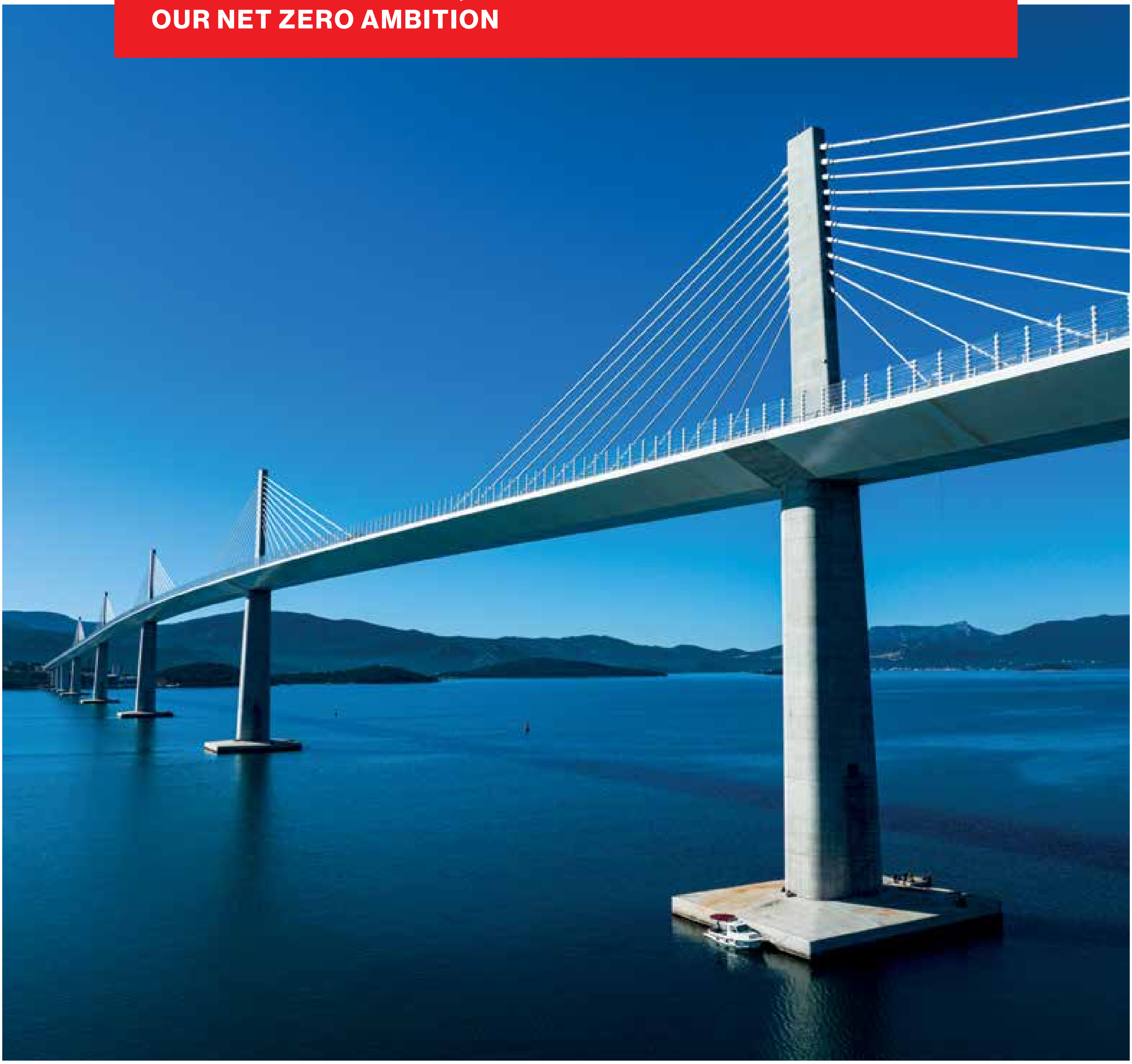
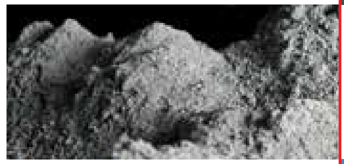
From Ambition to Deployment

THE ROAD TRAVELLED, PATHWAYS AND LEVERS TO SCALE UP OUR NET ZERO AMBITION



CEMBUREAU, the European Cement Association, is based in Brussels and is the representative organisation of the cement industry in Europe. Currently, its Full Members are 23 national cement industry associations and cement companies of the European Union (except for Malta) plus Norway, Switzerland and the United Kingdom. Croatia, Serbia and Slovakia are Associate Members of CEMBUREAU. Cooperation agreements have been concluded with Vassiliko Cement in Cyprus and UKRCEMENT in Ukraine.

The Association acts as spokesperson for the cement industry before the EU institutions and other public authorities, and communicates the industry's views on all issues and policy developments regarding technical, environmental, energy, employee health and safety and sustainability issues. In addition to the EU, permanent dialogue is maintained with other international organisations (e.g. OECD, IEA), the Global Cement and Concrete Association (GCCA) and sister associations in other parts of the world.



2050

A lot can happen in four years

In May 2020, CEMBUREAU published its **carbon neutrality roadmap**, setting out the sector's ambition to reach net zero emissions along the cement and concrete value chain by 2050.

In the past four years we have witnessed a global pandemic, the start of a large-scale conflict in Europe, the increased impact of climate change, political shifts, and global inflation. In this challenging environment, the European cement industry has accelerated the pace of change.

Continuing on this path requires a strong regulatory framework, including appropriate financing and infrastructure.

Introduction

From ambition to deployment

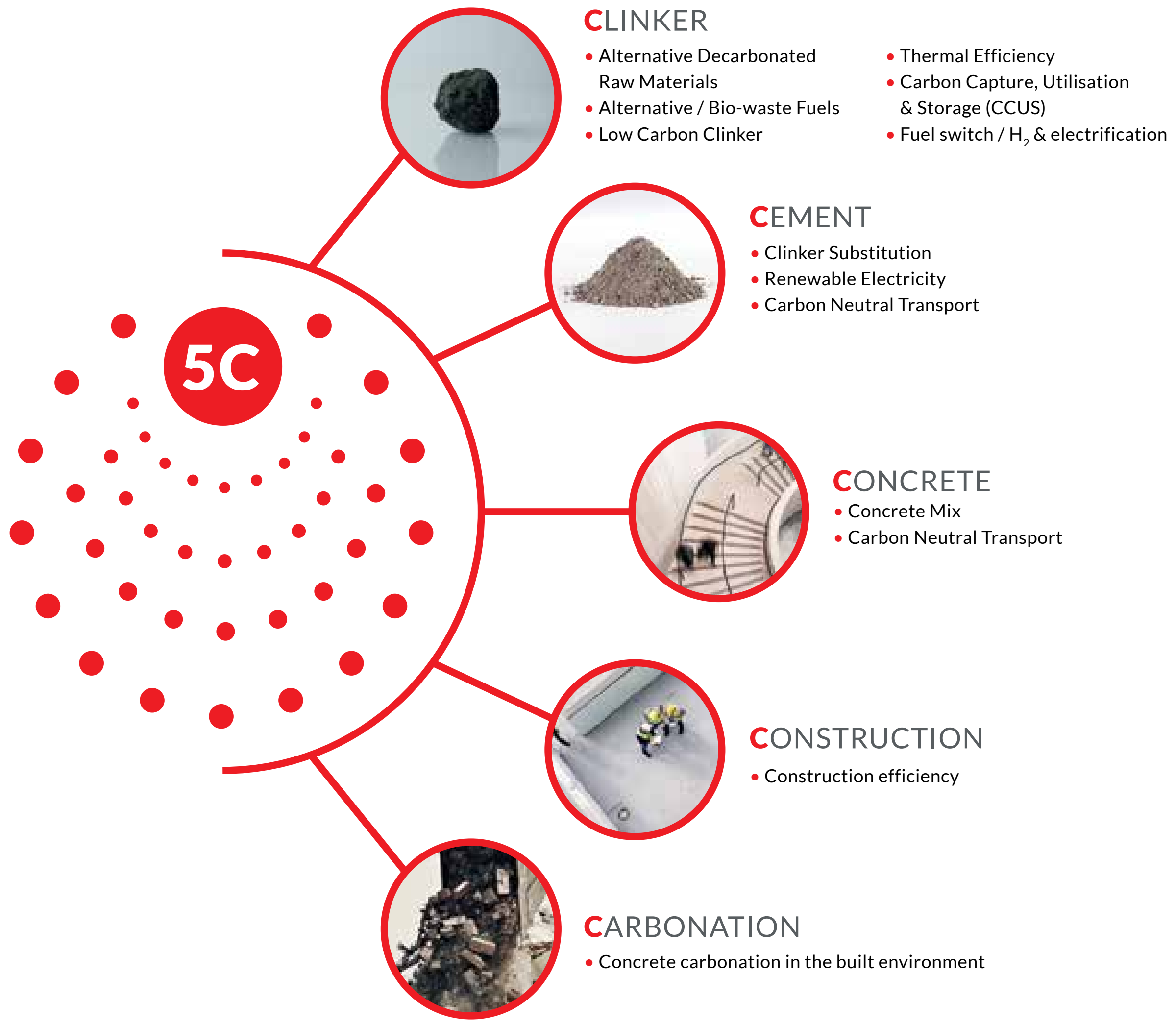
Taking stock of where we are

Four years after publishing our roadmap, we decided to take stock of where we are and to revise our level of ambition based on our progress, the evolution of technology and the outcome of research and pilot projects. We analysed what we can do as the European cement industry, what role the concrete and construction sectors can play and what policies are required to go from ambition to reality.

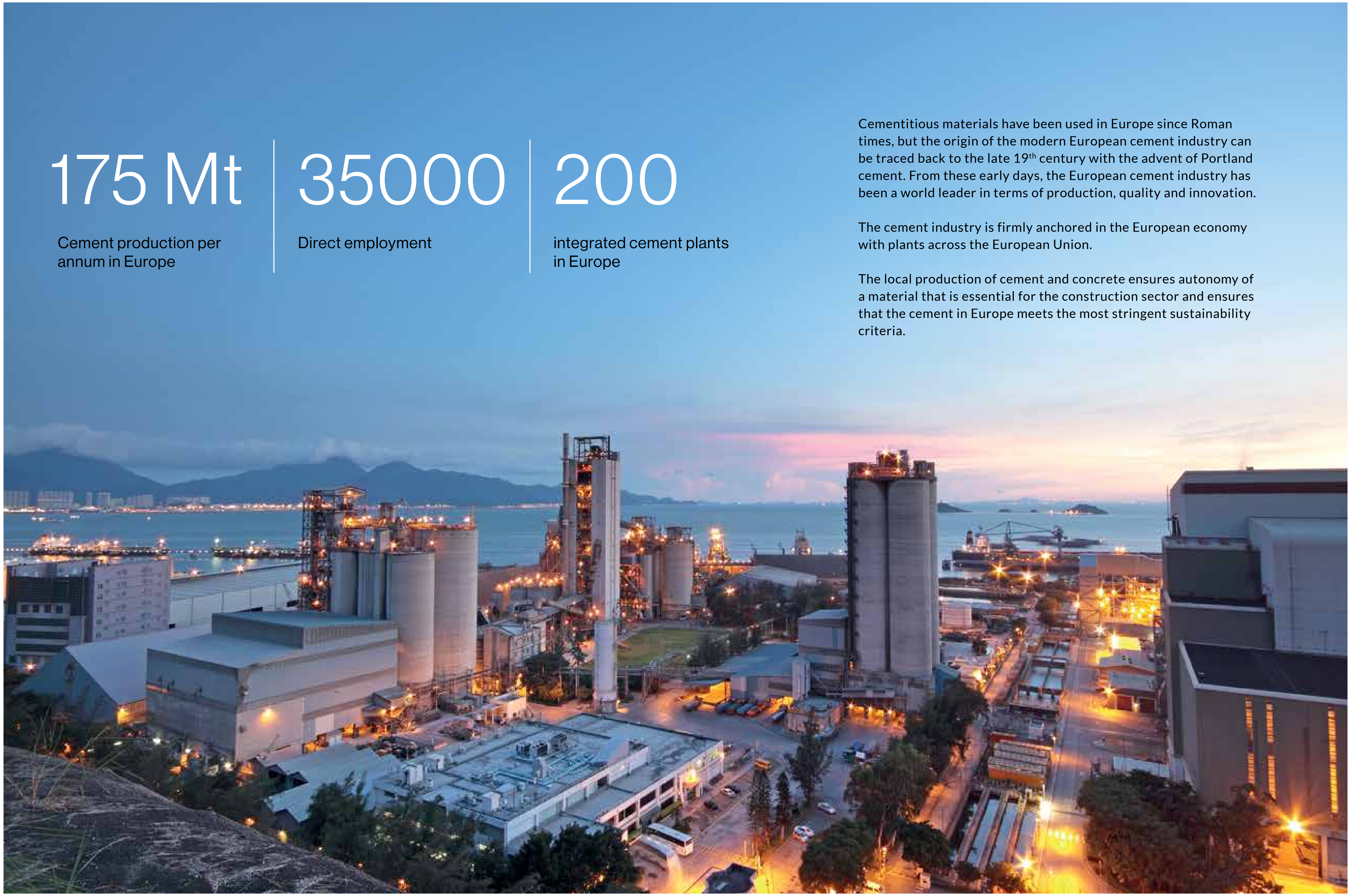
Our 5C approach down the value chain

To guide the European cement industry on its path towards decarbonisation and to establish clear KPIs, we developed the "5C approach" in 2020 promoting a collaborative approach along the clinker-cement-concrete-construction-carbonation value chain involving all actors to help turn the low carbon vision into reality. The 5C approach aims at identifying the key areas that allow for significant CO_2 reduction along the cement and concrete value chain, highlighting the role played by different technologies and stakeholders. In this update, we take stock on where we stand on each of the 5C levers, highlight the innovation projects we engage in and identify the policy drivers we need to deliver the business case for these.

