake in the months and years ahead, as well as the important contributions from designers, contractors, developers and clients in the use of concrete in the built environment, and those from policymakers.

We will succeed with the right policy support in place to shape demand for low carbon products (economic viability), enabling a transition of the sector and making full use of circular (economy) opportunities, as well as supporting the development and implementation of innovations and key infrastructure.

The roadmap outlines this collective endeavour and our **'Concrete Future'** which will guide us to a net zero future for society's critical building material and for the world.

01 / proportionate relates to per unit of product

Net zero is used throughout this document with respect to the industry and its products and relates to reduction of CO_2 emissions, across the whole life cycle, to zero. Carbon capture by our industry at our industrial plants is included amongst our actions to reduce carbon emissions to zero. Offsetting measures such as planting of trees or other nature based solutions are not included in the calculations to get to net zero. These offsetting measures are seen in some countries and regions as significant contributors to climate mitigation, but at a global level are not accepted within net zero definitions.

Carbon neutral was used in the GCCA 2020 climate ambition statement and has the same meaning as net zero as defined above.

Concrete refers to all cement-based products including mortar, render, cement-based plasters and precast cement-based products such as masonry units and cladding products.

OUR MEMBERS OPERATE IN ALMOST EVERY COUNTRY OF THE WORLD

About the Global Cement and Concrete Association

The GCCA is the trusted, authoritative platform and voice for the cement and concrete sector across the world. Our members are producers of Portland cement clinker and other natural cementitious clinkers used in the manufacture of cement around the globe.

GCCA members account for 80% of the global cement industry volume outside of China, and also includes several large Chinese manufacturers.

Our vision

Our vision sees a world where concrete supports global sustainable economic, social and environmental development priorities; and where it is valued as an essential material to deliver a sustainable future for the built environment.

Our mission

Our mission is to position concrete to meet the world's needs for a material that can build and support growing, modern, sustainable and resilient communities.

Our Members

- Asia Cement Corporation
- Breedon Group
- Buzzi Unicem S.p.A.
- Cementir Holding S.p.A.
- Cementos Argos S.A.
- Cementos Moctezuma
- Cementos Molins S.A.
- Cementos Progreso
- Cementos Pacasmayo S.A.A
- CEMEX
- China National Building Materials
- CIMSA CIMENTO
- CRH Group Services Ltd
- Dangote Group
- Dalmia Cement
- Grupo Cementos de Chihuahua S.A.B
- HeidelbergCement
- Holcim Group
- JK Cement Ltd
- JSW Cement
- Nesher Israel Cement Enterprises Ltd.
- Medcem Madencilik
- Orient Cement Ltd
- Schwenk Zement KG
- SECIL
- Shree Cement Ltd
- Siam Cement Group (SCG)
- Siam City Cement Ltd
- Taiheiyo Cement
- Taiwan Cement Corporation
- Titan Cement Group
- Ultratech Cement Ltd
- Unión Andina de Cementos S.A.A (UNACEM)
- Vassiliko Cement Works Public Company Ltd
- Vicat S.A
- Votorantim Cimentos
- West China Cement
- YTL Cement Bhd

Our Affiliates

- Asociación de Productores de Cemento (ASOCEM) – Peru
- Associção Brasiliera de Cimento Portland (ABC/SNIP) – Brazil
- Betonhuis – Netherlands
- Federation of the European Precast Concrete industry (BIBM)
- Cámara Nacional del Cemento (CANACEM) – Mexico
- European Cement Association (CEMBUREAU)
- Cement Concrete & Aggregates (CCA) – Australia
- Cement Association of Canada (CAC)
- Cement Industry Federation (CIF) – Australia
- Cement Manufacturers Association (CMA) – India
- Cement Manufacturers Ireland (CMI/IBEC)
- Concrete NZ – New Zealand
- European Ready Mixed Concrete Organisation (ERMCO)
- European Federation Concrete Admixtures (EFCA)
- Federacion Interamericana del Cemento (FICEM) – Colombia
- Federacion Iberoamericana del Hormigon Premezclado (FIHP) – Colombia
- Japan Cement Association (JCA)
- Korea Cement Association (KCA)
- Mineral Products Association (MPA) – United Kingdom
- National Ready Mixed Concrete Association (NRMCA) – USA
- Portland Cement Association (PCA) – USA
- The Spanish Cement Association (Oficemen) – Spain
- Association of German Cement Manufacturers (VDZ) – Germany

CONCRETE FUTURE

CEMENT AND CONCRETE AROUND THE WORLD

Over the past 100 years, concrete has revolutionised the global built environment. All over the world, concrete structures are key to providing housing for an ever-increasing population, enabling transport on land, at sea and in the air, supporting energy generation as well as industry and providing protection.

In 2020

14.0 billion m^3

2020 volume of concrete globally

40%

The percentage of total concrete production for residential market

4.2 billion tonnes

2020 cement production globally

$440 billion

The global cement and concrete products market value in 2020

By 2050

9.8 billion

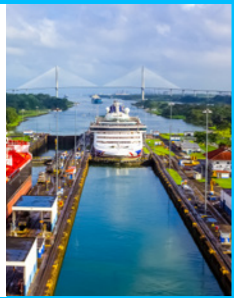
Estimated world's population by 2050

68%

Percentage of population living in cities

Panama Canal

By shortening shipping routes, the canal has avoided an incredible 650 million tonnes of CO_2 emissions.[01]



Offshore wind power in Europe

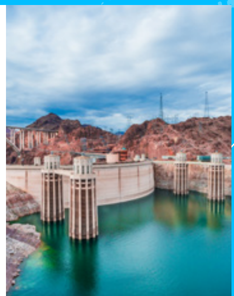
Offshore wind will play a key role in Europe's new power mix. Concrete foundations help anchor increasingly large wind turbines to the seabed.

Housing in expanding cities

Every year, China starts building about 15 million new homes, more than five times the amount in America and Europe combined.[02]

Durable concrete

The Hoover Dam built in 1935 still protects downstream communities, produces green energy and provides water storage and irrigation.



Sustainable materials in India

Concrete offers a durable and sustainable alternative to traditionally manufactured bricks, preserving the topsoil and limiting local air pollution.

Formalising housing in South Africa

Initiatives help residents in informal settlements across South Africa by providing, durable, safe, low-cost housing.[03]

Kuwait sea defences

Concrete structures protect coastlines against the erosive force and power of waves.

Sydney Opera House

The iconic Sydney Opera House is an excellent example of what can be achieved with concrete in terms of design and engineering.

1 https://oceanconference.un.org/commitments/?id=16622
2 https://www.economist.com/finance-and-economics/2021/01/25/can-chinas-long-property-boom-hold
3 https://www.dezeen.com/2017/12/28/empower-shack-urban-think-tank-low-cost-housing-khayelitsha-south-africa/

CONCRETE SUSTAINABILITY

Just a few of the incredible performance benefits of concrete.

Concrete is not only the world's most used building material, it is the world's most used material in general after water – for a reason. It is abundant, affordable, locally available and can be used in innumerable ways.

Concrete's remarkable properties make it a vital element in both limiting the scope, and combating the effects of climate change – enabling the development of sustainable and resilient building and communities around the world.

Availability

The availability of concrete as an abundant, local and cost-effective building material means the sustainability of concrete – its durability, flexibility, resilience, etc. – can be enjoyed in both developed and emerging economies.

Carbon Uptake

Concrete reabsorbs a significant amount of CO_2 over its lifetime in a process known as carbon uptake or recarbonation.

Circular Economy

The industry utilises recycled/secondary aggregates and cementitious industrial by-products in concrete and alternative fuels/raw materials in cement kilns. Concrete buildings are long-lasting and can be re-used or adapted and re-purposed.

Design for Disassembly

Certain concrete buildings can be designed and built for easy disassembly as to enable the reuse of its component parts in other construction projects, reducing use of raw materials and lowering waste.

Disaster Resilience

Concrete stays standing more often than alternative building materials in the face of disaster, reducing the need for reconstruction and enabling communities to recover more quickly.

Durability

Concrete buildings last longer and require less maintenance. They better survive disasters and can be reused many times over in their lifetime, meaning less demolition and reconstruction.

Fire Resistance

Concrete's resistance to fire improves the safety of occupants, fire fighters and neighbours during fire events, and minimises damage, so buildings can return to use quickly, boosting community resilience.

Passive Cooling using Thermal Mass

Due to its ability to absorb and store heat, concrete can be used to passively heat or cool buildings, reducing the energy consumed by heating or air conditioning as well as reducing the risk of overheating.

Strength

Society expects the built environment – buildings, bridges and other infrastructure – to be enduring and safe – safety is the first priority. Concrete is well known for its attributes of strength, durability, resilience and safety – concrete for example does not burn.

Structure as Finish

Concrete as a finished surface (e.g. ceiling, wall or floor) lowers material usage in construction and future maintenance needs. And it needn't be dull: concrete can come in a huge range of colours and textures!

Versatility

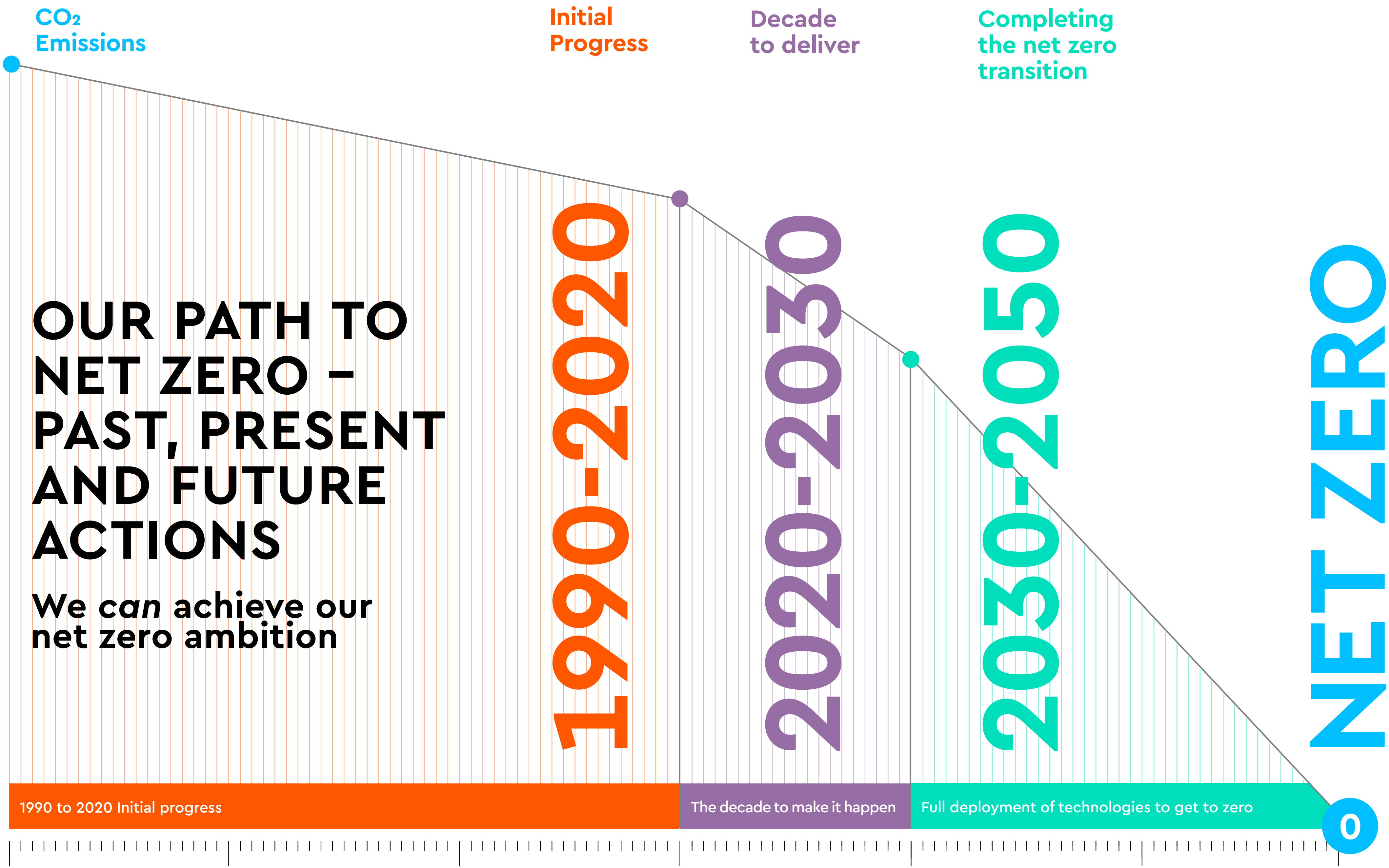
Concrete is a hugely versatile material, allowing structural designers enormous scope to meet and optimise application requirements with concrete in the most sustainable manner.