5C approach decarbonisation levers



Cement – a strategic material for Europe



175 Mt
Cement production per annum in Europe

35000
Direct employment

200
integrated cement plants in Europe

Cementitious materials have been used in Europe since Roman times, but the origin of the modern European cement industry can be traced back to the late 19th century with the advent of Portland cement. From these early days, the European cement industry has been a world leader in terms of production, quality and innovation.

The cement industry is firmly anchored in the European economy with plants across the European Union.

The local production of cement and concrete ensures autonomy of a material that is essential for the construction sector and ensures that the cement in Europe meets the most stringent sustainability criteria.

Through its end product, concrete, cement makes a decisive contribution to reducing CO_2 emissions in buildings and infrastructure, and is a key construction material for renewable energy equipment and sustainable transport.

Decarbonising cement production requires a fundamental global shift. In recent years, our industry has made significant strides, as evidenced by the inclusion of over 100 innovation projects on CEMBUREAU's interactive map of innovation projects.

Discover innovation in the European cement industry

Over
100
innovation projects on CEMBUREAU's interactive map

Cement and concrete are crucial materials in the construction industry, with significant importance for Europe and the world at large.

Cement

Cement is a powdery substance made from a mixture of limestone, clay and other minerals. These are heated at high temperatures to form a material called clinker. This clinker is then ground into a fine powder and mixed with other materials, resulting in cement. Cement acts as a binder in concrete, holding the other ingredients together.

Concrete

Concrete is a composite material made from cement, water, aggregates (such as sand or gravel), and often other additives or admixtures. It is the most widely used construction material and is used in buildings, roads, bridges, dams, and various infrastructure projects.

Cement & concrete

Concrete Needs

New Residential Buildings

Across Europe, there is a need for new affordable homes to meet the growth of urban population.

Renovation

To improve the energy efficiency of the existing building stock, we need to achieve a renovation rate of 3%.

Energy Infrastructure

As Europe transitions to a decarbonised economy, renewable energy infrastructure will require large volumes of concrete.

Transport Infrastructure

Europe has set bold goals in terms of transport infrastructure, be it road or rail, that all rely on concrete.

Public Buildings

Many public buildings including schools, hospitals, day-care centres, elderly homes and administrative buildings will need to be constructed in the decades to come.

Re-industrialisation

As Europe becomes more self-sufficient in many sectors, new industrial facilities will need to be built.

Climate Adaptation

The effects of climate change are already being felt across the world. Concrete plays a pivotal role as a construction material used in infrastructure needed to protect people and property.

Why Concrete?

Concrete is a versatile and widely used construction material known for several unique qualities:

Strength and Durability

Concrete is exceptionally strong in compression, making it an ideal material for supporting heavy loads and resisting deformation. Concrete structures are long-lasting, with a construction life of over 100 years, and can withstand various environmental conditions.

Versatility

Concrete can be moulded into almost any shape and size, allowing for the creation of intricate architectural designs and structural elements. It is used in a wide range of applications, from building foundations and roads to decorative elements and artistic sculptures.

Fire Resistance

Concrete has excellent fire-resistant properties, which makes it a preferred material for constructing buildings and structures. It does not burn or emit toxic fumes when exposed to fire, helping to contain flames and limit fire spread.

Thermal Mass

Concrete possesses high thermal mass, meaning it can absorb and retain heat effectively. This property helps regulate indoor temperatures in buildings, reducing the need for additional heating and cooling systems and improving energy efficiency. It can also allow to better manage our energy system by allowing for consumer energy demand to be shifted in time.

Sound Insulation

Concrete has good sound insulation properties, which make it useful for reducing noise transmission between rooms and blocking external noise in buildings located in noisy environments.

Low Maintenance

Concrete structures generally require minimal maintenance compared to other construction materials.

Cost-Effectiveness

Concrete is a cost-effective building material, especially when considering its long lifespan and low maintenance requirements.

100% Recyclability

Concrete is fully recyclable into new aggregates.

An increased ambition

Moving the goalposts

What has changed as compared to our 2020 roadmap

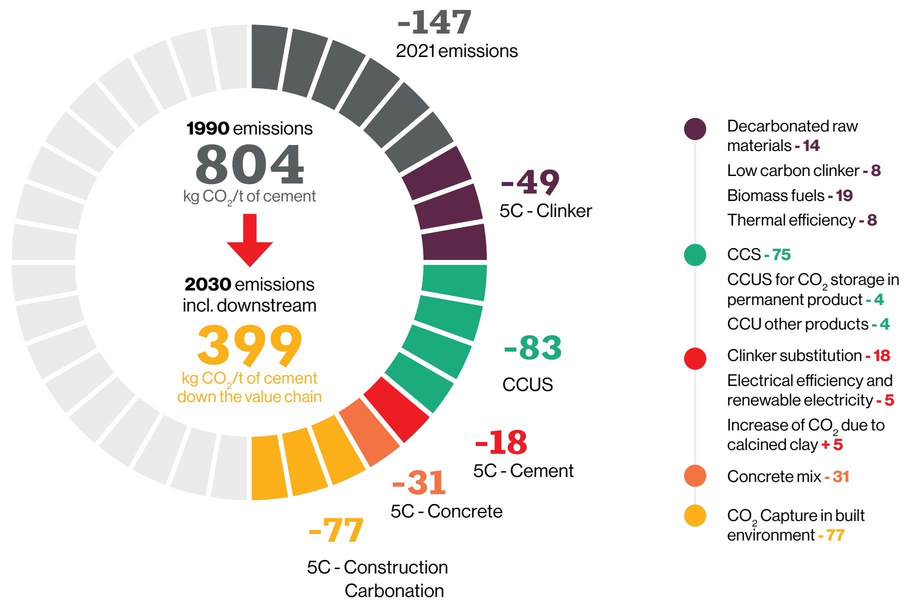
- Based on our progress to date (53% in 2021), we have increased our alternative fuel objectives for 2050 from 90% to 95%.
- We have revised the clinker substitution ambition for 2050 to achieve a clinker to cement ratio of 60%, compared to 65% in the initial roadmap. Sufficient availability of clinker substitution materials will be a key driver in reaching this objective.
- A more detailed breakdown of CCUS volumes has been developed. Given the planned investments, we now have included a 2030 estimate for CCUS deployment.
- We have included 2040 objectives for all levers to be able to track our progress and assess how we can align with the EU's objectives.

What does this mean for the path towards decarbonisation?

- **More ambitious 2030 objectives**
  Substantial investments have allowed to set more ambitious reduction objectives for 2030. In 2020, we had planned for a CO_2 emissions reduction of 30% on cement and 40% down the value chain. We have now revised this overall number to 37% on cement and 50% down the value chain.
- **Strong 2040 ambition for the cement sector**
  By combining all levers, we project a 78% reduction of CO_2 emissions on cement by 2040, and of 93% down the value chain.
- **Potential for negative emissions over the value chain by 2050**
  With the ambition to reach net zero emissions on cement by 2050, the sector has the potential to become carbon negative over the value chain.

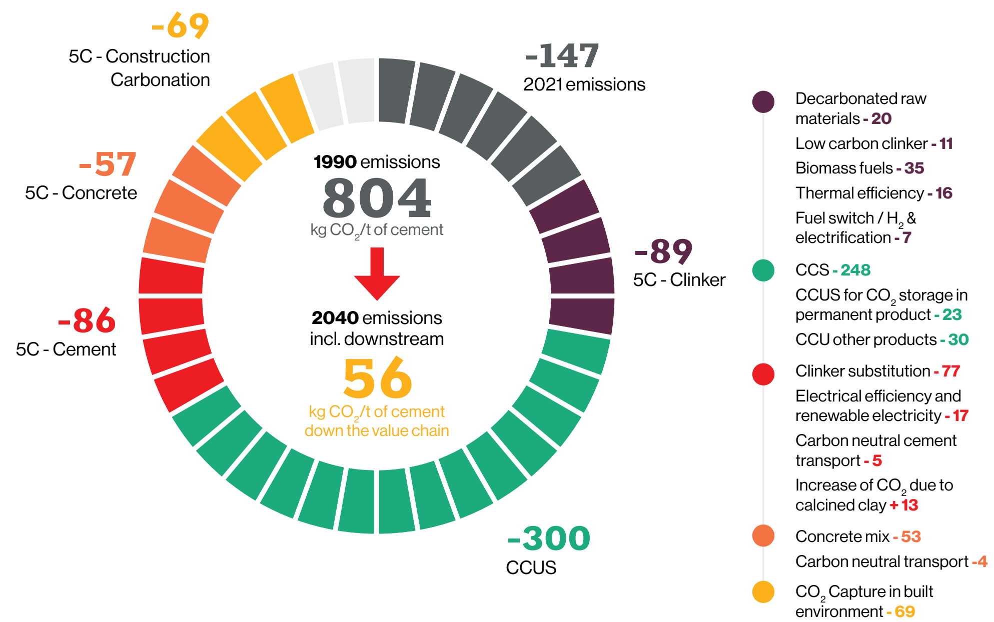
CEMBUREAU **2030** roadmap

CO_2 reductions along the cement value chain (5Cs: clinker, cement, concrete, construction, carbonation)



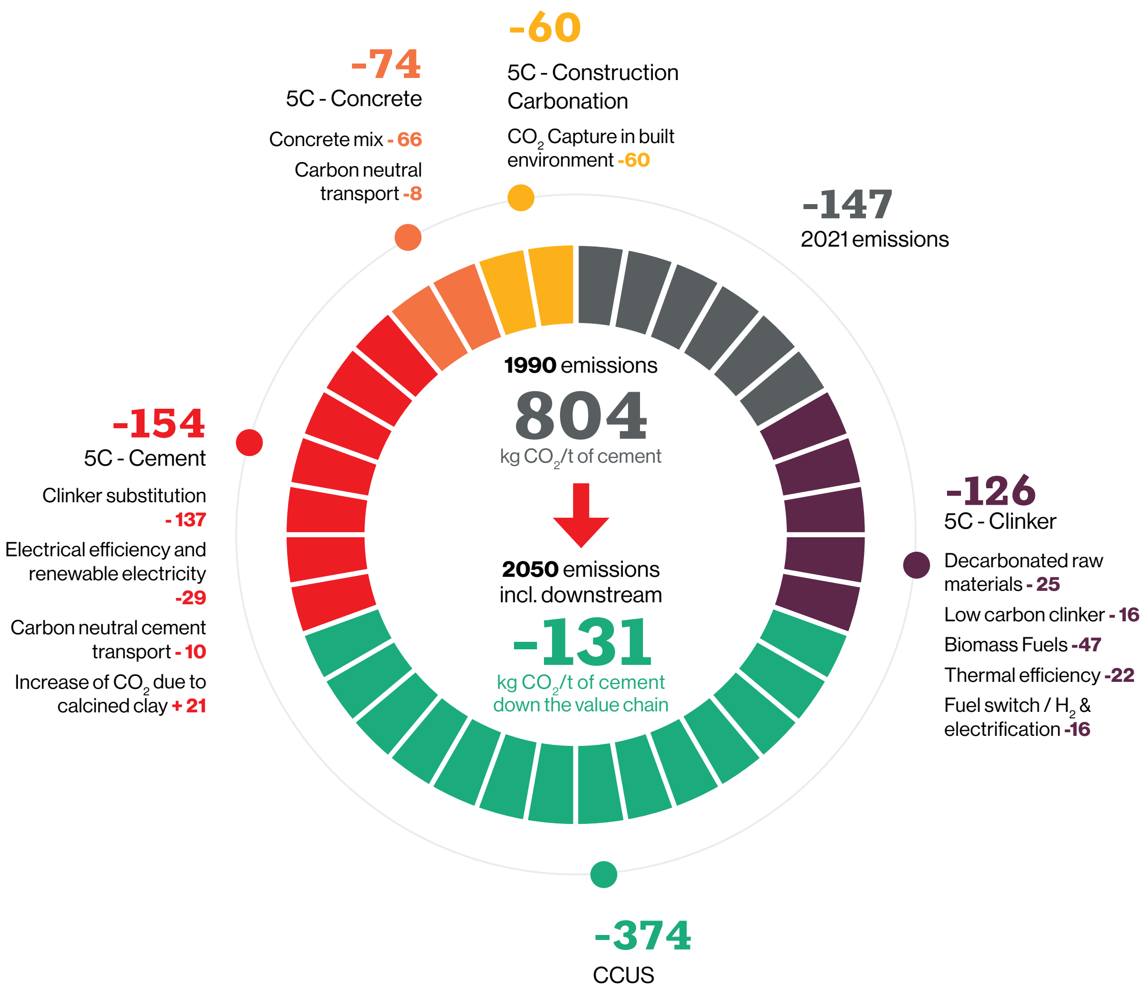
CEMBUREAU **2040** roadmap

CO_2 reductions along the cement value chain (5Cs: clinker, cement, concrete, construction, carbonation)



CEMBUREAU **2050** roadmap

CO_2 reductions along the cement value chain (5Cs: clinker, cement, concrete, construction, carbonation)



Our roadmap shows what the EU cement industry can achieve in terms of CO_2 emissions reduction at a 2030, 2040 and 2050 horizon. However, this ambition will only materialise if the sector is supported by a robust regulatory framework, as well as by a strengthening of EU competitiveness.