Wide Range of Placements

The huge variety of concrete placement techniques allows the use of concrete in a wide range of applications, enabling designers and contractors to choose the optimum technique to deliver efficient projects.

OUR PATH TO NET ZERO – PAST, PRESENT AND FUTURE ACTIONS

We *can* achieve our net zero ambition



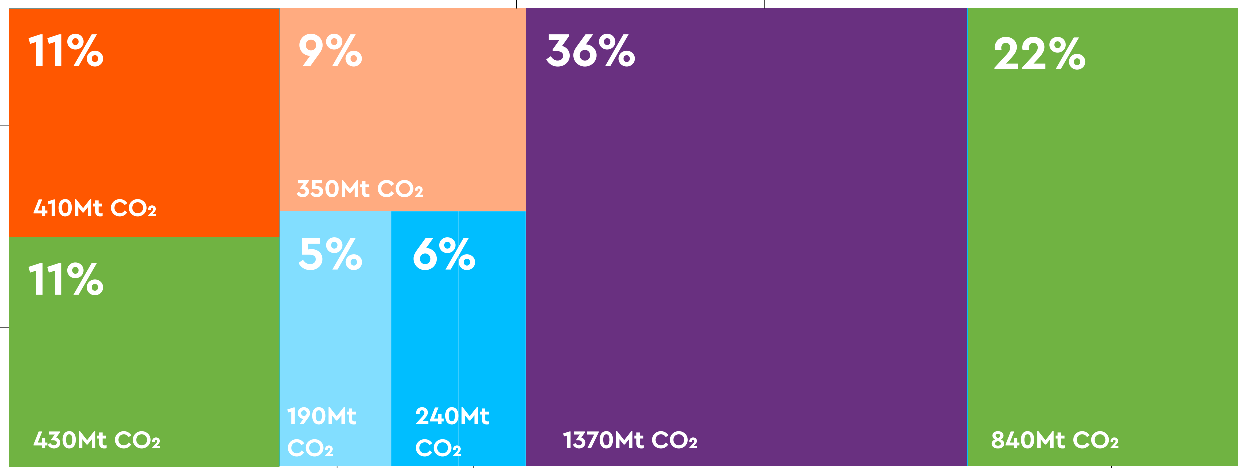
ACTIONS TO A NET ZERO FUTURE

Savings in clinker production
- thermal efficiency
- savings from waste fuels ("alternative fuels")
- use of decarbonated raw materials
- use of hydrogen as a fuel

Savings in cement and binders
- Portland clinker cement substitution. Also expressed through clinker binder ratio
- alternatives to Portland clinker cements

Carbon capture and utilisation/storage
- carbon capture at cement plants

PERCENTAGE CONTRIBUTION TO NET ZERO AND CO_2 EMISSION SAVINGS IN 2050



Efficiency in concrete production
- optimised mix design
- optimisation of constituents
- continue to industrialise manufacturing
- quality control

Decarbonisation of electricity
- decarbonisation of electricity used at both cement plants and in concrete production

CO_2 sink: recarbonation
- natural uptake of CO_2 in concrete – a carbon sink

Efficiency in design and construction
- client brief to designers to enable optimisation
- design optimisation
- construction site efficiencies
- re-use and lifetime extension

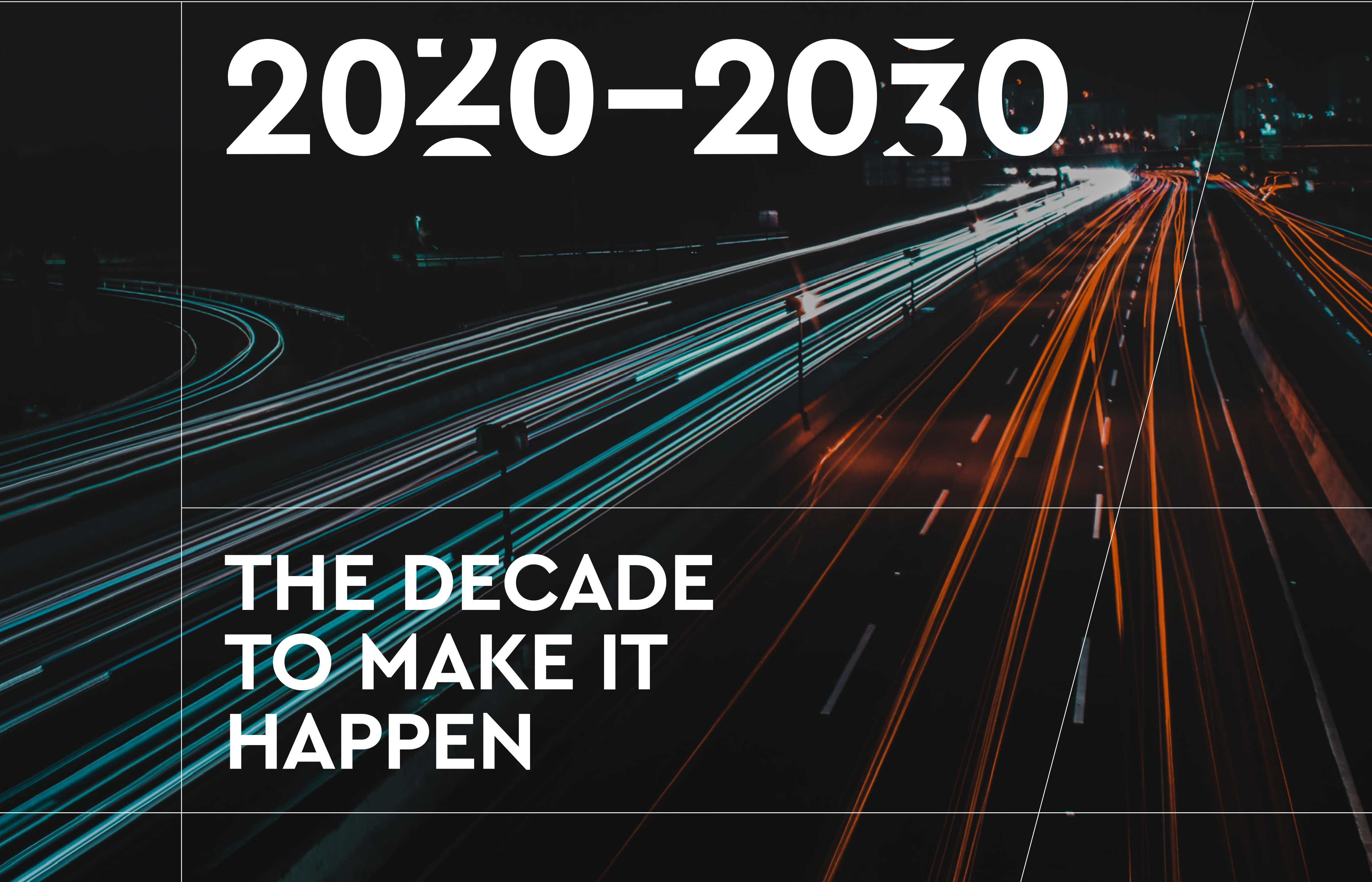
1990–2020

INITIAL PROGRESS

1990 TO 2020 - INITIAL PROGRESS

The cement industry was the first sector to monitor and publicly report its CO_2 emissions on a global level. We have done so for the past 20 years and transparently continue to do so today. Over the past three decades, our industry has reduced its emissions proportionately by around a fifth, predominantly by clinker substitution and fuel side measures. The reductions represent the efforts of producers right across the world.

Concrete production has also been advanced in the past three decades. Investment in mixing equipment, control and quality systems and new admixtures are amongst the developments which have enabled concrete manufacturers to produce concrete more efficiently. There has also been a steady shift in some emerging economies from producing concrete on small project sites using bagged cement to utilising factory production of ready mixed or precast concrete. In developed economies digitisation is now being introduced. Amongst the benefits of all these advancements is a reduction of CO_2 footprint for equivalent performing concretes.



2020–2030

THE DECADE TO MAKE IT HAPPEN

The LEILAC I (Low Emissions Intensity Lime And Cement) pilot.

2020 TO 2030 - THE DECADE TO MAKE IT HAPPEN

In this key decade, we will accelerate our CO_2 reductions through the following actions and initiatives:

- increased clinker substitution – including fly ash, calcined clays, ground granulated blast-furnace slag (ggbs), and ground limestone.
- fossil fuel reductions and increased use of alternative fuels
- improved efficiency in concrete production
- improved efficiency in the design of concrete projects and use of concrete during construction, including recycling
- investment in technology and innovation
- CCUS technology and infrastructure development

In addition, we will strive for and collaborate in establishing a policy framework to achieve net zero concrete.

2030 CO_2 REDUCTION MILESTONES:

(Compared with 2020 Baseline)

Concrete

25%

CO_2 reduction per m^3 of concrete by 2030

Cement

20%

CO_2 reduction per tonne of cement by 2030

2020 TO 2030 - THE DECADE TO MAKE IT HAPPEN

“A comprehensive policy framework will need to be developed in this important decade, in order to achieve the shared goal of net zero concrete.

We will accelerate reductions over the course of this critical decade. With respect to clinker substitution – increased use of fly ash and ground granulated blast-furnace slag (ggbs) will still play an important role in this decade; ground limestone, recycled concrete fines and introduction of calcined clays and other new promising materials will also play an increasing role.

Further reductions will mean limiting fossil-fuel use at every point in supply and production chains, as well as repurposing society's waste as a smart and greener alternative. We are making progress on this important energy transition which, at the scale of the sector, is substantial.