Decisive political action must be taken by EU and national policy-makers to deploy net zero technologies. De-risking projects in the early breakthrough period (next 5-15 years) is key. We need an industrial policy to complement the Green Deal and a close coordination between all parts of government with a focus on permitting, clean energy, infrastructure, market incentives, funding and skills to facilitate decarbonisation investments.

The key role of EU policy

The following policies are indispensable to realise our ambition:

Implementing a watertight Carbon Border Adjustment Mechanism (CBAM) to level the playing field on CO_2

- Closely align CBAM with the rules of the EU Emission Trading Scheme (ETS) to ensure that EU industries and third countries compete under the same rulebook.
- Prevent CBAM fraud and evasion through robust monitoring systems and ensure a uniform implementation of CBAM across the EU, through close collaboration with national customs authorities.
- Develop an export solution that adheres to WTO regulations while protecting the EU industry against carbon leakage on exports.

Ramping up financial support for investments

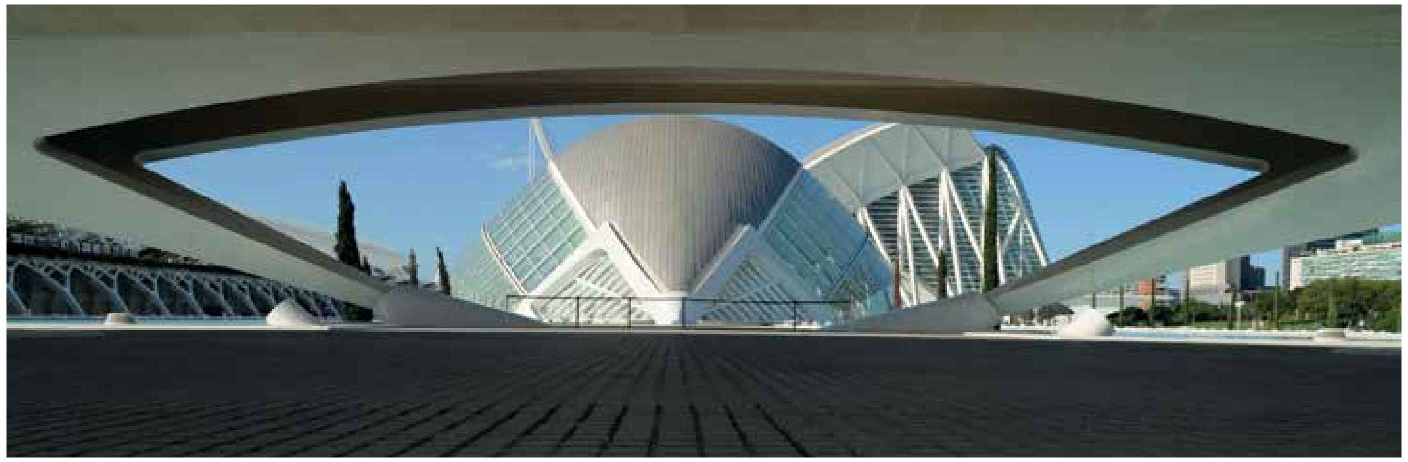
- Transform the ETS Innovation Fund into a genuine Cleantech Deployment Fund for energy-intensive sectors. Requiring an 'innovative aspect' for each project runs counter to the deployment phase we are in.
- Allocate at least 75% of the future payments by the cement sector into the EU ETS (approximately €80-100bn by 2034) through frontloading in a dedicated “cement fund” to help finance the deployment of large-scale transformation projects.
- Turn the National Energy and Climate Plans into proper industrial decarbonisation plans, with key measures to facilitate investments and de-risk projects (e.g. through Contracts for Difference).
- Pool national and European finance resources and provide support (covering both CAPEX and OPEX) through simple and coordinated procedures, adopting a one-stop-shop approach.

Guarantee access to affordable decarbonised energy, infrastructure and raw materials

- Provide access to decarbonised energy at a reasonable price.
- Introduce a sandbox/simplified permitting regime for the deployment of renewables on industrial sites.
- Support power prices stability and protect industrial customers in case of spike.
- Boost the internal electricity market through stronger interconnection.
- Provide fair access to CO_2 transport and storage infrastructure.
- Ensure continued access to sustainable bio-waste, alternative waste streams and raw materials.

Create lead markets for low carbon, circular products

- Define an EU low-carbon products strategy that sets a clear ambition for their uptake in 2030/2040 and supports the establishment of private buyer initiatives.
- Review public procurement rules and standards to create lead markets for low CO_2 products.
- Encourage demand incentives through progressive, predictable and material-neutral building regulations.
- Make a step change on the circular economy: ban the landfilling of waste, incentivise recycling processes, support the use of waste in industries and encourage circularity and life cycle thinking throughout the construction value chain.
- Recognise concrete carbonation and CO_2 use in construction materials as a carbon sink.



A joint effort

The relationship between industry and policymakers is often seen as conflictual. This is not the way we see things. When it comes to decarbonising cement and concrete in Europe, we share a common goal, and we are committed to make the relationship work in a symbiotic way.

The cement industry is characterised by an investment cycle of 30-50 years. Therefore, investment decisions aiming to fully decarbonise the industry by 2050 need to be made today. We can do our part, but a facilitating regulatory framework is an indispensable second part of the equation. That is why we need Europe and its Member States to have our back when it comes to our decarbonisation investments.

Alongside our key policy asks, we also identify in the following chapters the policy drivers needed to deliver the business case for each of the decarbonisation levers along the value chain.

The business case for scaling up

Most of these levers require significant financial investments. For example, it is beyond any doubt that there is no viable alternative to carbon capture when aiming for net zero cement and concrete production by 2050. In the last section of this roadmap, we provide some cost estimates, based on external sources. These funding needs make clear that, to deliver our roadmap's ambition, it is indispensable to put funding structures in place and provide a clear business case for investments.

> "To deliver our roadmap's ambition, it is indispensable to put funding structures in place and provide a clear business case for investments."

Compared to 1990, our roadmap estimates

-37%

of CO_2 emissions on cement by 2030

-78%

of CO_2 emissions on cement by 2040

-100%

of CO_2 emissions on cement by 2050

Cement and concrete are going circular

Circularity is an integral part of our net zero ambition, allowing for significant CO_2 reduction along the cement and concrete value chain. For the past decades, the European cement industry has promoted circularity by using waste materials in the production of cement, both as raw materials and as fuel in its kilns. End-of-life concrete has also been extensively used as a stabiliser in the construction industry. The past years have seen an accelerated pace in adopting new ways of increasing the role of cement and concrete in the circular economy.

Waste is a resource

Cement manufacturing has always relied on locally sourced raw materials, such as limestone. Over the past decades, we have steadily increased the use of a variety of locally sourced waste streams as raw material or fuel. By using waste for energy recovery or material recycling purposes in the cement kilns, our industry not only reduces recourse to primary fuels and materials but also avoids waste going to landfill.

As shown throughout this roadmap, we also have a symbiotic relationship with other industries, incorporating their waste into our production process, and we are continuously researching new decarbonated raw materials to be used in cement manufacturing.

Circularity is just down the road

Our commitment to circularity extends throughout our value chain. Concrete, the main product of cement, is fully recyclable into new aggregates for concrete or road construction. Moreover, our roadmap includes plans to use recycled concrete fines as supplementary cementitious materials.

Buildings go circular

Concrete buildings lend themselves well to circularity; converting an office building into a residential one, for example, is more feasible with concrete structures. Deep renovation projects, common in cities like Brussels, often preserve existing concrete structures, renovating around them.

Circular Carbon

In our journey towards decarbonisation, carbon capture and utilisation presents additional circular opportunities. Projects are underway to capture CO_2 emissions from cement kilns and convert them into e-fuels, feedstocks for the chemical industry, catalysts for algae cultivation, or to carbonate construction waste.

“The industry recognises the need for reskilling and upskilling its workforce to meet challenges related to climate change, biodiversity, and resource scarcity.”

Skilling up for the future

The industry recognises the need to take its workforce along on its path to decarbonisation. This does not only involve reskilling and upskilling workers to meet challenges related to climate change, biodiversity, safety and resource scarcity. We also need to invest in communicating internally about the decarbonisation efforts made and turn all of our employees into ambassadors for the contribution cement and concrete bring to the built environment of tomorrow.

Profiles Needed

The decarbonisation of the industry requires skills in carbon capture, alternative fuels, circular value chains, and digital expertise, including data analytics and AI. These skills are needed across all functions, including plant-specific roles. As an industry, we remain committed to social inclusiveness.

Education and Training

There is a need for better alignment between educational curricula and industry demands. The industry advocates for enhanced cooperation between industry and the educational system as well as practical and efficient education, including apprenticeships, to meet future needs. There are examples of successful practical education programs in countries like Germany, Ireland, and Cyprus.

Access to Skills/Shortages

Apart from green and digital transformations, demographic shifts lead to shortages in various profiles such as drivers, technicians, electricians and mechanical workers. Language skills and transport infrastructure to access the workplace are also crucial for workforce mobility and access to further training. CEMBUREAU collaborates with partners to forecast future skill needs and is ready to engage with European institutions on skills development and Industry 5.0 initiatives.

01. Clinker

Clinker is the backbone of cement production. It is essentially a mix of limestone and minerals that have been heated in a kiln and have been transformed by this heat. Our plants are built around the quarries where limestone is found which firmly anchors the cement industry in local communities all over Europe. When limestone is converted to clinker through calcination, CO_2 is released. These unavoidable process emissions account for 60%-65% of total cement manufacturing emissions.

The remaining CO_2 emissions relate to the combustion process in the kiln which operates at temperatures around 1450° C. Traditionally, the cement industry used fossil fuels for the combustion but as of 2021, the industry already sources 53% of its energy needs from alternative fuels taken from a variety of waste streams, that are sourced locally.

The vast majority of cement, mixed with water, sand and aggregates is used as a key ingredient in concrete. Thanks to the hydraulic binder properties of cement, concrete is a resilient, durable material.

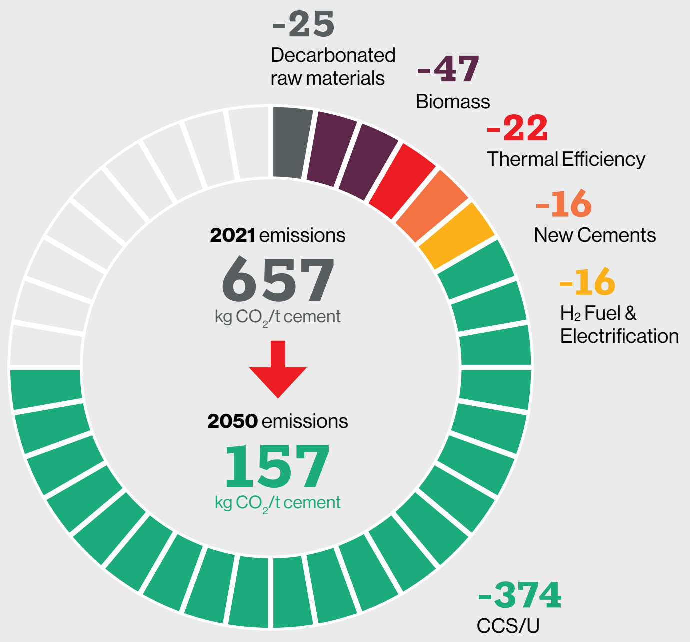
The industry already sources

53%

of its energy needs from alternative fuels

Clinker Emissions Reduction Pathways

In order to achieve our goals, we continue to focus our efforts on each of the decarbonisation levers along the 5 C value chain. As compared to the initial roadmap, several of the pathways have been changed based on progress to date.



Alternative Raw Materials

By 2030,

3.5%

reduction of process CO_2 using decarbonated materials

By 2050, up to

8%

reduction of process CO_2 using decarbonated materials

As most of the cement manufacturing CO_2 emissions originate from the clinker production, the cement industry is constantly looking to replace natural raw materials by alternative or secondary raw materials (ARM). These are waste materials or by-products from other (mainly industrial) processes or societal sectors. Typical wastes used as ARM in the clinker burning process include fly ash as a residue from the power sector, as well as used foundry sand and residues from the iron and steel manufacturing industry.

The use of alternative raw materials provides significant opportunity to decarbonise the EU cement industry whilst applying a circular approach and minimising waste.

Alternative materials are already used at scale at plants across Europe and the European cement industry is continuously looking at increasing their use.

Progress

The use of alternative sources of decarbonated materials is progressing. We maintain our objective of a 3.5% reduction of process CO_2 using decarbonated materials by 2030 and up to 8% reduction by 2050. This amounts to using 32 million tonnes of alternative raw materials a year in 2050.

Challenges & Opportunities

- The increased use of alternative raw materials is dependent on their availability.
- The cement sector turns its focus on new materials that are expected to come up or increase, like concrete fines, slags from non-ferrous metal production, contaminated soils.

Innovation in Action

In Austria, the Retznei plant uses customised preprocessing equipment to make construction demolition waste, iron scrap, and ashes suitable for cement production, allowing 30% of its raw materials to be sourced from recycled products.

At the Rudniki plant in Poland, the decarbonised waste raw materials now account for over 13% of clinker's material input.

The role of policy

The access to alternative raw materials can be encouraged through a variety of measures. Policymakers should:

- Explore material recycling options through an EU-wide mapping and facilitated access to historical landfills through simplified permitting procedures.
- Review country waste management policies & programs/plans to recognise the potential of recovered materials (from historic landfills) in enabling circularity.

Fuel Substitution and Zero Emission Fuels Research

By 2050,

95%

alternative fuel used in clinker production

including

50%

bio-waste use

With 35% to 40% of its overall CO_2 emissions stemming from combustion emissions, the cement industry has made significant strides to replace fossil fuels with alternative fuels sourced from a variety of waste streams. The ambition is to achieve a 95% alternative fuel use by 2050 (with 50% bio-waste) from the 53% today.

Through co-processing, the cement sector is a central player in the circular economy, significantly contributing to local waste management and municipal strategies. By substituting fossil fuels with alternative waste streams, the industry not only reduces CO_2 emissions but also mitigates emissions that would occur from incineration or methane release in landfills.

Progress

The sector made significant progress over the past years, with alternative fuels accounting for 53% of the sector's fuel mix in 2021, against 46% in 2017 and an original 2% in 1990. We are therefore maintaining our objective to reach 60% alternative fuels containing 30% bio-waste in 2030 and increasing our 2050 objective to 95% alternative fuels with 50% bio-waste by 2050. We have also set ambitious objectives for 2040. Besides the substitution of fossil fuels, the first uses of hydrogen and electrification of kilns are being experimented and we therefore maintain our objectives for these.

Challenges & Opportunities

- The EU cement sector will need to secure access to significant volumes of sustainable bio-waste.
- The circular role of co-processing in cement plants, which allows both to recover energy from waste and recycle its material content, plays a decisive role in reducing our reliance on fossil fuels and materials.

The role of policy

The cement sector will need to have access to significant quantities of waste and low carbon fuels to deliver against its roadmap and make a decisive contribution to the circular economy. Policymakers should:

- Ensure sufficient and long-term access to zero-rated sustainable biowaste.
- Acknowledge the dual benefits of material recycling and energy recovery achieved through co-processing in the cement sector.
- Count the portion of materials effectively recycled through co-processing towards Member States recycling targets under the Waste Framework Directive.

Innovation in Action

Phasing out our fossil fuels through co-processing

Several cement plants throughout the European Union are surpassing co-processing rates of 90%, employing innovative methods to recycle raw materials effectively.

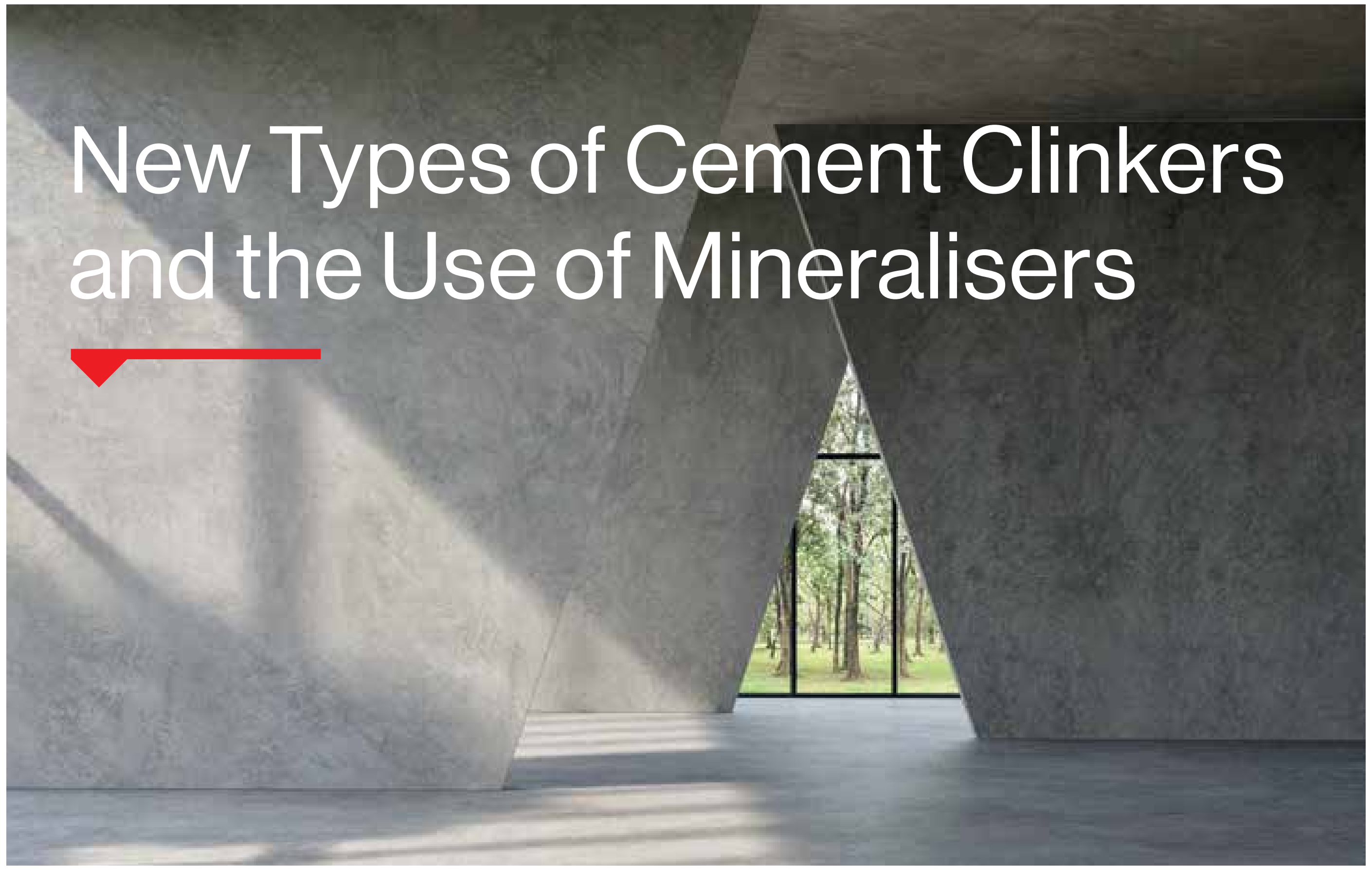
Check out co-processing case studies from across Europe

Using de-commissioned wind turbine blades to reduce emissions

Using decommissioned wind turbine blades presents an innovative solution for reducing emissions in the cement industry. Through co-processing, end-of-life composite materials, such as wind turbine blades, can be recycled in a circular manner. Cooperation between industry sectors, like the Kimura project in Finland, aim to integrate crushed composite materials into cement production processes efficiently, minimising residual waste. The structural waste from wind turbine blades serves as a valuable raw material in clinker production, leading to a significant decrease in CO_2 emissions.

Hydrogen in Cement Production

Moreover, the cement industry is actively exploring alternative energy sources to further mitigate its environmental impact. Some plants in Europe have already begun incorporating small amounts of hydrogen into their operations, with ongoing investigations into scaling up its usage. For example, the H2CEM project in Greece focuses on producing green hydrogen at various cement plants. Additionally, initiatives like the CEMZERO project in Sweden have explored the possibility of fully electrifying cement production, while Finland has launched a new project in collaboration with Coolbrook to pursue similar goals. Furthermore, several EU cement companies are considering harnessing solar power for their production processes, with projects in partnership with Synhelion in Spain among the frontrunners of these efforts.



New Types of Cement Clinkers and the Use of Mineralisers

By 2030,

2%

reduction in process CO_2 emissions

By 2050, up to

5%

reduction in process CO_2 emissions

New types of cements have been developed. Examples of these types of cements are Aether, Alpenat and Ternacem (Belite-Ye'elimiteFerrite) and Futurecem (Calcined Clay Limestone Cement). These cements typically have a 20 – 30% lower carbon footprint than Ordinary Portland Cement (CEM I). The CO_2 savings for these new cements have been included under the clinker stage, as they will result in a reduction of calcination emissions and also the thermal energy to make the clinker. However, it is important to acknowledge that these novel cements have unique characteristics which limit their applicability to niche markets.

Progress

New cement clinkers are being researched on but there are limits in their application and market acceptance.

We therefore maintain our objective of a 2% reduction in process CO_2 emissions by 2030 and 5% by 2050.

Challenges & Opportunities

- The development and production of these new types of cement clinker would need to be scaled up to industrial scale.
- Cement made using these new clinkers would need to be authorised in building codes and product' standards.

Innovation in Action

- In Germany, the Celitement project focuses on crafting cements with reduced lime content or a modified calcium-to-silica ratio.
- Portugal's X-clinker method enables the utilisation of conventional raw materials like limestone, clay, marl, and sand through a process of raw mixture fusion at 1550 degrees, requiring significantly less limestone compared to traditional methods.
- CSA (Calcium Sulfoaluminate) Cement presents an opportunity for reduced energy consumption, as it requires lower temperatures in both cement kiln operation and grinding processes.

The role of policy

The cement sector needs an agile standardisation process to recognise new cement types. Policymakers should:

- Keep the current composition-based standards system in place whilst introducing, in parallel, a complementary, more performance-based system. Such a dual approach should facilitate the standardisation of new low-carbon products, whilst ensuring the safety and reliability of cements put on the European market.

Thermal Efficiency

"Energy efficiency investments already made allow the cement industry to reach a thermal efficiency level of 70%-80%, depending on raw material moisture content."

The European cement industry already operates efficiently, typically within a range of 70 to 80%. While already very efficient, enhancements can further boost the thermal efficiency of certain kilns. This can be achieved by converting preheater and other kiln types into precalciner kilns and by harnessing heat from the cooler to help meet the electricity requirements.

Progress

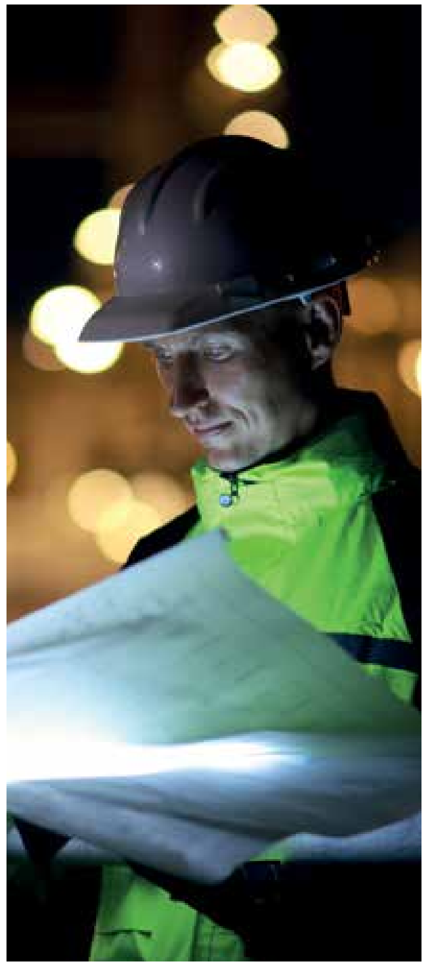
Upgrades of thermal efficiency in plants across Europe have been implemented, but this lever is limited given the already high efficiency of most kilns. We therefore maintain our existing objectives.