Additionally, it is critical that in this decade we bring forward the required breakthrough technologies to be ready for commercial scale deployment by the end of it. Investing now in technologies and innovation that will come on stream in later years.

Our members are investing and researching into alternatives to Portland clinker cements. Whilst these may contribute to CO_2 reductions, they will likely have a limited role because of the lack of raw material at the required scale.

Carbon Capture Utilisation and Storage (CCUS) is an essential component of our Roadmap. CCUS pilots already have substantial momentum with live projects and announcements picking up pace in North America, China, India and Europe. This technology works, so we need to work with stakeholders such as policymakers and the investment community to help develop, de-risk and deploy the technology and infrastructure over this time to help transform the industry worldwide.

Whilst by no means straightforward, there are also relatively easier wins in the concrete production and concrete design and construction phases. Indeed not all changes require investment, and some can even reduce costs – reducing the quantities of raw materials through improved design processes, use of reprocessed and recycled material, through re-use of elements, and extending the lifetime of whole projects. Design efficiency and utilising the benefits and versatility of concrete can result in less material being used. This means viewing concrete and cement not only as products to be produced, but as crucial components in a circular economy.

A comprehensive policy framework will need to be developed in this important decade, in order to achieve the shared goal of net zero concrete. This will need to be a joint endeavour by industry, policymakers and governments.

2030 MILESTONE: CARBON CAPTURE PROGRESS

Carbon capture technology is applied at industrial scale in

10 plants

to contribute to delivering net zero concrete

2030–2050

FULL DEPLOYMENT OF TECHNOLOGIES TO GET TO ZERO

2030 TO 2050 - FULL DEPLOYMENT OF TECHNOLOGIES TO GET TO ZERO

"Deployment of carbon capture technology at full scale during cement manufacturing could fully eliminate its process emissions and potentially result in the future delivery of carbon negative concrete for our world.

In this period, we will continue to build on the progress in the previous decade.

Clinker substitution will continue. Whilst recognising that supplies of fly ash and ggbs will likely decline, ground limestone and calcined clay will increase in availability and be deployed as a key tool.

Even into the 2030s there will still be scope for the further use of alternative fuels to drive down CO_2 emissions.

Alternatives to Portland clinker cements may also play a role in decarbonisation, albeit limited, perhaps around a 5% of the market.

Ultimately, our process emissions mean that whilst we will do all we can to reduce them, CO_2 will need to be captured, re-used if possible, or stored. Having established by 2030 the capability and commercial case, and with infrastructure development in place, we will be at the start of deployment of CCUS at scale to ensure that we can achieve net zero by 2050.

Deployment of carbon capture technology at full scale during cement manufacturing could fully eliminate its process emissions. This, in conjunction with biomass and recarbonation could potentially result in the future delivery of carbon negative concrete for our world.

Additionally, our members' investment, collaboration and focused work on innovation through our Innovandi programmes could also unleash new technologies in our mission to decarbonise. For example, green/clean hydrogen and kiln electrification are forecast to play a role from 2040.

UNLOCKING A NET ZERO FUTURE – THE ROLE OF PUBLIC POLICY

Public policy will play a central role in the ability of the industry and the wider value chain to decarbonise cement and concrete over their lifecycle. A comprehensive policy framework will need to be developed. This will be a joint endeavour by industry, policymakers and governments, to:

- **make low-carbon cement manufacturing investable**
- **stimulate demand for low-carbon concrete products**
- **create the infrastructure needed for a circular and net zero manufacturing environment.**

Some specific policies to achieve the above outcomes and support transition to net zero concrete are listed here.

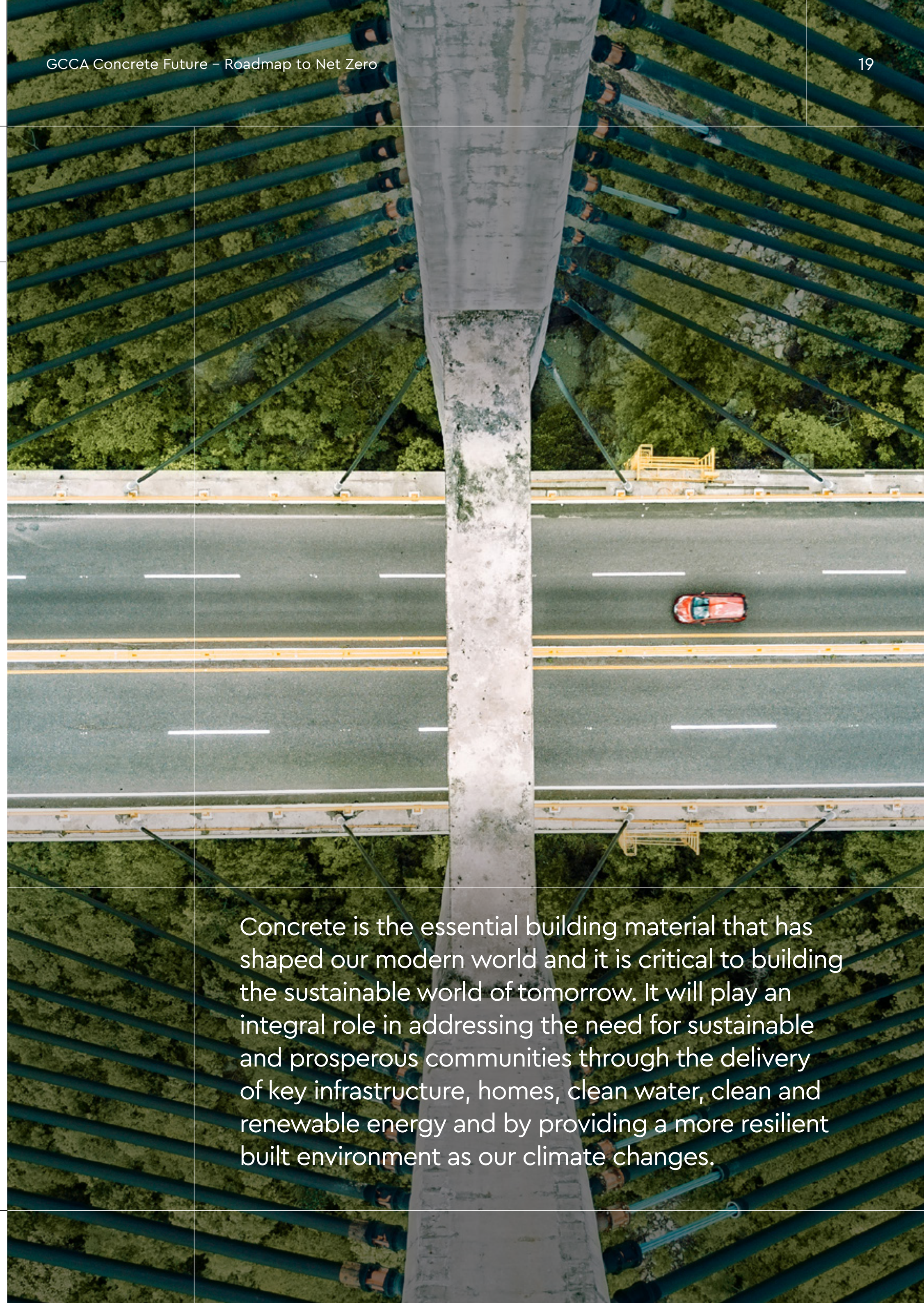
- Use appropriate carbon pricing mechanisms to create a level playing field on carbon costs and avoid carbon leakage through adequate carbon pricing mechanisms.
- Unlock the full circular economy potential of the cement and concrete value chain by prioritising the use of, and improving access to waste and by-products as alternative fuels and materials; a ban on landfill, promoting the collection, sorting, pre-treatment, recovery, recycling and co-processing of waste.
- Through changes to standards and public procurement policy accelerate the adoption of low carbon cements and concrete products, that utilise cements with new chemistries and compositions.
- Support R&D and innovation through public funding and risk sharing investment mechanisms. Provide incentives for the creation of climate innovation hubs which foster the participation of all relevant stakeholder groups.
- Support carbon capture utilisation and storage, providing fair recognition of all carbon capture technologies with adapted carbon accounting and supporting the provision of, and access to transport and storage infrastructure.
- Boost the supply, distribution, availability and affordability of renewable energy.
- Recognise in national greenhouse gas accounting and in lifecycle analysis the natural CO_2 uptake in concrete over its lifetime and at end of life (recarbonation) as a permanent CO_2 sink and facilitate access to concrete demolition waste to enable the industry to maximise CO_2 uptake (recarbonation).
- Set ambitious standards for energy performance of buildings that are demanding and sophisticated enough to take into account the benefits of properties such as thermal mass.
- Adopt material/technology neutrality and CO_2 lifecycle performance in construction regulations and standards, as well as in public procurement, to optimise sustainable outcomes.
- Tackle (non-regulatory) systemic barriers to enable the optimisation of concrete design and construction and prioritisation of CO_2 performance alongside other objectives at the procurement, design and construction stages.

WHY OUR ROADMAP IS IMPORTANT

We believe the publication of the GCCA 2050 Roadmap to net zero concrete is a pivotal moment for our industry, the built environment and the world. It sets out a net zero pathway to help limit global warming to 1.5°C.

Through the roadmap, concrete and our industry, has a global pathway demonstrating how it can be wholly decarbonised and fully contribute to a net zero world.

This journey is complex and will be challenging but we are fully committed. We will work together within our sector, and with others, to realise this goal and to unleash the amazing potential of net zero concrete for our world.



Concrete is the essential building material that has shaped our modern world and it is critical to building the sustainable world of tomorrow. It will play an integral role in addressing the need for sustainable and prosperous communities through the delivery of key infrastructure, homes, clean water, clean and renewable energy and by providing a more resilient built environment as our climate changes.

WHAT THE ROADMAP MEANS FOR GCCA MEMBERS

GCCA and its member companies commit to implementing the cement and concrete roadmap to net zero emissions by 2050.

Key points are:

- the roadmap cannot be achieved without right policies and support of built environment stakeholders and government
- the actual pathway for companies, regions and countries varies
- members will contribute in accordance with their position in the value chain.

Member companies agree to:

- advocate for the policies identified in the roadmap as being required for achieving net zero concrete
- contribute to net zero concrete in line with your position in the cement and concrete value chain
- contribute to a range of 2030 milestones and targets in line with your position in the cement and concrete value chain as well as your decarbonisation progress to date
- report progress.

MONITORING OUR PROGRESS

The GCCA recognises the need to monitor progress and to clearly communicate performance to all stakeholders. Our Sustainability Guidelines provide industry and stakeholders with a means to document and hence improve the sustainability performance of the global cement and concrete sector against the GCCA Sustainability Charter.

The seven guidelines include simple, reliable and representative key performance indicators against which full member companies must monitor and report on their sustainability performance across key activities (associate members are companies that share GCCA's mission but do not fulfil the requirements for full membership.)

The current GCCA guidelines on CO_2 monitoring do not yet encompass CO_2 in concrete, but this is under development. Also, GCCA intends to put in place mechanisms to monitor progress across all roadmap levers and milestones.

WORKING IN PARTNERSHIP

> To deliver our ambition, we must partner with stakeholders to support our thinking, challenge us and set an ambitious but achievable roadmap for the industry that meets global expectations and drives the appropriate response in taking climate action.