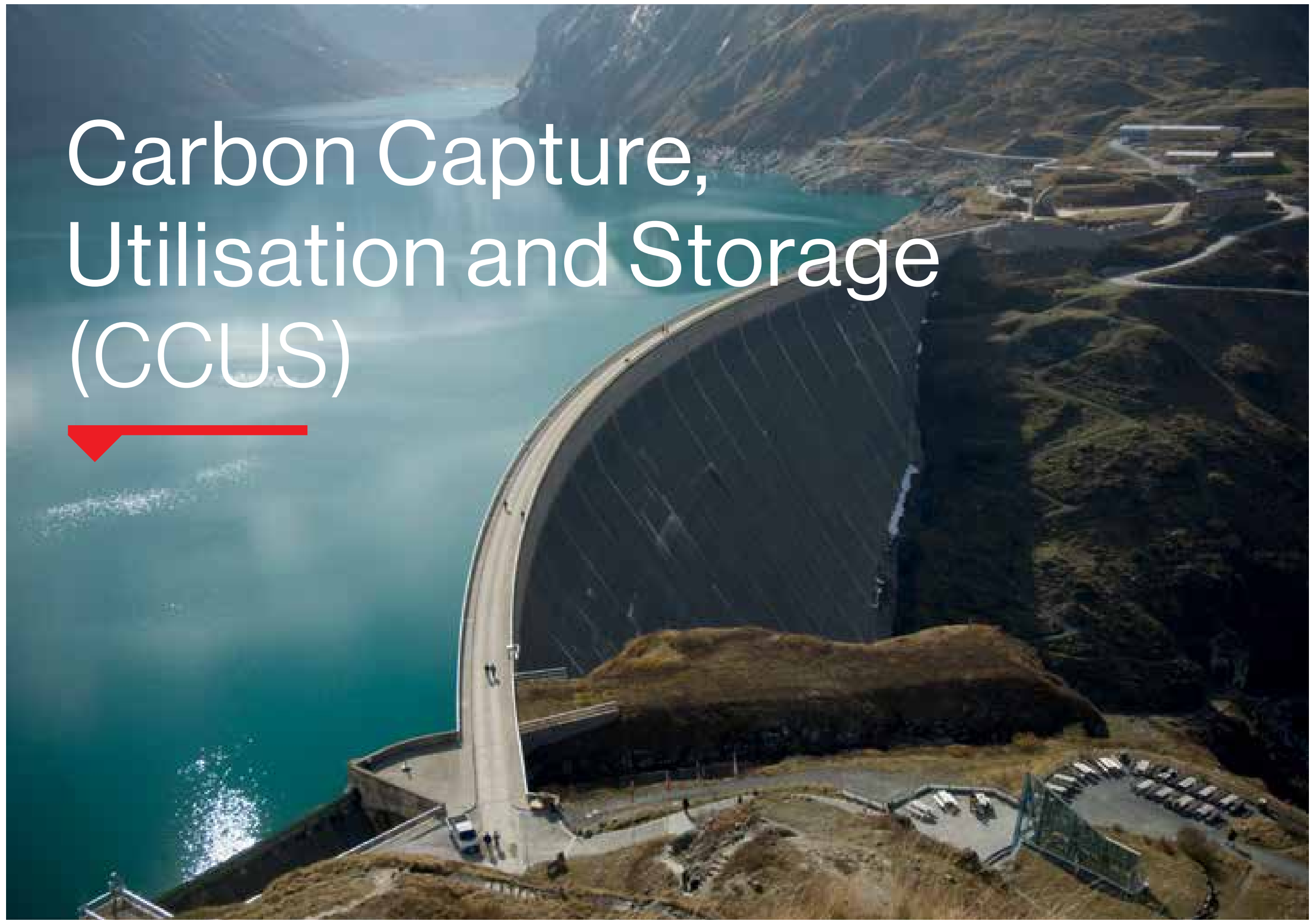
Challenges & Opportunities

- Most European kilns already operate at a very high level of efficiency.

Innovation in Action

- Harnessing power generated from waste heat, the Rohrdorf plant in Germany converts the high temperatures required for cement production into electricity. By using waste heat recovery technology, the plant efficiently transforms the heat emitted from the flue gases into electrical energy. This innovative approach covers **approximately 30% of the plant's electricity requirements**.





Carbon Capture, Utilisation and Storage (CCUS)

Over

30

projects looking at the CCUS technology across Europe

By 2050, potential of up to

62 Mt

of CO_2 being captured every year

The role of CCUS in curbing CO_2 emissions from cement plants is crucial.

CCUS technology can capture CO_2 emissions from cement plants before they are released into the atmosphere. The captured CO_2 can then be routed to geological formations, such as depleted gas fields or saline aquifers, for permanent storage or used in concrete production or for the manufacturing of new products.

The fast deployment of CCUS and its development are essential for advancing the technology, making it more cost-effective and allowing for deep CO_2 cuts. As more cement plants adopt CCUS technology, economies of scale can drive down costs and improve efficiency, making it a more attractive option for widespread implementation.

Carbon capture can be integrated into a circular economy framework, where captured CO_2 is used in other industrial processes or converted into valuable products such as synthetic fuels, chemicals, or construction materials. This integration allows to decarbonise other hard-to-abate sectors and cut the EU's reliance on fossil CO_2.

The deployment of CCUS holds significant potential for the European cement industry to reduce its carbon footprint, meet sustainability goals, and contribute to global efforts to combat climate change. It also positions the sector firmly on carbon removals, as the bio-waste used in cement production can also be captured, resulting in negative emissions.

Progress

There has been considerable progress on CCUS development in the cement sector in recent years, with over 30 projects looking at the technology across Europe. Many projects are now foreseen to be operational before 2030, allowing to permanently store up to 12 million tonnes of CO_2 yearly by then. We have therefore quantified the CO_2 emissions reduction from CCUS as part of our 2030 objectives, and increased our ambition at a 2050 horizon, amounting to up to 62 million tonnes of CO_2 being captured every year.

Challenges & Opportunities

- CCUS projects are highly capital-intensive and require financing to de-risk the full CCUS value chain. Operational costs are equally significant.
- The mapping of a pan-European CCUS infrastructure has been initiated but is still largely incomplete. Time is of the essence to build the infrastructure or repurpose the existing assets.
- Regulatory uncertainty around CO_2 use seriously hampers investments in CCU projects.

Innovation in Action

Carbon capture in action: paving the way towards carbon neutral cement

The first cement plant capturing and storing CO_2 at industrial scale is targeting mechanical completion at the end of 2024 in Norway through the Brevik CCS project. The following projects are currently supported by the EU ETS Innovation Fund, and are planned to be operational by 2030:

- **In Belgium**, Go4Zero will look at both permanent CO_2 storage and CO_2 utilisation in industrial products.
- **In Bulgaria**, the ANRAV project aims to be the first full-chain CCUS project in Eastern Europe and will permanently store CO_2 from the cement plant in the Black Sea.
- **In Croatia**, the Kodeco project will create an end-to-end CCS value chain.
- **In France**, the K6 project will look at storing CO_2, whilst the eM-Rhône project looks at re-using captured CO_2 to produce methanol, for use in the shipping and chemical industries.
- **In Germany**, the GeZero project is a full-scale CCS project, whilst the Carbon2Business looks at re-using the captured CO_2 – which will be converted to e-methanol through methanol synthesis or reprocessed as a raw material, for example to produce plastics.
- **In Greece**, both the IFESTOS project and the Olympus project will capture CO_2 from cement plants and permanently store them in geological storage sites.
- **In Poland**, the GO4ECOPLANET project will capture the plant's CO_2 emissions to transport them to the North Sea.

The cement sector aims to capture up to

14 Mt

of CO_2 per year by 2030

50 Mt

of CO_2 per year by 2040

62 Mt

of CO_2 per year by 2050

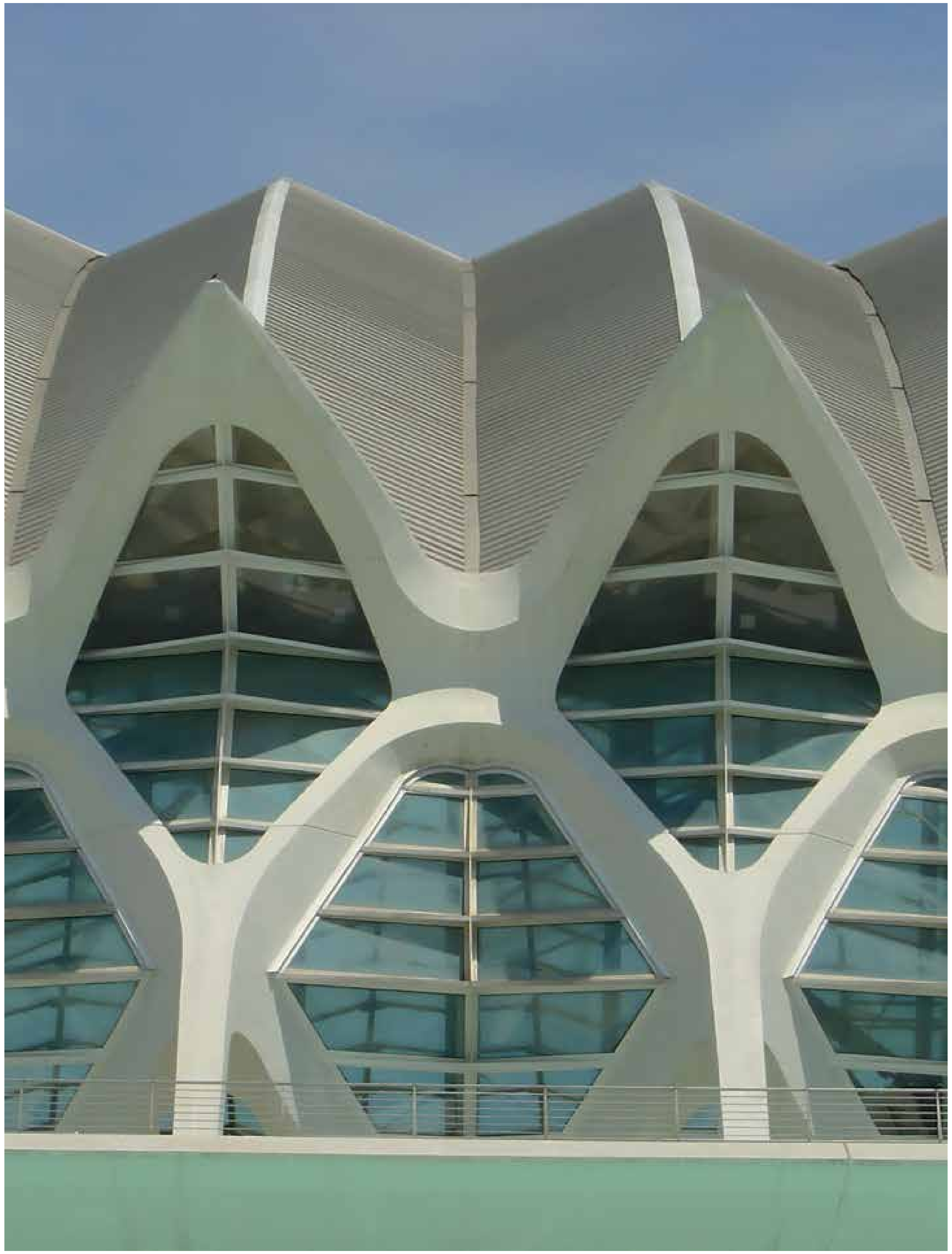
The role of policy

Provided the right regulatory framework is in place, the cement sector can capture up to 14 million tonnes of CO_2 per year by 2030, 50 million tonnes by 2040, and 62 million tonnes by 2050. Deploying cutting-edge technologies like carbon capture requires substantial investment in innovation and support infrastructure. Policymakers should:

- Expedite CO_2 infrastructure deployment at national level, including pipelines and storage sites, so that each cement plant has access to CCUS infrastructure.
- Address bottlenecks in CO_2 infrastructure, such as permitting and pipeline location restrictions.
- Eliminate unjustified zoning restrictions and facilitate cross-border transport via clear minimum EU-wide standards for CO_2 specifications and recognition of all transport modes.
- Streamline permitting processes for carbon capture development (including renewable power supply) and prioritise carbon capture infrastructure as being of "overriding public interest".
- Guarantee access to CO_2 infrastructure- storage and transport- under reasonable and transparent commercial terms, avoiding unrealistic volume commitments.
- Clarify the role of carbon removal certificates with the aim to include these into the EU Emission Trading Scheme.
- Promote public understanding of CCUS challenges and facilitate project acceptability through positive and transparent communication.

Carbon Capture and Utilisation (CCU) is vital to decarbonise the sector. Policymakers should:

- Recognise the benefits of a circular use of CO_2 to decarbonise hard-to-abate sectors such as chemicals or transport whilst tackling unavoidable process/geogenic emissions from industrial sectors.
- Support CCU specifically for sectors faced with unavoidable process/geogenic CO_2 emissions and allow for the use of CO_2 from these sectors in products (fuels, chemicals, etc.) past 2050.
- Differentiate "fossil" CO_2 from unavoidable process/geogenic emissions CO_2.
- Taking into account future CO_2 needs in a variety of applications, carry out an impact assessment assessing the sources and quantities of CO_2 feedstock supply with inclusion of CO_2 from unavoidable process emissions.
- Provide a clear regulatory framework for CCU, recognising that CO_2 emissions need to be accounted for at the point of release into the atmosphere.
- Acknowledge permanent CO_2 mineralisation as a CO_2 sink equivalent to CO_2 storage, thus unlocking additional economic and circular decarbonisation routes.



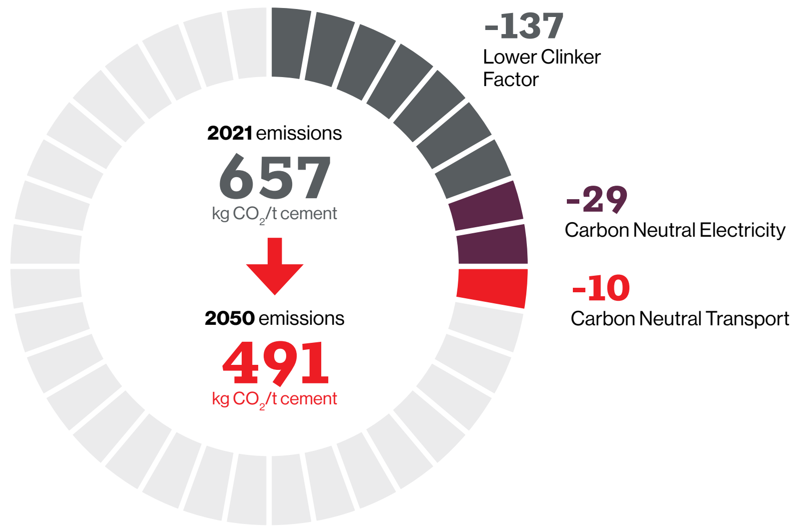
02. Cement

After its production, clinker is mixed with gypsum and supplementary cementitious materials (SCMs) followed by grinding to the appropriate fineness to produce cement. This stage does not involve further process emissions. However, electricity is consumed for grinding and mixing operations, and both raw materials and final cement products require transportation.

To reduce emissions from cement production, several opportunities exist. Firstly, adopting cements with reduced clinker content can lead to substantial emission reductions. Additionally, ensuring a dependable and cost-effective supply of renewable energy, along with exploring zero-carbon alternatives to diesel for industrial vehicles, can further mitigate emissions during the cement manufacturing process.

Cement Emissions Reduction Pathways

One of the key levers in decarbonising cement production is the reduction of the clinker-to-cement ratio as clinker is the most CO_2-intensive part of cement production. With the decarbonisation of the steel and energy sectors, granulated blast furnace slag and fly ash inevitably become less available over time. Identifying new suitable materials to reduce the clinker to cement ratio is therefore a key priority for the European cement sector.



Low Clinker Cements

Today, on average, 23% of clinker was replaced with SCMs, which corresponds to a

77%

clinker-to-cement ratio

By 2050, we aim for

60%

clinker-to-cement ratio

The adoption of low clinker cements has gained momentum over the past decades, and cements with very low amounts of clinker are already available on the market today. In Europe, the clinker to cement ratio stood at 77% in 2021. This means that, on average, 23% of clinker was replaced with supplementary cementitious materials (SCMs) like granulated slag from steel blast furnaces and fly ash from coal-fired power plants.

Download our FAQ on clinker to cement ratios

Progress

Constant innovation is ongoing to look for alternative materials to replace clinker, with new substitutes (calcined clay, recycled concrete fines) being developed. We have set a more ambitious objective, aiming for a 60% clinker-to-cement ratio by 2050, which amounts to 66 million tonnes of supplementary cementitious materials being used in cement installations every year.

Challenges & Opportunities

- The EU cement sector is therefore constantly on the lookout for new sources for these SCMs (e.g. recuperation from landfills) as well as alternative SCMs such as calcined clay, recycled concrete fines, natural pozzolans, etc.
- Not all potential SCMs could replace clinker without risks on the durability and strength of concrete used or without specific design provisions. A sizable amount of clinker per tonne of cement will always be needed, with the amount of SCMs used depending on their individual properties and qualities.

Innovation in Action

Harnessing the potential of calcined clay

The Xeuilley's cement plant in France is currently in the process of constructing a facility for producing calcined clay as part of the Argilor project. This process will enable the substitution of clinker, resulting in a reduction of up to 16% in CO_2 emissions compared to traditional cement products. Similarly, the Saint Pierre La Cour cement plant aims to establish an advanced production line for calcined clay, with the capacity of up to 500,000 tonnes of low-carbon cement annually. Similar projects are ongoing across the EU, exemplified by projects like Calliste in Denmark, which seek to further optimise the use of calcined clay in cement production.

Exploring Supplementary Cementitious Materials

Throughout Europe, cement plants are actively exploring avenues to augment the incorporation of SCMs in cement manufacturing. In addition to existing SCMs, the industry is actively researching potential alternatives. For example, in Denmark, the CemShale/CemTower project focuses on a process involving the calcination of shale to produce a high-performance clay mineral based SCM. Meanwhile, the CO2 Valorize project investigates the SCM potential of waste materials such as mine tailings and recycled concrete. Recycled concrete fines present another promising avenue, with numerous plants already implementing this technology across the EU.

The role of policy

The European cement industry is actively exploring the substitution of clinker with SCMs. To achieve our goals, we require access to significant quantities of clinker substitutes (such as fly ash, steel slag, calcined clay...). Policymakers should:

- Develop a coherent policy framework allowing for access to landfills, including historical (closed) sites.
- Develop ambitious waste management policies to incentivise the recovery and use of materials from industrial waste as SCMs, facilitate waste shipment between EU countries, discourage landfill and minimise exports of waste outside the EU.
- Acknowledge recovered materials (such as reclaimed / beneficiated fly ash) as secondary materials (i.e. no longer waste after processing).

Renewable Electricity

As the sector decarbonises, we will need an increased amount of electricity across all decarbonisation levers, from drying new types of alternative raw materials, developing new clinker substitutes to operating carbon capture installations. This increased demand will need to be met by decarbonised energy sources.

Transport

Transportation currently contributes 1.5% of the overall CO_2 emissions in cement manufacturing. This encompasses the movement of materials within the quarry and cement plant, the transport of raw materials and fuels to the plant, and the delivery of cement products to consumers. Extensive investments are underway to deploy industrial-scale vehicles suitable for both on-site quarry and plant operations as well as on-road transportation. These efforts include the commissioning of BEVs, hybrid vehicles, renewable fuels, and hydrogen.

Progress

The EU cement industry is looking at ways to reduce energy consumption and develop on-site electricity generation.

"The decarbonisation of the cement industry will entail an increase in energy demand from 20 TWh in 2021 to a range between 47 TWh and 113 TWh in 2050."

Challenges & Opportunities

- The decarbonisation of the cement industry will entail an increase in energy demand from 20 TWh in 2021 to a range between 47 TWh and 113 TWh in 2050. The wide range is explained by the fact that each company will choose its own path to decarbonisation. Some technologies such as CCU may, depending on the type of CO_2 usage, require significant amounts of electricity.
- On-site renewable generation is being deployed across European cement plants but is sometimes confronted with slow permitting procedures.

Innovation in Action

The objective of the Clean Cement line project in Portugal is to pioneer a new cement production technology at an industrial scale. The goal is to reduce CO_2 emissions by a minimum of 20%, enhance energy efficiency by 20%, and achieve a 30% electricity generation boost. This will be accomplished through an innovative hybrid generation system that harnesses heat recovery from the manufacturing process alongside concentrated solar thermal energy.

The role of policy

With the decarbonisation of the cement sector, our electricity demand will significantly increase in the coming decades. Policymakers should:

- Ensure access to decarbonised energy at a reasonable price that preserves EU industries' global competitiveness.
- Introduce a sandbox/simplified permitting regime for the deployment of renewables on industrial sites.
- Support power prices stability and protect industrial customers in case of a spike in energy prices.
- Boost the internal electricity market through stronger interconnection.

Find out more in the TNO Report

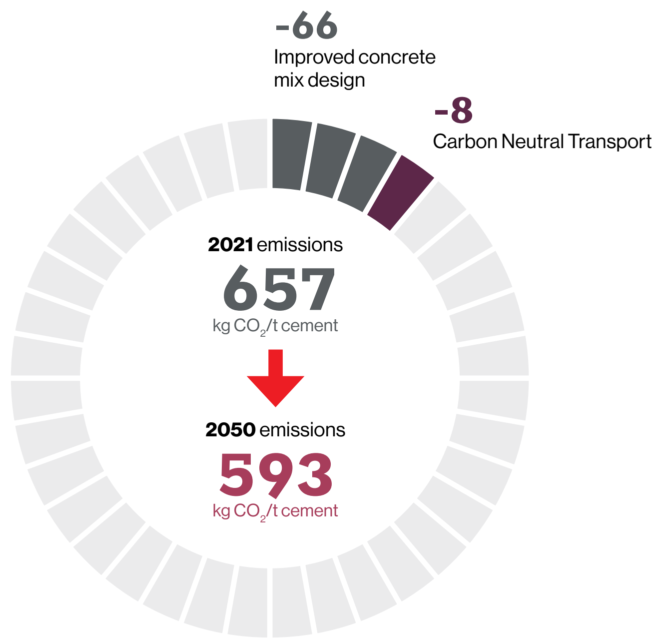
Cement is primarily used to produce concrete, the second most used material globally after water. Its production entails blending cement with water and aggregates, along with minimal amounts of chemical admixtures aimed at enhancing concrete properties and fulfilling particular standards. Cement typically constitutes approximately 10-15% of this composite mixture. Notably, the principal CO_2 emissions associated with concrete stem from cement manufacturing, while some indirect emissions arise from the transportation of concrete to the construction site.

The decarbonisation of the cement sector allows to bring low carbon concrete to market. Low carbon concrete will be the material of choice for deep emission reductions in the building sector, thanks to its multiple advantages, including thermal mass. Low carbon concrete will also be an essential input for renewable energy assets and mass transit transport.

03. Concrete

Concrete Emissions Reduction Pathways

We maintained our existing ambition, considering the potential of lower CO_2 concrete mixes.



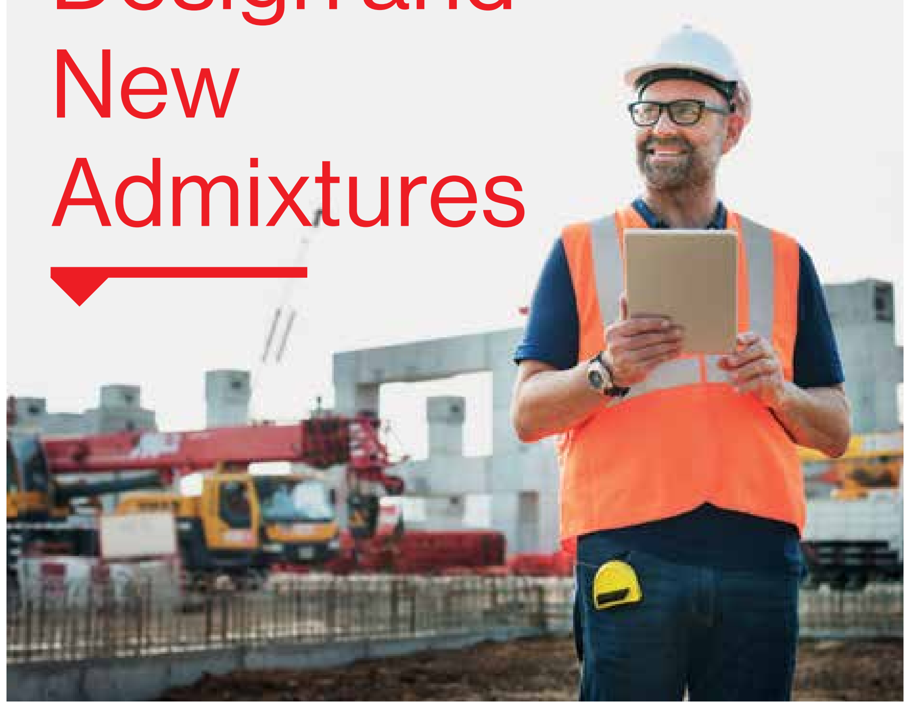
Transport

Transporting concrete to construction sites and pumping it requires significant amounts of energy, contributing substantially to CO_2 emissions. By 2050, it is anticipated that most transportation will be accomplished using zero-emission vehicles powered by electric, renewable fuels, hydrogen, or a hybrid of both technologies.

PROGRESS

The original ambition has been maintained, based on the expected decarbonisation rate from the transport sector. Extensive investments are underway to deploy industrial-scale vehicles suitable for concrete deliveries. These efforts include the commissioning of electric vehicles, hybrid vehicles, renewable fuels, and hydrogen.

Digitalisation, Improved Mix Design and New Admixtures



Low carbon cements and the use of cement substitutes

Using low carbon cements and incorporating cement substitutes in concrete production can significantly diminish the carbon footprint associated with concrete. By integrating materials such as fly ash, granulated slag, silica fume, pozzolan, and others during the manufacturing process, substantial CO_2 savings are achieved, with these reductions already factored into the initial cement manufacturing phase.

Producing concrete with less cement

Since cement is the most carbon intensive component in the concrete mix, using less cement whilst guaranteeing performance, will impact the carbon intensity of the concrete. Selecting the most optimised concrete type can also promote the use of lower-cement formulations.