The cement and concrete industry has a long-held commitment to improving its environmental footprint. The GCCA provides a platform for accelerating alignment and action for the industry to meet the opportunity of achieving net zero concrete. Our critical task ahead is to address the challenges that stand in the way.

Because of concrete's fundamental importance to the world we live in today, and the critical role it will play in building the sustainable world of tomorrow, GCCA and its member companies are aware of the responsibility to further enhance and accelerate the progress we have made.

However, while we have a vision and an aspiration to deliver net zero concrete to society by 2050, we recognise that we do not have all the answers, nor can we achieve our goal on our own. It is a significant undertaking. The policy settings and levers need to be correct. Significant work and investment are required across the construction value chain to promote innovation in new products, processes and technologies.

To deliver our ambition, we must partner with stakeholders to support our thinking, challenge us and set an ambitious but achievable roadmap for the industry that meets global expectations and drives the appropriate response in taking climate action.

We call on policymakers, governments, investors, researchers, innovators, customers, end-users and financial institutions to join with us on this critical journey and help to ensure the right resources, tools and policies are in place to deliver net zero concrete for the world.

ROADMAP PURPOSE AND SCOPE

The GCCA 2050 Roadmap to net zero concrete builds on the ground-breaking GCCA climate ambition and aligns with global climate targets of limiting global warming to a 1.5°C scenario. It describes how the industry, with the support of others, can complete the transition already underway, and fully achieve zero carbon concrete by 2050.[01]

The roadmap outlines the wide range of interconnected requirements needed to reach this critical destination, including: the commitments and obligations of the industry itself; the input of the wider built environment stakeholders, including from architects, engineers, and the full value chain; the necessary policy framework that governments will need to enact to support the transition; as well as the underpinning technological levers, advancements and accompanying investment.

The roadmap to net zero concrete is a comprehensive plan of action for the net zero commitment to be achieved by the mid-century, highlighting the important progress to date, the range of decarbonising action underway today by the sector, and the implementation blueprint for the years ahead towards net zero concrete. The roadmap includes key milestones for 2030.

It is a global roadmap which our member companies and their CEOs are committed to achieving, by working together, and through the involvement of stakeholders across society. In its development there has been detailed input from across all global regions from GCCA members who operate in almost every country of the world and from other sector players.

Our roadmap is a global reference. All GCCA members are committed to delivering the global roadmap to net zero concrete but may have to follow different pathways to achieving it. Every company, region and country has specific opportunities and challenges that means their specific roadmap to net zero concrete may vary as the technology levers are applied in different ways according to local and regional conditions.

01 / The cement and concrete sector emissions are primarily scope 1 and scope 2. The roadmap forecasts do not include scope 3 emissions.

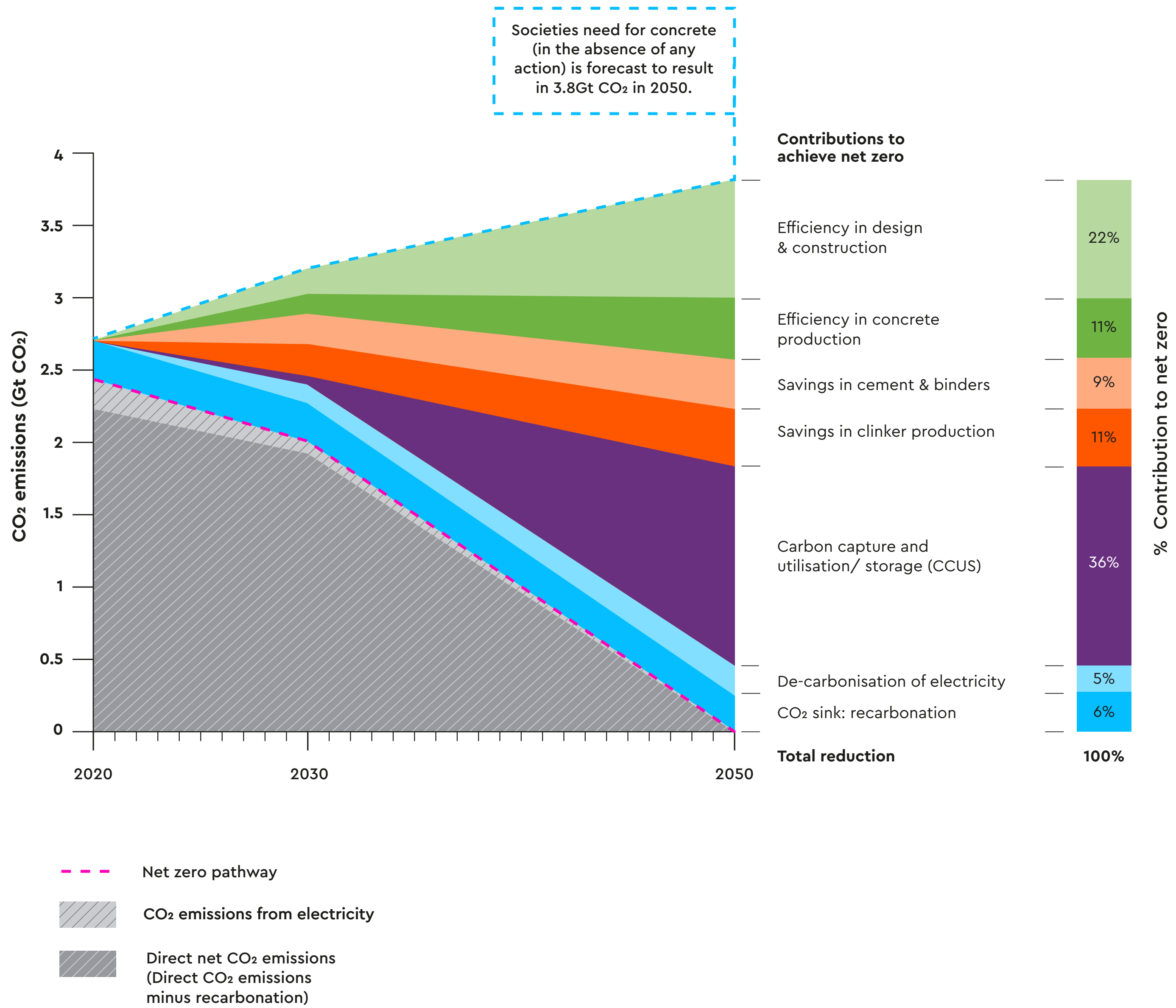
The major scope 3 CO_2 emissions are transport related and this has been estimated at between 15–20% of total emissions associated with a typical concrete. Further work is underway to better understand these. Our sector has a role in procuring low carbon and zero carbon transport and will support full decarbonisation of the transport sector by 2050 to enable our sectors' transport emissions to align with our net zero commitment.

GETTING TO NET ZERO

Total global CO_2 emissions from the sector today are in excess of 2.5Gt. They are primarily direct CO_2 emissions which in turn are primarily from the heated limestone itself (approx. 60%) and combustion of the fuels used in the cement kiln and other plant processes (approx. 40%). Electricity used by the sector contributes further CO_2 emissions as shown.

There are multiple levers that will be implemented to reduce CO_2 emissions at different stages of the whole life of cement and concrete. Our roadmap process has evaluated the role that each of these levers will play to reach net zero. The global average is presented in the adjoining graph. Across the world each lever will be implemented in accordance with local factors.

The Net Zero Pathway



THE CO_2 EMISSION REDUCTION LEVERS

The means to achieve net zero were introduced on page 24 "Getting to Net Zero". In this section detail is provided for each of these groupings.

Savings in clinker production

This includes CO_2 reductions through use of decarbonated raw materials, energy efficiency measures, use of sustainable waste materials ("alternative fuels") to replace fossil fuels and innovations such as use of hydrogen and kiln electrification.

Use of decarbonated raw materials to replace some of the limestone in the kiln reduces the total emissions from decarbonation of the limestone. By definition the decarbonated materials, such as the fine material from recycled concrete, do not emit CO_2 when heated because they have already had the CO_2 removed. Globally this is forecast to provide a 2% reduction in total emissions from the sector.

Thermal energy efficiency measures are already widely implemented across the globe through deployment of existing state-of-the-art technologies in new cement plants and retrofitting existing facilities. Further improvements will be made. With many newer energy efficient cement plants in emerging economies, this is an area where these regions have already made good progress.

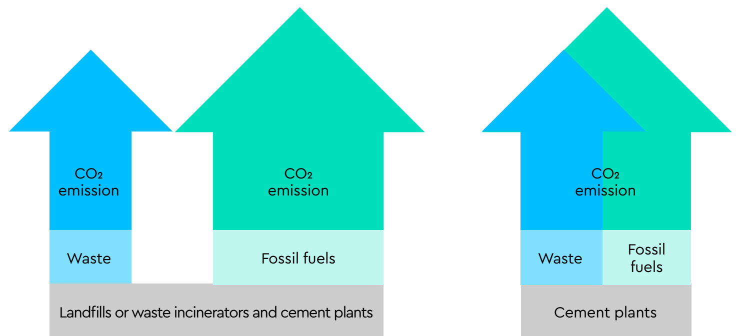
It is to be noted that with an increase in use of alternative fuels, there can be a slight decrease in the thermal energy efficiency. Higher substitution rates of alternative fuels in combination with different parameters, for example burnability, higher moisture content, design and size of the plant, can typically result in a slight increase in thermal energy demand. This effect was taken into account in the forecasting.

01 / Emissions from pure waste biomass and from the biogenic carbon content of mixed fuels is considered as climate neutral in accordance with the Greenhouse Gas Protocol

Alternative fuels are derived from non-primary materials i.e. waste or by-products and can be biomass, fossil or mixed (fossil and biomass) alternative fuels.[01] There are current examples of cement kilns operating with 100% alternative fuels which demonstrates the potential of this lever.

The industry is a well-established consumer of non-recyclable waste-derived alternative fuels from a range of sources, for example, municipal, agricultural, chemical and food production. The extremely high temperatures and residence times reached in cement kilns ensure these are managed in a safe and environmentally sound way. Supply chain logistics and infrastructure, permitting and waste policy to reduce/ eliminate waste to land fill are required to support the industry in increasing their use of alternative fuels.

On average globally, alternative fuel use is forecast to increase from the current 6% to 22% and 43% by 2030 and 2050 respectively. Innovations such as use of hydrogen and kiln electrification are forecast to play a small role from 2040.



Utilisation of waste fuels in cement plants results – according to the Greenhouse Gas Protocol – in CO_2 and even GHG emission reductions at landfills and incineration plants.

Savings in cement and binders[01]

At the cement plant or the concrete plant, fly ash, ggbs, ground limestone and other materials can be added to deliver concretes with reduced CO_2 emissions but still the required performance. In some applications the concrete performance is enhanced. This lever is also referred to as clinker[02] substitution. In this roadmap it is described by clinker binder ratio.

Availability of suitable materials around the world varies now, and will into the future, because for example fly ash comes from coal fired power stations and ggbs from the steel industry's blast furnaces and these industries are also transitioning.

In coming decades there will be increased use of ground limestone and the introduction of calcined clays to both compensate for reduced supply of fly ash and ggbs, and further reduce the clinker binder ratio. Calcined clays rely on clay deposits that are geographically spread and sufficiently abundant to meet projected demand.

Whilst availability of materials can be a limitation on clinker binder ratio, client acceptance is a current barrier in fully exploiting this lever in some developed and emerging economies.

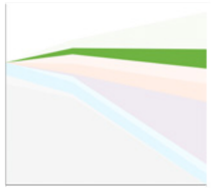
On average globally, the clinker binder factor is currently 0.63. It is projected to reduce to 0.58 and 0.52 by 2030 and 2050 respectively. Regional and even country variations are inevitable due to differing material availability and market requirements.

Alternatives to Portland clinker cements have been the subject of much research but their impact is not forecast to be significant primarily because of fundamental lack of availability of raw materials at the scale required. Furthermore, they also come with CO_2 emissions (about half of common cements).

On average globally it is forecast that alternatives to Portland clinker cements will be 1% and 5% of cement in 2030 and 2050 respectively and in 2050 contribute a 0.5% reduction in overall CO_2 emissions.

01 / **Binder** means all material in concrete such as cement, fly ash, ggbs, limestone fines etc. that is permitted as cementing material in the local jurisdiction

02 / **Clinker** is produced in a cement kiln and is ground to manufacture ordinary Portland cement. Clinker can be ground with other materials to produce cements with lower CO_2 emissions



Efficiency in concrete production

In terms of concrete production, industrialisation is the key specific lever. Moving from small project site batching of concrete using bagged cement to industrialised processes offers significant CO_2 emissions savings because of the adherence to mix specifications and quality control. In some emerging economies such as India, the vast majority of concrete production is currently on project sites. A transition to industrialised production has been seen in other countries.

More broadly utilisation of admixtures, improved processing of aggregates are good opportunities for CO_2 emissions savings in concrete production. These savings have already been implemented by parts of the industry, but broader and deeper application will deliver further savings.

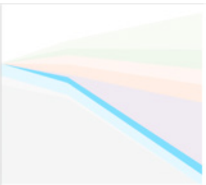
On average globally, optimisation of concrete production in terms of binder utilisation can lead to binder demand reductions of 5% and 14% in 2030 and 2050 respectively.

Carbon capture and utilisation/storage is a new lever, and its contribution is forecast to only become significant beyond 2030 when commercial viability and necessary infrastructure have been established. Once captured the CO_2 will be utilised within the cement and concrete industry, by other industries or stored.

Utilisation of captured CO_2 within the cement and concrete industry includes injection into wet concrete, curing of hardened concrete and in the manufacturing of aggregates from waste products. Further development and expansion of all three of these uses of captured CO_2 is underway.

See page 34 for a focus on carbon capture and utilisation/storage.

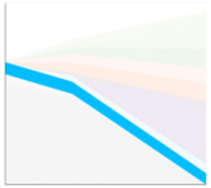
It is forecast by 2050 that 1370Mt CO_2 will be captured and utilised/stored.



Decarbonisation of electricity across the globe over coming decades will result in emissions from generation of electricity used in cement and concrete production to be reduced to zero.

Demand for electricity from the sector will increase to 2030 in line with increased total production and to 2050 primarily due to electricity demand of carbon capture. This increase in demand is countered by decarbonisation of the electricity. International Energy Agency (IEA) global data has been used for 2020 and 2030 for forecasting the impact of grid decarbonisation over the next 10 years.

Reductions in CO_2 emissions to 2030 are 54% compared with 2020, with 100% reduction to 2050.



01 / "CO_2 uptake in cement containing products" www.ivl.se/co2-uptake-concrete

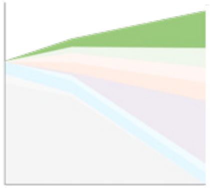
Recarbonation is a natural process of CO_2 uptake by concrete. It has been well understood by engineers and has been incorporated into engineering standards for decades. Only recently has it been considered in carbon accounting, most recently the IPCC 6th Assessment Report published in August 2021.

In this roadmap, tier 1 of the IVL methodology[01] has been used. This permits a 20% value for recarbonation to be adopted, with this being applied to the theoretical maximum carbonation possible for a tonne of clinker (525kgCO_2/tonne) i.e. 105kgCO_2/tonne clinker. This is a lower bound conservative value within the IVL methodology.

From 2020 to 2050, the clinker binder ratio decreases (see savings in cement and binders). The reduced clinker per m^3 of concrete, and total clinker volume globally results in a slight decrease in recarbonation over the coming decades.

This forecast is intentionally conservative because it is the first global roadmap to include recarbonation and work is still progressing on more detailed evaluation of recarbonation and efforts to enhance recarbonation through active exposure of crushed concrete to CO_2 at end of life.

Global recarbonation is forecast as 319, 318 and 242 Mt CO_2 in 2020, 2030 and 2050 respectively.



Efficiency in design and construction can be achieved by applying many specific levers. These levers are able to be applied with current standards and regulations.

The primary means of unlocking design levers is ensuring that reduction of CO_2 emissions becomes a design parameter in addition to the current parameters of quality, cost, speed and specific project client requirements.

Designers of buildings, with support of clients, can achieve CO_2 emission reductions through their choice of concrete floor slab geometry and system, choice of concrete column spacing and optimisation of concrete strength/element size/reinforcement percentage. This can be achieved whilst still obtaining all the performance benefits of concrete construction. Infrastructure projects offer analogous opportunities.

Across all projects globally, the CO_2 emissions reductions achievable through design and construction levers is forecast as 7% and 22% in 2030 and 2050 respectively.

SOCIETAL DEMAND FOR CEMENT AND CONCRETE

Concrete is widely used in significant volumes because of its versatility and multiple performance benefits – for example it is abundant, strong, robust, durable, fire resistant and water resistant. For these reasons it has and will continue to be the foundation of society.

Growth in societal need for concrete is expected due to:
- megatrends of population growth and urbanisation
- necessity of concrete to deliver sustainable development
- contribution to resilience and climate adaptation.

A forecast has been made of what the total need for concrete might be through to 2050, assuming current practice. This forecasted an increase from the current 14.0bn m^3 of concrete to approximately 20bn m^3 in 2050. The CO_2 emissions associated with this volume of concrete have also been calculated, assuming current practice, and amount to 3.8Gt CO_2 emissions.

There is significant regional variation in forecast demand through to 2050. Following recent decades of significant investment in infrastructure in China, where the majority of global concrete is consumed, demand is forecast to reduce. The rest of the world, in particular Africa, India and Latin America, has a forecast increase in demand, due to population growth, urbanisation and need for infrastructure, even after taking into account the design and construction efficiency savings outlined in this roadmap.

GCCA MEMBER ACTION TODAY

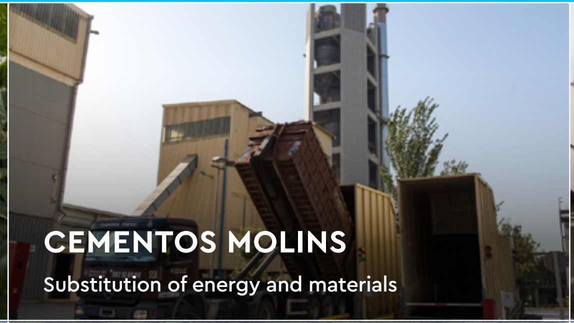
Our members are committed to climate action today to drive sustainability in our sector. Here are a few examples from around the world.

CEMENTIR HOLDING

FUTURECEM™ enabling up to 30% lower carbon footprint

CEMENTOS ARGOS

Green Cement to reduce CO_2 emissions and energy consumption



CEMENTOS MOLINS

Substitution of energy and materials

CEMEX

Deploying hydrogen technology as part of the fuel mix of its cement plants to reduce CO_2

CNBM

Decarbonising cement plants through waste heat recovery

DALMIA CEMENT

Decoupling CO_2 emissions from profitable growth

HEIDELBERG CEMENT

Industrial scale CCUS

HOLCIM

ECOPlanet green cement, delivering at least 30% lower carbon footprint with equal to superior performance

JK CEMENT

Heat reduction during clinker manufacturing to reduce CO_2

JSW CEMENT

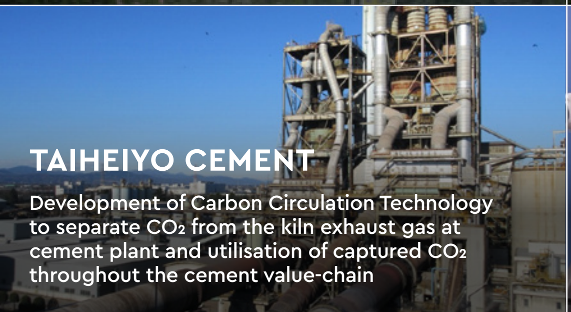
Co-prossessing using biomass, industry and plastic waste to reduce CO_2 emissions

SCHWENK ZEMENT

Celitement™ – developing an alternative binder to enable CO_2 savings

SHREE CEMENT

In-house production of synthetic gypsum

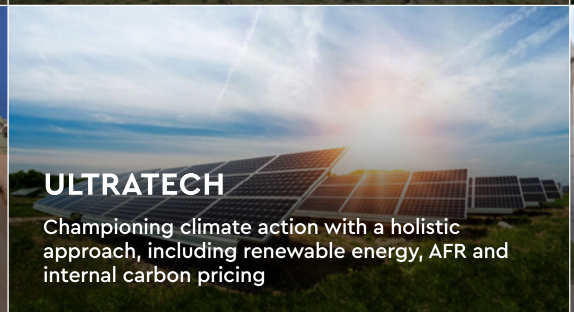


TAIHEIYO CEMENT

Development of Carbon Circulation Technology to separate CO_2 from the kiln exhaust gas at cement plant and utilisation of captured CO_2 throughout the cement value-chain

TITAN

Recycling landfilled fly ash to reduce cement and concrete carbon footprint



ULTRATECH

Championing climate action with a holistic approach, including renewable energy, AFR and internal carbon pricing

VOTORANTIM CIMENTOS

Using Açai biomass as an energy source

CEMENT AND CONCRETE: EMPOWERING THE SUSTAINABLE DEVELOPMENT GOALS

This roadmap aligned with the industry's commitment to sustainability guided by the UN Sustainable Development Goals (SDGs).

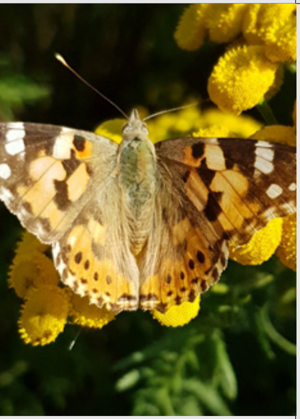
As an industry, cement and concrete touches many areas of sustainable development. Concrete's remarkable properties make it a vital element in both limiting the scope, and combating the effects of climate change – enabling the development of sustainable and resilient buildings and communities around the world.

The widespread and low-cost availability of concrete, as well as its durability and resilience, will be a critical resource in achieving many SDGs. This is particularly so for those goals related to urbanisation, and where large-scale improvements to vital infrastructure or to affordable decent housing are needed.