Promoting Circularity

Embracing innovative concrete blends featuring recycled aggregates can avoid waste and promote recycling of demolition waste.

Digitalisation

The digitalisation of construction processes presents significant opportunities for reducing CO_2 emissions associated with concrete usage. Enhanced data collection and processing capabilities will empower builders to accurately estimate the required amount of concrete for each project, thereby minimising waste.

Additionally, digital tools can facilitate real-time monitoring of concrete transportation and ensure precise pouring on-site. Accessible data on cement and concrete composition will enable contractors and building purchasers to assess the carbon footprint of construction activities and trace the origin of materials used.

Furthermore, digitalisation allows for continuous monitoring of building energy performance over time.

Progress

We maintained our ambitions for this pathway.

Challenges & Opportunities

This pathway will enable immediate emissions reduction but requires the adoption of new practices in the concrete and construction sector.

Innovation in Action

Advancing Concrete Innovation

In France, the Recygenie initiative aims to construct a building using entirely recycled materials, from cement to aggregates and water. Simultaneously, research endeavours are rapidly progressing in the realm of novel concrete formulations, such as the Lightcoce project, which focuses on scaling up lightweight and multifunctional concrete.

Harnessing 3D Printing for Sustainable Construction

Concrete is ideal for 3D printing in construction, presenting an avenue for both cost-effective housing solutions and significant reductions in CO_2 emissions through minimised concrete usage. Rapid advancements are evident in various areas, including the construction of 3D-printed bridges, as seen in the Phoenix project, in Switzerland, the construction of Europe's largest 3D-printed building to date in Germany, and the refinement of 3D printing technologies, exemplified by the Lithosys project in France.

The role of policy

The cement sector needs an agile standardisation process to ensure the timely adoption of standards and the development of low-carbon construction products. Policymakers should:

- Keep the current composition-based standards system in place whilst introducing in parallel a complementary, more performance-based system. Such a dual approach should facilitate the standardisation of new low-carbon products, whilst ensuring the safety and reliability of cement and concrete put on the European market.
- Encourage demand incentives through progressive, predictable and material-neutral carbon building regulations, whilst guaranteeing a high level of insurability for structures and an identical level of safety between construction solutions.

The circular use of concrete should be promoted to reduce material demand and encourage recycling. Policymakers should:

- Set higher targets for recycling Construction & Demolition Waste (CDW) to boost concrete recycling rates and avoid the landfilling of waste. These targets should be in line with the market demand for recycled materials.
- Encourage demand-led incentives for the most appropriate products to support eco-design, rather than imposing specific values that are often inconsistent with the resources and means of each market.
- Adopt an ambitious waste management framework which would discourage the use of landfills for CDW, support the development/deployment of collection, sorting and recycling processes, while prohibiting exports of waste outside the EU.
- Establish clear standards and transparent procedures for supplying recycled aggregates to the market.

Structures must be safe, durable, and affordable, addressing the social aspect of sustainability. Secondly, there is a pressing need to enhance CO_2 and energy efficiency, aligning with environmental priorities. Lastly, construction and renovation efforts must continue to drive economic growth and job creation, as underscored by initiatives like the Renovation Wave initiative under the Green Deal.

Concrete emerges as a standout solution that fulfils these criteria effectively. It embodies versatility and cost-effectiveness, making it a cornerstone material in construction. With a lifespan exceeding 100 years, concrete offers inherent fire resistance and contributes to significant energy savings, reducing heating and cooling demands by up to 25%.

04. Construction

Concrete Emissions Reduction Pathways

Concrete Emissions Reduction Pathways and circularity can go hand in hand by changing the way we design and build structures. Not only can we build using less materials, but we can also increase the energy efficiency of buildings thanks to the unique properties of concrete.

Energy Efficiency

Currently, approximately 72% of the total CO_2 emissions associated with an average building stem from the energy consumed during its operational phase. Buildings that harness the thermal mass attributes of concrete have the potential to reduce energy consumption by 25% to 50%, particularly during peak demand periods.

The role of policy

Substantial reductions in CO_2 emissions are achievable by implementing policies that address the entire life cycle of cement and concrete. Policymakers should:

- Maintain a holistic "life cycle", material-neutral perspective in all policies aimed at promoting sustainability and circularity.
- Avoid policies that stop at the factory gate and instead consider the benefits of products throughout their lifetime.

Deep CO_2 emissions reduction can be secured at the building level through a more efficient use of concrete and forward-looking architectural practices. Policymakers should:

- Embrace a Whole Life Carbon strategy, looking at both operational and embodied carbon, to effectively reduce CO_2 emissions in the construction sector.
- Champion a comprehensive, material-neutral approach that considers the entire lifecycle of materials to drive decarbonisation efforts across European buildings.
- Work throughout the construction value chain to encourage architectural best practices and reduce the construction sector's carbon footprint.

Design for Adaptability and Disassembly

The construction sector is increasingly interested in embracing the "design for deconstruction" approach. This entails conceiving buildings with the intention of easily dismantling them at the end of their lifespan. Such an approach enables materials and components to be efficiently reclaimed and reused in constructing new buildings.

Moreover, existing structures can be repurposed for a different use. Office buildings are often designed with versatility in mind, enabling them to serve different purposes. For instance, an office block can be repurposed into an apartment building should the demand for office space decrease in the area. Concrete's durability and longevity make it particularly suitable for accommodating shifts in market demands. Rather than demolishing older buildings outright, there is a growing trend towards repurposing their concrete structures for new uses.

Innovation in Action

Greening Europe's cities through concrete innovation

Throughout Europe, cities are aiming to reduce their carbon footprint, enhance energy efficiency, and embrace renewable energy sources. A cornerstone of this endeavour lies in sustainable construction practices employing concrete.

The success stories are numerous and diverse. From employing low CO_2 cement for constructing bridges in Dubrovnik, to utilising precast concrete for solar parks in Lisbon, erecting hydro-plants in Salzburg, and envisioning buildings crafted from recycled concrete in Milan and Paris, to repurposing ageing concrete structures in Brussels, the cement and concrete value chain offers a wealth of solutions for nurturing sustainable urban environments.

Explore the sustainable construction project examples

More efficient use of concrete

Innovation and increased efficiency in structural design could potentially reduce embodied carbon by up to 30% in specific building types. Additionally, advancements in construction, such as 3D printing, offer further opportunities for improvement.

Optimising concrete usage in construction projects could decrease concrete use by 5 to 10% in the short terms and by as much as 10 to 30% by 2050.

05. Carbonation

Concrete carbonation refers to the chemical reaction between carbon dioxide (CO_2) from the atmosphere and the calcium hydroxide ($Ca(OH)_2$) present in the cement paste of concrete. This reaction forms calcium carbonate ($CaCO_3$), water (H_2O), and releases heat. The process occurs over the lifetime of the concrete structure.

This chemical reaction turns concrete structures into carbon sinks, slowing absorbing and sequestering a significant proportion of CO_2 released during the production of the clinker.

Moreover, promoting re-carbonation of concrete construction waste, using processes that accelerate and promote the chemical reaction (such as exposure of the ground waste to the ambient air) can lead to the sequestration of large amounts of CO_2.

Concrete carbonation is increasingly recognised by scientific institutions. The Intergovernmental Panel on Climate Change (IPCC) acknowledged in its 2021 report the “cement carbonation sink”, and, most recently, the Global Carbon Budget made detailed calculations on the carbonation uptake of cement. This adds to many studies published on the topic in recent years, notably by the Swedish Environmental Research Institute, IVL.

Opportunities and challenges

- The rate of concrete carbonation is impacted by a variety of factors including porosity, moisture and cement type, and the reaction happens over years.
- An increasing number of cleantech and cement companies are looking at concrete's CO_2 storage potential, including for the storing of biogenic CO_2 as carbon removals.

Concrete carbonation in the built environment

In the built environment, concrete infrastructure undergoes natural carbonation. IVL research indicates that 23% of the CO_2 emissions generated during the cement manufacturing process are captured annually.

Innovation in Action

Enhancing the carbonation capacity of concrete to mitigate emissions down the supply chain

Projects like Zephyr Ost in Switzerland leverage CO_2-enriched recycled aggregates, sourced from wastewater treatment plants, to produce fresh concrete. Similarly, initiatives such as Circo2beton in France and ReConcrete-360° in Germany explore using hardened cement paste from demolished structures to absorb CO_2, thereby serving as a long-term carbon sink.

Using concrete for permanent carbon removals

Leading companies such as Neustark, CarbonCure, and Heirloom are exploring avenues to permanently embed CO_2 within concrete materials. Coupled with the capture of biogenic emissions, this approach presents an opportunity for generating negative emissions and facilitating carbon removal through mineralisation.

Enhanced carbonation of recycled concrete

Carbonation rates increase following the demolition of a concrete building. This is attributed to the higher surface area of recycled concrete aggregates, allowing for more efficient absorption of CO_2 from the surrounding air into the concrete paste (comprising cement, water, and sand).

Initial studies indicate that this process can be expedited by using exhaust gases from cement kilns, which contain elevated levels of CO_2 and are at higher temperatures, resulting in a potential increase of up to 50% in CO_2 capture from process emissions. Moreover, separating the aggregates from recycled concrete and grinding the cement paste facilitates even greater CO_2 capture. This approach offers the additional benefit of producing a material suitable for use as a clinker replacement in cement production.

The role of policy

Concrete carbonation effectively turns our cities into carbon sinks. Its benefits can be enhanced through targeted policies. Policymakers should:

- Incorporate the CO_2 absorption facilitated by concrete structures and infrastructure into national greenhouse gas inventories.
- Acknowledge CO_2 mineralisation (in particular through the carbonation within secondary aggregates and concrete) as a form of permanent CO_2 storage, thus allowing for carbon removals when biogenic or atmospheric CO_2 is used.
- Fully harness the potential of carbonation in building policies (for instance, architectural design and buildings end-of-life strategies) to maximise concrete carbonation.
- Recognise concrete carbonation as a carbon removal when arising from the production of carbon neutral cement.

Assumptions, investments & external validation

Production forecast until 2050

In the absence of reliable and publicly available sources on the long-term evolution of the construction market, CEMBUREAU's roadmap update assumes a constant production level of cement until 2050. It is important to note the following points:

- On the one hand, the decarbonisation of the cement and concrete sector will result in a more efficient use of all materials along that value chain, starting from a lower clinker content in cement to using less cement in concrete, and a more efficient use of concrete in buildings.
- On the other hand, the bringing to market of low carbon cement and concrete will boost demand for our end product concrete which is an essential input for the EU's built environment. In Europe, 75% of the current building stock predates 1990. Achieving the EU's climate goals will require ramping up the renovation rate from the current 1% (0.2% for deep renovation) to 3%. Furthermore, the construction of wind turbines and other renewable energy assets will require large amounts of concrete. Our end product will also be an integral part of a climate resilient building design and climate-proof solutions for major new infrastructure works.

While maintaining a constant cement production level as an assumption, the sector is therefore confident that the market will effectively record a 1-3% yearly market growth by 2050.

Emissions accounting

Emissions accounting

CEMBUREAU's roadmap update uses the following emissions accounting methodology:

- Emissions from the use of bio-waste emissions are deducted, in line with the EU Renewable Energy Directive.
- For carbon capture and utilisation (CCU), the CO_2 captured is deducted at the level of the capturing plant when it is transferred for non-permanent use by a third party.
- For carbonation, CEMBUREAU has used a conservative value of 20% of the process emissions from cement production being absorbed into concrete structure, in line with the work of IVL. Other estimates (IPCC reports, Global Carbon Budget) foresee a higher carbonation uptake.

Gross and net emissions

The roadmap update maintains a 'gross' emissions approach – under which the emissions from the use of alternative fuels are accounted as fuel emissions – as this is in line with the methodology used in European legislation. As a complement to the gross emission figures, the update also includes a net emission figure in Annex 3, where the alternative fuels used are accounted as carbon neutral, reflecting the accounting methods of international cement associations.

Investment needs

The funding needs for carbon capture in the European cement industry across the main mature TRL levels are estimated to be in a range between EUR 200 million and EUR 500 million per plant. For more information, please see the Technology Papers published by the European Cement Research Academy (ECRA) in Annex 2. These estimates consider a wide variety of potential capture technologies and CEMBUREAU acknowledges that they therefore indicate a wide range of funding needs for CCS.

They do not factor in any necessary infrastructure costs (CO_2 pipelines, storage sites, site preparation costs). CEMBUREAU also recognises that it is for each individual company to choose the appropriate technology and determine the plant footprint for its operations.

External verification

CEMBUREAU commissioned PwC to evaluate the levers and parameters used in this roadmap, culminating in a comprehensive report issued in January 2024. PwC's assessment focused on gauging the technical viability, resource accessibility, policy commitment, and CO_2 mitigation potential of individual decarbonisation levers. The key conclusions of the work from PwC can be found **online** and a summary of the findings on each decarbonisation lever is included in Annex 1 of this document.