The role of the industry, and the benefits of the material, play a role in achieving almost all Sustainable Development Goals:

- durable and cost-effective buildings and infrastructure are central to the transformation of communities out of poverty, providing education at all levels and combatting food waste.
- transport infrastructure made with concrete provides market access for local food producers, promotes access to education and creates economic opportunities and well-being.
- as a global industry, cement and concrete manufacturing drives economic growth and provides both direct and indirect employment; and, as an industry, we are committed to providing fair and safe working conditions.
- across the world, concrete is the material of choice for transporting water, providing clean drinking water and effective sanitation.
- concrete is integral to generating and transporting clean energy, whether by building hydro-electric dams, providing foundations for wind turbines or power lines, or infrastructure for tidal power or geothermal power.
- the unique reflective properties and thermal mass of concrete contribute to the energy efficiency for our built environment.
- as this document demonstrates, the cement and concrete industry is committed to net zero concrete by 2050, eliminating its climate impact.
- the strength and the unique resistance of concrete to both water and fire protects communities around the world from natural disasters and the effects of climate change.
- concrete is fundamental to the provision of resilient affordable housing for vulnerable urban communities.
- the cement and concrete industry is at the heart of the circular economy, using by-products from other industries as raw material or fuel, and by providing a product that can be repurposed or recycled.

BIODIVERSITY ACTION FOR NET POSITIVE IMPACT



It is increasingly recognised that climate change and society's impact on the natural world are so intertwined that solving one without addressing the other would be next to impossible. Biodiversity within the natural word is critical to the health of our planet. Ensuring a positive relationship with nature underpins the way that GCCA member companies operate throughout the world.

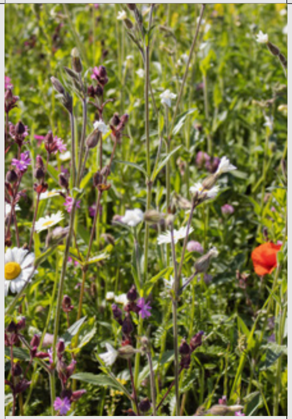
Our members operate in almost every country of the world and are custodians of the land in which they operate. To this end we have incorporated good practices on land stewardship and biodiversity into our key document, 'the GCCA Sustainability Charter', as well as the principles of the UN Sustainable Development Goals into our actions.

Production

GCCA member companies aim towards the achievement of Net Positive Impact in their cement, concrete and aggregates operations through 4 specific actions:

- formulate and execute effective and progressive Quarry Rehabilitation Plans (QRP) and Biodiversity Management Plans see GCCA Sustainability Guidelines for Quarry Rehabilitation and Biodiversity Management
- track, monitor, report, and establish assurance of information through Key Performance Indicators that provide valuable, reliable, easy-to-understand and verifiable information. This allows comparison and measurement of progress[01]
- highlight concrete's strong sustainability characteristics
- work in partnership to scale up efforts.

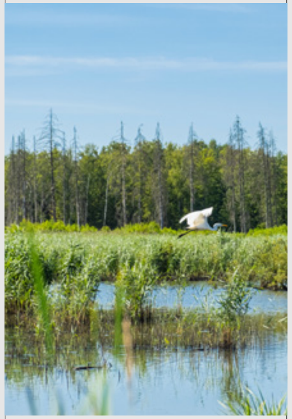
01 / See GCCA Sustainability Guidelines for Quarry Rehabilitation and Biodiversity Management https://gccassociation.org/sustainability-innovation/sustainability-charter-and-guidelines/



Use of Concrete

Concrete has an important role to play, as many parts of Green Infrastructure will also require a hard infrastructure element. The concrete industry is therefore committed to developing sustainable products that enable and contribute to Nature Based Solutions to mitigate the loss of biodiversity caused by the built environment. The inherent properties of concrete mean that it does not release toxic substances into the environment, nor does it require treatments and coatings that release substances. This makes it suitable for integration directly into green space including parks, playgrounds and gardens, with limited impact on biodiversity.

Designers are able to mitigate the impact of urban development by utilising the properties of concrete. For example, porous paving prevents surface run-off, and durable concrete enables underground transport structures and high density development, both of which limit the overall impact of development.



How can Net Positive Impact be achieved?

Rehabilitation of quarries, progressively during extraction and on completion of operations, offers significant opportunities for enhancement of biodiversity through creating more enhanced, thriving and connected habitats than were present before operations began. This can and does result in net positive impacts for biodiversity, as well as other components of Natural Capital (e.g., water storage, and landscape enhancement), and the industry has a long track-record of delivery on this. Net positive can be delivered, and measured, through ensuring that the biodiversity value of a site is assessed prior to development proceeding, calculating the relative losses (through soil removal and mineral extraction) and gains (through on or off-site management, and progressive and final rehabilitation) and taking action to ensure a net positive outcome.

RESILIENCE

Resilience against hazards matters because at the individual level it ensures that our basic needs – safety, shelter, food, clean water and sanitation – can be met and that employment and livelihoods are supported. At a community and national level, resilience supports the permanence of security, justice, public health services, communications, mobility and other critical services, and fosters economic prosperity. And at a global level, resilience may even matter to our very survival.

Our built environment – homes, buildings and infrastructure – are exposed to a wide range of natural and human-made hazards, and many of these hazards are exacerbated by climate change. A resilient built environment is also a vital component to reach the UN's Sustainable Development Goals.

Concrete is the most durable of major structural materials, and offers inherent resilience against many hazards. It can resist fire, wind and water. It won't rot, warp or be eaten.

Concrete also offers resilience to society by helping it to recover from a disaster event. In a world in which natural disasters are increasingly common, building structures that are resilient to flooding and high wind events is a key component of economic, societal and environmental sustainability. Often, such buildings are built from concrete, as its durability makes it more able to survive disasters, reducing the need for (and therefore favourably affecting the cost and speed of) post-disaster reconstruction.

The design and construction industry in general, and the concrete industry specifically, has the skills and products to deliver a more resilient built environment that will help society resist, absorb and adapt to many hazards to which it will be subjected.

CONCRETE FUTURE

INNOVATION

Continuous innovation has been the driving force behind the CO_2 reductions the industry has achieved over the last decades. Innovations have unlocked greater kiln and energy efficiencies, clinker substitution, efficiencies in production and use of concrete production, and more recently this has included carbon capture technologies. Further innovation, especially in the field of CCUS and new cement chemistries, will help meet the targets outlined in this roadmap. The global cement and concrete industry has two world class innovation initiatives underway under the GCCA's Innovandi activity.

Innovandi Global Cement and Concrete Research Network
Launched in 2020, the Innovandi Global Cement and Concrete Research Network is a consortium which critically brings together academia (40 leading global institutions) and industry (34 cement and concrete manufacturers, admixture companies, equipment and technology suppliers) to collaborate on essential pre-competitive research, in areas such as:

- energy efficiency
- efficiency of clinker production including alternative calcination technologies
- enabling implementation of CCUS/technologies
- understanding impact of new materials
- low carbon concrete technology
- concrete recycling.

Innovandi Open Challenge
The Open Challenge, launched in 2021, is a global programme to bring together start-ups with GCCA members to accelerate the development of technologies to help the cement and concrete sector decarbonise. The scope includes:

- carbon capture technologies
- calcination technologies – for heating materials during the concrete manufacturing process
- carbon use in the construction supply chain
- improved recycling of concrete.

CARBON CAPTURE, UTILISATION AND STORAGE

Carbon capture, utilisation and storage (CCUS) describes processes that capture CO_2 emissions from industrial sources and either reuses them in other industrial processes or stores them for centuries or millennia so that they will not enter the atmosphere.

CCUS is a crucial solution for the cement sector where a large share of emissions are not energy related but due to the specific chemistry of cement making.

Projects from around the world, with GCCA member involvement and technology advanced also shown.

CARBON CAPTURE, UTILISATION AND STORAGE

CCUS is a cornerstone of the net zero carbon roadmap for cement and concrete. The technology has been shown to work and is close to maturity but an industry-wide roll out of CCUS will require close cooperation between the industry, policymakers and the investment community.

While the technology is advancing, the economics remain challenging. The development of a 'carbon economy' is therefore an essential step in the move from a number of successful pilots across the world to widespread and commercial scale deployment. An essential part of this journey will be the re-evaluation of CO_2 as a usable commodity rather than a waste product.

Carbon Capture
CO_2 capture is still expensive today, but technology is improving and the significant number of demonstration facilities, currently being deployed in cement production, demonstrates the potential for significant cost reduction in the years ahead.

A variety of different capture technologies are currently being tested in pilot projects across the globe. These include post combustion (e.g. chemical absorption by amines), direct separation, oxyfuel and calcium looping. Typically additional energy is needed for these technologies to operate the CO_2 separation and handling processes.

> The 2030 goal is to have CCUS fully operational at 10 cement plants around the world

Utilisation (or Valorisation)
Captured CO_2 can be used in the production of e-fuels and as a feedstock for the chemical industry. More specific uses are to promote crop growth in greenhouses and in the food and drinks industries.

The construction industry can also play its part in developing an economy for CO_2 – and there are signs that this is happening. The process of carbonation has been long understood by engineers with respect to reinforced concrete and is rightly limited for the sake of durability. Recent development has focused on speeding up the reaction in various applications as a method of sequestering CO_2. Potential applications include:

- the manufacture of artificial aggregates
- curing concrete
- carbonation of recycled concrete.

Sequestration
CO_2 can be sequestrated in geological formations which would avoid it being released into the atmosphere.

Infrastructure
Both solutions, utilisation or sequestration, require the development of infrastructure between the source and point of use or storage.

TOWARD NET ZERO CONCRETE – COLLABORATING FOR AN ENABLING POLICY FRAMEWORK

Concrete's essential role in the modern world

Cement and concrete both literally and metaphorically lay the foundations for modern societies to grow and prosper. Manufactured with locally available materials and by-products, cement is the essential component of concrete that holds together houses and infrastructure, forming the backbone of economies and societies around the world.

The nature of concrete as the building material of choice lies in its availability, affordability, reliability, versatility and simplicity of use, in addition to the durability and resilience it bestows upon structures built with it. It has inherent safety qualities that make it fire, weather and flood resistant. It provides thermal mass in buildings and rigidity in road construction, both of which reduce demand for energy. Moreover, the concrete used in our cities and infrastructure absorbs CO_2 during its lifetime, making our built environment an effective and permanent carbon sink. Concrete also underpins the clean energy transition, allowing us to build renewable energy sources, and enables the transition towards a net zero built environment.

Commitment towards net zero concrete

Cement, whose key raw material is quarried limestone that is heated to high temperatures in kilns, is the material that binds together all the ingredients of concrete. It is well known that the manufacturing of cement is a CO_2 intensive process.

Improving the carbon footprint of cement manufacture involves mitigating the CO_2 directly emitted when limestone is heated and decomposes (known as process emissions). This represents 60% of emissions. The remaining 40% to be mitigated arises from direct and indirect energy emissions, i.e., the combustion of fuels required to generate the necessary heat for the process (direct emissions) and any emissions from the generation of electricity used (indirect emissions).

Cement manufacturing is rapidly decarbonising through the progressive elimination of fuel-related emissions, the use of innovative raw materials, embedding circularity across its operations and through the development of advanced process technologies like carbon capture usage and storage (CCUS). Over the past three decades, the industry has reduced its emissions proportionately by nearly a fifth.

The GCCA and its member companies, which represent 80% of the global cement industry volume outside of China, and also includes several large Chinese manufacturers, are committed to continuing to drive down the CO_2 footprint of operations and products. In 2020, we announced our climate ambition – to provide society with carbon neutral concrete by 2050. This was the first time the industry came together at a global level to announce a commitment on this scale, building on the decades of emissions reductions the industry had already achieved. Since concrete is such an essential building block of the sustainable world of tomorrow, this is a crucial part of the world's response to the climate emergency.

The industry is already working to achieve this and recognises the need to accelerate its actions today. It also recognises that the industry must have an active role in encouraging and engineering lower-carbon products and processes and in ensuring that our products are only used when they are needed.

But the industry won't be able to get there on its own. Lasting success depends on a set of specific policy actions at local, national and international levels, which help to:

- **make low-carbon cement manufacturing investable**
- **stimulate demand for low-carbon concrete products, and**
- **create the infrastructure needed for a circular and net zero manufacturing environment.**

1 MAKING LOW-CARBON CEMENT MANUFACTURING INVESTABLE

Cement producers are committed to accelerating the elimination of fuel and process emissions, scaling-up advanced low carbon technologies and embedding circularity across our operations. But the sector cannot achieve this on its own. It needs tailored policy support and targeted public finance to lower the financial risks associated with the use of low carbon technologies and spread them more widely. Along with the policies outlined in the following sections, this will make low carbon cement manufacturing investable.

Fuel Emissions

Specifically on fuel emissions, the sector is constantly making progress on two fronts: improving thermal energy efficiency and alternative fuel use.

Thermal efficiency

Overall, the consumption of thermal energy for production of clinker has improved tremendously over past decades[01 02] thanks to the continuous modernisation of kilns, as well as the implementation of state-of-the-art technologies in new installations. Furthermore, the sector is pioneering new ways to drive energy efficiency, based on novel concepts, including hydrogen.

In this direction – although not viable for all kilns – further progress can be achieved by the integration of Waste Heat Recovery (WHR) facilities in cement plants. These can enhance overall energy efficiency, while also helping to alleviate emissions originating from electrical energy consumption. It is important that such initiatives are facilitated with the support of local governments, allowing for fast and efficient permitting, and are incentivised with appropriate tax policies.

01 / www.gccassociation.org/gnr/

02 / lowcarboneconomy.cembureau.eu/5-parallel-routes/energy-efficiency/thermal-energy-efficiency/

Alternative fuels

The cement industry offers one of the best examples of industrial sectors that can realistically contribute towards the circular economy. By utilising waste to recover energy and recycling materials at the same time – a method known as co-processing – producers can substitute fossil fuels with industrial or residential wastes. CO_2 emissions are significantly reduced, by minimising landfilling and incineration and reducing the need to extract virgin fossil fuels. Co-processing offers more than just energy recovery: mineral components of waste-derived fuel are also used in a beneficial way.

In modern installations with adequate streams available, 100% of fossil fuels can be substituted by waste material for co-processing. Unlocking the potential to mitigate the majority of fuel CO_2 emissions with available co-processing technologies is primarily dependent on availability of waste streams, which are, in turn, linked with policies regulating waste management and distribution, at both the local and international level. Wherever regulations allow for increased usage of waste for co-processing, GCCA members quickly support the use of alternative fuel sources and proceed with the appropriate investments.

Process Emissions

Process emissions are those coming directly from the raw material: the decomposition of limestone in clinker production.

Alternative raw materials

Replacing natural minerals used for clinker manufacturing with alternative sources containing less or no carbon, such as processed construction and demolition wastes, industrial ashes and by-products, can lead to lower CO_2 emissions as well as reduce the need for quarrying. Such initiatives further enhance the circular character of cement manufacturing.

CONCRETE FUTURE

01 / www.gccassociation.org/gnr/

However, practical and technical challenges often limit the use of alternative raw materials.

Availability and proximity of such streams to cement plants, insufficient storage capacity, high concentrations of process incompatible elements (e.g., sulphur, magnesium or other), in addition to the presence of volatile organic compounds, are among the main reasons why alternative raw materials can currently replace only a relatively small part of natural resources for clinker manufacturing.[01] As in the case of alternative fuels, policy changes can bring forth necessary technological advances and guide waste management practices closer to the circular economy.

Reducing clinker content

Clinker is the essential, and at the same time, the most carbon intensive component of cement. The 'clinker-to-cement ratio' describes the amount of clinker versus other cement ingredients, and defines the properties of cement-based products, namely concrete and mortars. The amount of clinker, as well as the type of materials that can be used for cement production, are regulated by international and local standards everywhere in the world, making cement a highly standardised product that meets demanding specifications to ensure durable construction with a very long service life.

Substituting clinker with less carbon intensive constituents requires that such materials exhibit properties similar to or complementary to clinker, in terms of mechanical performance and durability, while also adhering to strict quality characteristics for use in cement and concrete. Commonly referred to as cementitious materials, these include ground limestone, natural and calcined pozzolans, as well as industrial by-products such as fly ash and ggbs.

01 / www.gccassociation.org/gnr/

The cement sector makes extensive use of such materials, as evidenced by the reduction of clinker-to-cement ratio in the last decades.[01]

Looking ahead, utilising additional volumes of cementitious materials is subject to local availability, standards and regulations, in addition to market acceptance, among other factors. As industrial sectors increasingly decarbonise, certain by-products, such as fly ash and gbbs are likely to become less available for use in construction. Novel approaches on reusing previously untapped industrial wastes, such as landfilled fly ash, can extend the availability of certain cementitious materials, providing additional time to de-risk other carbon-abating methods. In the same context, activating low-grade minerals and quarry wastes to produce calcined clays, can provide a sustainable new stream of cementitious materials with global potential.

What do we need?

Deploying advanced technologies requires economy-wide regulation in order to avoid carbon-leakage and ensure the ongoing competitiveness of the sector whilst it is deploying these innovations and technologies. The sector needs:

- policies to prevent unfair competition from imported cement or clinker produced by more carbon-intensive processes
- strategic public funding for the innovation and deployment of advanced low carbon technologies will be needed, targeting R&D as well as CAPEX/OPEX (development, industrial deployment and operation, including transport).

Unprecedented collaboration between governments and industry is needed in order to develop the needed long-term regulatory certainty to enable the sector to meet its carbon reduction potential and to ensure the continued availability of cement (and hence concrete) that are essential for economic and societal development.

The elimination of emissions relating to fuel use is a priority for the cement and concrete sector. To ensure that appropriate actions are taken, policy is needed to:

- prioritise co-processing in the waste treatment hierarchy policies to promote the benefits of dual energy recovery and mineral recycling, also as a means to efficient and environmentally benign industrial [and societal] symbiosis
- ensure waste legislation avoids landfill of residual waste with potential to replace fossil fuels, and/or natural resources
- assign a dedicated R-15 code "co-processing" in the Basel Convention, to achieve international recognition of the circular, societal and climate function of co-processing
- ensure a level playing field for the use of biomass waste by removing subsidies that favour particular industries, while also ensuring that carbon accounting of waste materials does not differ between sectors
- launch and support innovation and R&D initiatives (including the GCCA's Innovandi platforms) to promote increased recovery of materials with calorific potential and/or mineral content from waste, for co-processing.

CARBON PRICING

Background

Carbon pricing is an approach to reducing carbon emissions that uses market-based mechanisms to pass the environmental cost of emitting on to producers and consumers. Putting a price on carbon can create a financial incentive to reduce emissions and encourage lower-carbon behaviour and can also raise money that can be used to finance low-carbon investment and climate adaptation.

Carbon pricing schemes exist in many regions of the world, and several of these cover the cement industry.

Most of these established schemes follow the model known as cap-and-trade: overall emissions are limited by a declining "cap", and credits giving the right to emit are given out or traded within the system, but are limited in number by the cap. This ensures total emissions reduce over time. Alternatively, some regions use carbon taxes, mostly applied today to fossil fuels.

- In Europe, the EU Emissions Trading Scheme (EU ETS) has existed since 2005 and has led to over 35% emissions reductions in covered sectors since then. UK and Switzerland also have schemes, the Swiss one being linked to the EU ETS, which means credits can be traded between the two, creating a larger market.
- In North America, emissions trading schemes exist in some US states, although only the California scheme currently uses cap-and-trade and covers cement. Several other states are considering including cement in their schemes. In Canada, provincial schemes as well as the federal fall-back scheme cover cement. The Quebec and California schemes are linked.
- In China, the government has announced its intention to include cement in the national ETS from as early as 2022. Regional schemes already cover cement.
- In other parts of the world, carbon pricing schemes exist but mostly apply to the power sector and so do not yet include cement. For example, the V20, a group of 20 developing countries vulnerable to climate change, has announced its intention to adopt carbon pricing by 2025.

GCCA position

A GCCA supports the use of market-based carbon pricing to incentivise decarbonisation at lowest cost

An appropriate carbon price, as well as long-term predictability, allows companies to make the investments needed to reduce their CO_2 emissions in line with the GCCA ambition for net zero by 2050.

The advantage of market-based instruments such as cap-and-trade schemes is that they direct financial resources towards wherever it is most economical to reduce emissions, lowering the financial burden on society.

B The use of carbon pricing must not lead to distortions of competition between domestic producers and importers

If carbon pricing is applied in a region where other regions do not have similar carbon pricing, there is a risk that investments will move to those regions where carbon pricing is lower, leading to a global increase in CO_2 emissions (if production in those regions is more CO_2-intensive, or transport emissions for importing from those regions). This concept is known as carbon leakage. All carbon pricing schemes need mechanisms to avoid the risk of carbon leakage, such as the award of a certain number of CO_2 credits for free to best performers in the most leakage-exposed sectors.

Since it has been seen in recent years that such measures can be insufficient to avoid carbon leakage where the carbon pricing disparity is very large (such as between the EU and other countries), "border mechanisms" applying a carbon cost to importers are also being considered as a way to level the playing field and ensure global emissions continue to decrease. In the case of North America this would also apply to differing carbon costs between states or provinces. Such mechanisms must be developed with care to ensure they benefit the climate and fairly apply similar carbon costs to importers and local producers. Once more regions of the world apply carbon pricing, such mechanisms will become less necessary.

The Paris Agreement Article 6 establishes the potential of trading emission reduction credits across borders, between nations or jurisdictions. In this context, GCCA believes it is crucial to advance discussions on cooperative mechanisms at the next COP.

C

For carbon pricing to drive meaningful emissions reduction, environmental integrity is essential. This means that clear monitoring, reporting and accounting rules are needed. Carbon pricing should also drive innovation.

Carbon pricing should encourage both conventional and breakthrough technologies to reduce CO_2 emissions. Accounting rules must be designed to reward investment in carbon capture technology, both where the CO_2 is ultimately stored or used in products. The GCCA CO_2 protocol and guidelines[01] provides such clear monitoring, reporting and accounting rules.

01 / www.cement-co2-protocol.org/en

D

The transition towards carbon neutral economies is dependent on the acceptance of carbon constraints and costs by all actors along economic value chains: a competitive level playing field on carbon cost must prevail.