Annex 1

CEMBUREAU roadmap, assessment of different decarbonisation levers by PwC

Feasible (green) · Lever feasibility regarding CEMBUREAU ambition might be at risk (yellow) · Lever feasibility regarding CEMBUREAU ambition is at risk (red)

Lever	Technical readiness	Resource availability	Policy willingness	CO_2 Benefit	Roadblocks and opportunities	Global Feasibility risk assessment (Low – High)
Alternative raw materials	Yellow	Red	Yellow	Green	• **Resource availability will limit the ARMs[1] rate** as ARMs sources are in decrease • **Managing ARM mix to increase calcium content is key** to optimize CO_2 reduction • **Proper market structure at EU and national level would help** cement industry to increase this rate	High
Novel cements	Green	Green	Green	Green	• **Some novel cement technologies seem promising and scalable at ambition horizon** • **Commercialization in Europe need to be accelerated** and novel cements use promoted	Low
Biomass	Green	Yellow	Yellow	Green	• **A 50-150% gap between demand and supply of biomass will appear** as demand increase and supply stabilized • **Cement industry cannot compete with others industry** for biomass resources and need to either rely on other sources of alternative fuels or manage to have a certain quota reserve for them	Medium
Thermal efficiency & waste heat recovery	Green	Green	Green	Green	• **Technology is available** to reduce thermal energy demand although kiln change is costly • **Impact of AFRs[2] and ARMs mix on energy demand need to be further analysed** to manage it well	Low
H2 / electrification / biogas	Green	Yellow	Yellow	Green	• **Kiln electrification would allow to reduce combustion emissions to zero** although **scalability is in doubt** • **Biogas is easier to leverage**, although resources access might be constrained by other sectors (e.g. transport)	Medium
Clinker in cement content	Yellow	Yellow	Yellow	Yellow	• **Resource availability will constraint SCMs[3] mix, SCMs sources need to be further developed in Europe** • **Technical properties of cement might be changed**, impact of calcined clay and limestone on cement quality is unclear • Using **calcined clay** as one of the main substitute in cement will require **additional thermal energy**	High
EU grid emission factor	Green	Green	Green	Green	• **Net zero grid emission factor by 2050 is feasible** and consistent with EU objectives	Low
Cement and concrete transport	Green	Green	Green	Green	• **Carbon neutral transport by 2050** is slightly more **ambitious than EU objectives** requiring an **additional effort** to make it • **Cement transport depends more on infrastructure development pace** while concrete transport is easier to decarbonate	Low
Cement in concrete[4]	Green	Green	Yellow	Green	• **Usages optimization and new type of concretes** will help reducing cement volume in concrete • **Cement EN206-1 standards need to be reframed** to support reduction ambition by 2050	Low
Construction efficiency[4]	Green	Green	Green	Green	• **Design/specification optimization** and **concrete waste reduction** will allow to reduce raw materials used in construction • **Concrete reuse is also key** to limit CO_2 emissions of new constructions and should be further supported	Low
Recarbonation	Green	Green	Yellow	Yellow	• Although recarbonation is recognized by IPCC, the **reporting accountability is not yet decided** • **The variation of other levers is impacting recarbonation rate** (e.g. SCMs mix)	Medium
CCUS	Green	Green	Yellow	Green	• **CCUS is the main opportunity for cement process decarbonation** with technologies already mature or by 2030 • **Infrastructures for transport and local storage should be further developed** to meet needs of the cement industry	Low

Source: PwC, January 2024

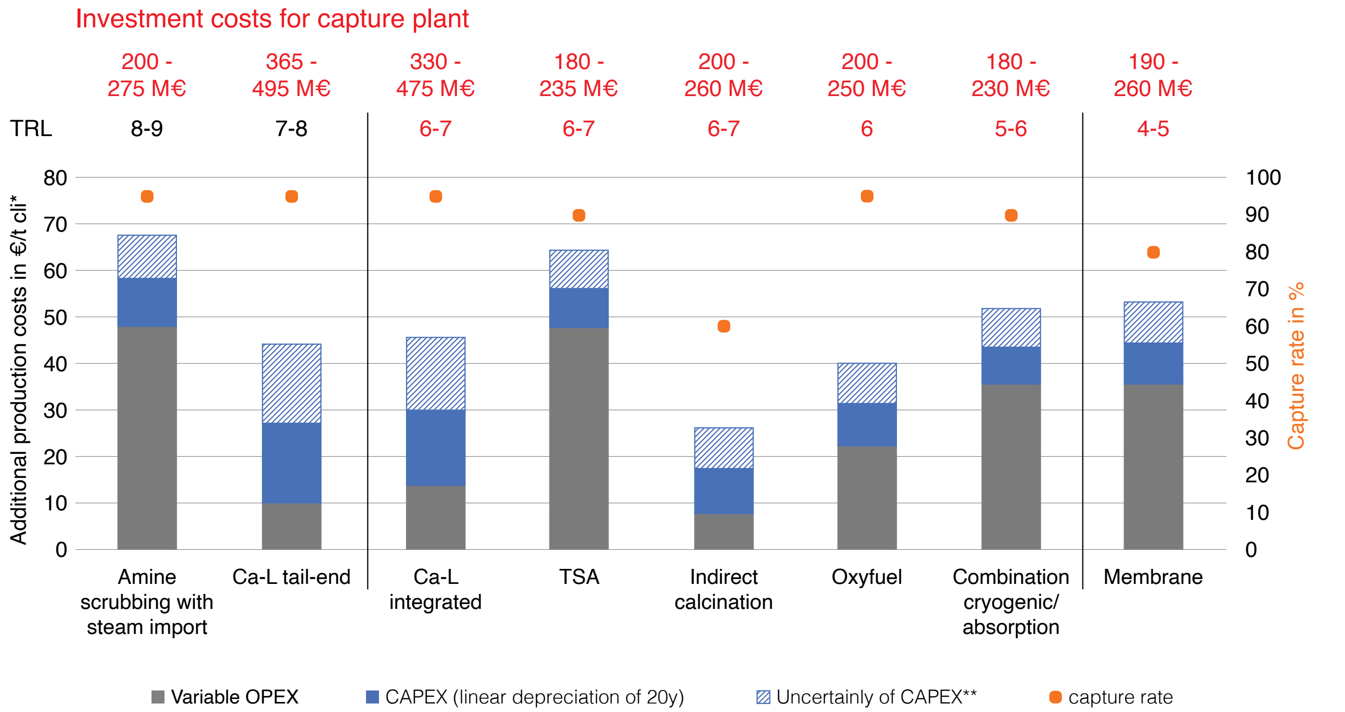
[1] ARM : Alternative Raw Materials [2]AFR : Alternative Fuel Rate [3]SCM : Supplementary Cementitious Materials
[4]These levers cannot be considered directly in the relative roadmap, but it will impact cement demand

Annex 2

ECRA cost estimates on carbon capture

Additional production costs for carbon capture

Costs can vary significantly due to uncertainties in CAPEX because of the different situation at plant level



* Additional production costs
** All assumptions been made are given in detail in the ECRA Technology Papers (2022)

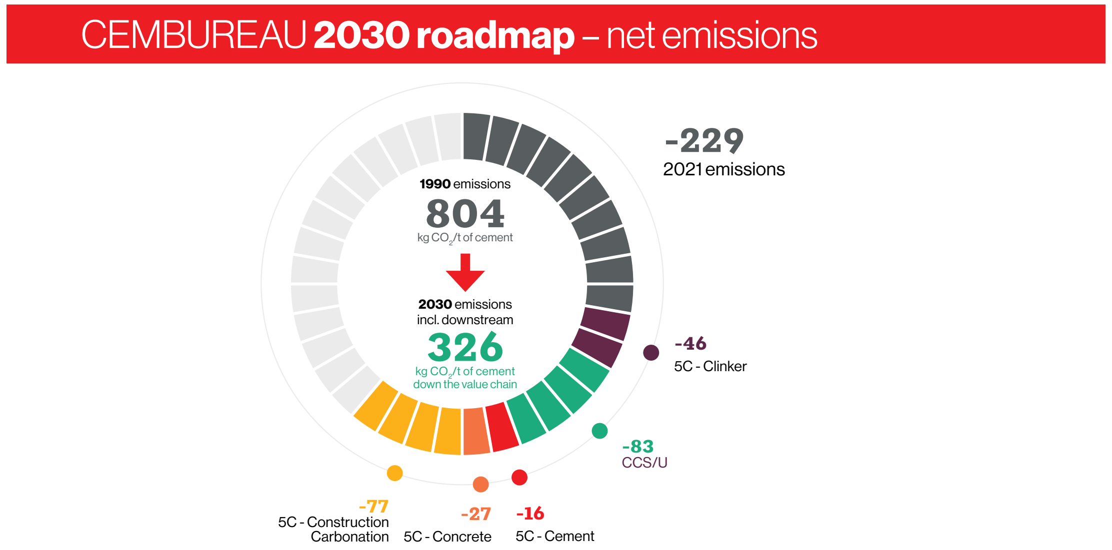
- OPEX depend on site-specific situation (available excess heat) and energy costs
- CAPEX can vary up to around 100% due to:
  - Regional differences such as labour costs
  - TRL
  - Need for additional site specific onsite infrastructure
  - Differences in CO_2 transport infrastructure on plant level

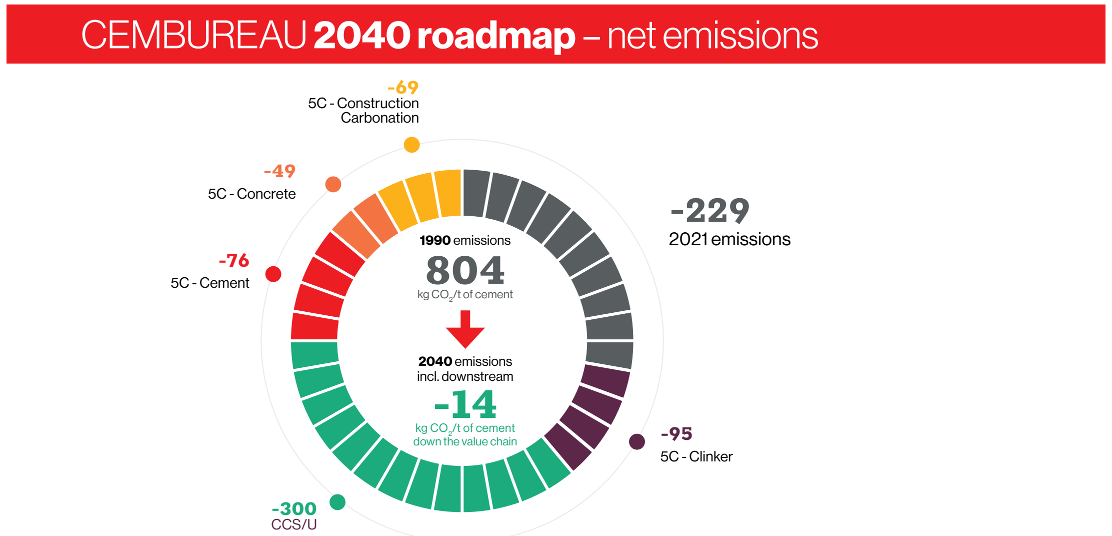
ecra

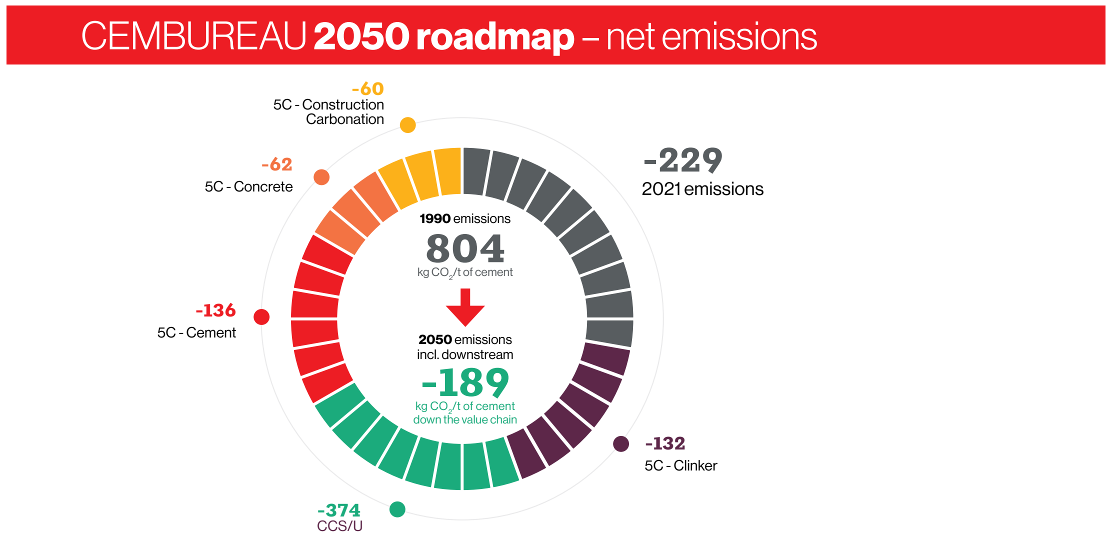
Source: European Cement Research Academy (ECRA)

Annex 3

CEMBUREAU roadmap – net emission figures







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