While cap-and-trade schemes are a powerful means to apply carbon pricing, they tend to be applied to the source of emissions, for example at the electricity, cement or steel plant. This makes them difficult to apply to dispersed sources of emissions, such as forestry.

A carbon consumption charge, covering all embodied emissions in products as well as carbon absorbed over the asset's life using a life-cycle approach, could be a fair way to apply carbon pricing to diverse products and ensure a level playing field for competing products.

This is a solution for the medium term, to allow time for the adoption of life-cycle accounting methods and data.

2 CREATING MARKET DEMAND FOR CARBON NEUTRAL CONSTRUCTION AND DECARBONISED VALUE CHAINS

Policy measures are needed to reduce both the embodied and operational emissions of buildings and structures. Concrete is a key enabler of this net zero transition, both through its own decarbonisation and through reducing emissions in the built environment and society (ranging from buildings to sustainable infrastructure).

Policy should incentivise innovation, lead to increased demand for low carbon solutions and facilitate the introduction of low carbon products on the market, whilst maintaining essential traditional criteria (e.g., technical performance, strength, durability, safety). Its local availability and versatility mean that if the policy signals are right, concrete's possibilities as a net zero enabler are virtually limitless.

GCCA members are aware of the need for the correct demand-side signals to drive procurement of low carbon structures and products – while recognising the potential complexity, trade-offs and risks. GCCA already provides a harmonised lifecycle assessment tool for concrete and commits to working further on practical approaches to define what low carbon procurement should look like.

What do we need?

The industry is committed to accelerating the introduction of net zero products on global markets and will continue to drive innovation in new products. The long-term success of our innovation is highly dependent on the regulatory and standardisation frameworks that will lead to a market transformation and establishes market demand for low carbon products.

We need policy frameworks that:

- enable the integration of CO_2 performance in public procurement, building standards and construction codes alongside traditional criteria (e.g. technical performance)
- provide harmonised tools to assess CO_2 performance of buildings and infrastructure based on whole-life performance in a technology and material neutral manner, to ensure the best results for the climate and society
- provide standards for energy performance of buildings that are demanding and sophisticated enough to take into account the benefits of properties such as thermal mass
- tackle systemic barriers to selection of the best performing materials from an emissions standpoint.

More details on whole life performance

The integration of CO_2 performance in buildings and construction – alongside traditional priorities such as cost, performance and safety – is a must, and should be based on full lifecycle performance and the principle of material neutrality. Whole-life assessments allow for circularity benefits – such as reuse of concrete elements – and phenomena that occur beyond the factory gate – such as natural recarbonation of concrete – to be included. Prescriptive approaches, where certain materials are specified for their perceived climate advantages, risk leading to worse overall outcomes for the climate if a whole-life assessment is not made.

Concrete offers the means to save emissions in the structures it is used in. For example, its thermal mass reduces the energy demand of buildings; another example is renewable energy infrastructure built from concrete that offers huge emissions savings. This demonstrates the need for a system-wide view when assessing the climate contribution of any material. And energy performance of buildings standards must be sophisticated enough to take dynamic effects like thermal mass into account.

CONCRETE FUTURE

More details on the removal of systemic barriers

Concrete design and construction can be optimised to reduce CO_2 impact, but there are often systemic barriers and practical constraints preventing this potential from being realised. For example:

- demands on speed of construction meaning low-carbon mixes are less economical
- fragmented value chains meaning the possibility and responsibility to reduce CO_2 is spread across different actors with diverging incentives
- the pace of change in revision of standards and building codes which (justifiably) prioritise avoiding risk.

An understanding and recognition of these barriers is needed to start to remove them. Prioritisation of CO_2 performance alongside other constraints at the procurement, design and construction stages would help to align value chains to the same goal.

3 PROVIDING THE INFRASTRUCTURE FOR CIRCULAR AND NET ZERO MANUFACTURING

Decarbonisation of necessary-to-abate sectors, such as cement and concrete, requires the right policy and legal framework on the one hand, and supportive infrastructure that will be shared across industrial sectors on the other. A shared understanding of the infrastructure needs for a decarbonised economy is key to enabling not just decarbonisation of the cement sector but industry and society in general.

Ultimately, deployment of advanced technologies such as CCUS at full scale will eliminate the process emissions of cement manufacturing and result in the future delivery of carbon net zero concrete for our world.

What do we need?

Whilst the cement and concrete sector is committed to advancing the deployment of advanced technologies such as CCUS, moving towards decarbonised manufacturing and markets is an endeavour that is larger than any individual sector. It requires the infrastructure that enables us to operationalise the transition to a sustainable low-carbon economy.

Low carbon production technologies, especially carbon capture and electrical heating, are increasing the cement and concrete industry's demand for clean energy from low-carbon sources at the same time as every industry's demand is growing for the same reason. The infrastructure needed to supply this demand must be in place.

Widespread deployment of CCUS will mean every cement plant needs transport and storage capacity to convey large volumes of CO_2 to distant sites where it can be stored or used in other industrial processes. For many this may mean a pipeline, rail-link or shipping route, with the significant funding needed coming from public sources.

CCUS isn't developing as fast as it might because clear policies affirming its long-term future are not yet developed and nor are enabling laws and regulations.

The development, therefore, of such a policy and legal framework and infrastructure will be, in many instances, not unique to the sector and will have broader benefits for industry and society. Nevertheless, to accelerate deployment of advanced technologies for the cement industry, this support is needed as a prerequisite and therefore it is imperative to develop near-term plans for deployment and implementation so that these are in place as CCUS comes online. Similarly, strategic public funding for the innovation and development of key elements of the supportive infrastructure will be needed.

Governments at all levels and society alike will need to make long-term commitments and define clear plans so that the industry can with confidence invest in technology development. This certainty will enable the sector to meet its carbon reduction potential and to ensure the continued availability of cement (and hence concrete) that are essential for economic and societal development.

This calls for:

- reliable access to abundant and competitively priced renewable energy, including hydrogen and H_2 networks as part of the enabling infrastructure
- public-private partnerships to speed-up CCUS developments, including shared investment in CO_2 transport and storage networks
- regulatory certainty provided by long-term policy that continues to justify investment in carbon abatement technologies along with the appropriate fiscal, legal and regulatory support to speed-up their development e.g.
  - regulations to allow the construction of carbon storage facilities, determine liability for stored CO_2 and ensure long-term access to carbon stores
  - fiscal support for R&D in new uses in other sectors of CO_2 captured by the cement industry.

More details on energy infrastructure

Electricity: as an energy and electricity intensive sector, sufficient and reliable availability of power is fundamental. For electricity this means not just access to the electricity grid, but often it will need a significantly improved capacity and reliability to meet the increased demands that low carbon technologies will require, especially carbon capture or even electrical heat options.

Electricity should preferably be from a renewable source, which of itself will often necessitate a fundamental transformation of the way in which electricity is generated and supplied. This is a clear example of a supportive policy that will benefit society and industry alike, impacting both scope 1 and scope 2 emissions. The costs of renewables deployment policies should not fall disproportionately on industry, which needs competitively priced electricity.

Hydrogen: the availability of sufficient hydrogen for use by the industry is another key component. Therefore, the development of supportive hydrogen policies is necessary for countries and society to meet their CO_2 reduction ambitions. However, in developing the necessary policies and infrastructure it is vital that production and use of hydrogen is prioritised for uses where there are few if any alternatives such as in industry. Hydrogen is equally important to help decarbonise transport emissions associated with cement manufacture such as via Heavy Goods Vehicles (HGVs) or rail, and potentially the use of ammonia as a fuel for use by shipping.

More details on CCUS

The deployment of carbon capture technology in the cement sector is associated with key infrastructure requirements to enable the cement sector to use carbon capture technologies effectively.

CO_2 transport and storage: there needs to be a suitable and sustainable network to allow transport and storage of any captured carbon. The transport solutions will vary from site-to-site but, due to the volumes and distance involved, will likely need a pipeline, rail-enabled link, or shipping facility to take the CO_2 to a suitable storage site or for use in another industrial process.

Given the dispersed, often rural nature of cement plants this could be the significant infrastructure support needed to enable a plant to achieve its carbon reduction potential.

Public acceptance for geological CO_2 storage, either under land or sea will be required. In particular, if these are land-based then there will need to be a public acceptance of the solution; this will need politicians and communities alike to be supportive, backed by appropriate legal mechanisms.

Liability: To facilitate long-term storage other issues such as liability for the CO_2 need to be resolved. It is preferable if these types of liabilities are public (or shared, as with interesting planned models in the UK); otherwise it will place an unaffordable burden on the sector.

Likewise, access to any storage option will require robust, long-term legal certainty to facilitate investment. Similarly, where transportation and storage options are being supported by funds from the public purse, affordability is key to allow the cement manufacturing process to be competitive.

Use of carbon and carbon accounting: Whilst storage presents its own challenges, there also needs to be a significant investment in use options for captured CO_2. The opportunity exists to create new industrial symbiosis relationships, with other sectors taking CO_2 supplied from the cement sector to produce products substituting more carbon intensive ones (e.g., e-fuels). The business case for deploying these technologies rests heavily on the ability for installations that capture CO_2 to discount it from their emissions, whether used for permanent geological storage, for mineralisation or for the production of products substituting more carbon intensive ones.

ACKNOWLEDGEMENTS

This roadmap is the output of the membership of the Global Cement and Concrete Association. Whilst GCCA retains full responsibility it is important and right to acknowledge the crucial role that has been played by member companies, affiliate associations and individuals within those organisations. On behalf of the GCCA membership and the GCCA Board we extend the following thanks.

Thank you to over 100 individuals from GCCA member companies and GCCA Affiliates (national and regional cement and concrete associations), and their invited experts, who have contributed to fourteen task groups over a 15-month period. They have brought an understanding from countries and regions across the world. By sharing their expertise, contributing information and assessing future issues they have ensured that this global roadmap is built on local and detailed knowledge of future challenges and opportunities.

Thank you to the countless stakeholders who contributed information and provided feedback. We look forward to continuing to work with you, and many more of your colleagues, as we implement the roadmap and continue the journey to net zero. In particular, we highlight our collaboration with the World Economic Forum, the Mission Possible Partnership and the joint Concrete Action for Climate initiative that will build on the outputs of this roadmap.

Finally, we thank Dr Martin Schneider and his team at ECRA who have acted as consultants through this process. They have ensured that the inputs from around the world have been consistent and they have developed and run a comprehensive model. Their deep expertise and experience have facilitated the development of a rigorous global roadmap.

DOCUMENT DETAILS

Publication version 0.1
12th October 2021

Global Cement and Concrete Association
Paddington Central
6th Floor, 2 Kingdom Street
London, W2 6JP
United Kingdom
T +44 (0)20 3580 4268
info@gccassociation.org
www.gccassociation.org

Follow us across our social media platforms at Twitter, LinkedIn and Instagram

Photo credits:

Pages 3, 12 & 23 Sies Kranen
Pages 4, 6, 7, 11, 14 LEILAC project
Page 7 Ramachandra V, Ultratech Cement
Page 13 Cris Ovalle
Page 31 Margaret Polinder, Coralie Meurice, Claude Lorea


Global Cement and Concrete Association
CONCRETE FUTURE
We are fully committed to working together, and with partners, to achieving our net zero destination.