FAST-TRACKING CEMENT DECARBONISATION

From underperforming to performance-based standards

ALLIANCE for LOW-CARBON CEMENT & CONCRETE

www.allianceLCCC.com

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EXECUTIVE SUMMARY

The cement industry represents one of the most carbon-intensive sectors in Europe, and beyond, being responsible for a staggering 7-8% of global emissions. The main culprit of these emissions is the production of clinker, the key ingredient from which cement and concrete derive their binding properties.

Not surprisingly, clinker substitution is generally seen as the most promising lever for decarbonisation. It allows for considerable reductions to the industry's footprint in the short term at near-zero costs, followed by other levers such as carbon capture, usage, and storage. Safe and low-carbon solutions already exist but need market access through environmentally ambitious standards and policies.

Today, cement and concrete standards prevent this from happening. They follow a prescriptive logic that does not allow new materials and innovations to enter the market at a large scale. Shifting to performance-based cement and concrete standards would remove this barrier and create a level-playing field for low-carbon cement and concrete solutions. This could potentially slice the industry's emissions by half.

Europe is particularly well placed to lead on clinker-substitution, building upon a strong cement industry, leading research institutes on cement and concrete, and a large availability of clinker substitutes. As such, the EU has the potential to follow the example set by other regions and countries, successfully moving from recipe-based to a performance-based standards approach. Embarking on this journey would put the cement industry on a fast track to meeting the EU's ambitious climate goals.

How do we get there:

- The European Commission should urgently adopt a standardisation request for the development a performance-based standard for common cements, replacing existing recipe-based standards.
- Upon acceptance, the European standardisation body CEN should fast-track the development of this performance-based standard, securing sufficient resources to the drafting process.
- CEN should revise and align cement testing standards with performance-based approaches.
- CEN and National Standards Bodies should revise concrete standards so that they allow and promote the use of all low-carbon constituents.

INTRODUCTION

Cement is, and will remain, indispensable in our modern-day life as it serves as the key binding ingredient of concrete. Concrete, in turn, is a critical component of the construction industry, used in roads, houses and other infrastructure which is essential in today's world. However, the production of traditional cement is highly polluting. At present, it accounts for almost 7-8% of all global CO_2 emissions. The industry is one of the most carbon-intensive sectors globally: its emissions increased by 1,5% every year between 2015 and 2022[1,2,3]

A similar picture emerges when we zoom in on the European Union. In 2019, the cement sector emitted 109 million tonnes of CO_2 in the EU27, distributed over 202 production sites. This is equal to the annual CO_2 emissions of Belgium, (greatly) exceeding the footprint of most other EU member states except for Germany, France, Poland, Spain, Italy and the Netherlands. To make matters worse, the problem keeps growing: recent years have witnessed a 4% increase in emissions between 2013 and today.[4,5]

As global demand for cement and concrete is expected to rise by 25% to 50% before 2050, it is time for rapid, radical reductions. **The purpose of this report is to showcase how major CO_2 savings can be achieved in the short term in this supposedly hard to decarbonise sector, by better standardisation,** allowing for a quick and effective uptake of low-carbon cement and concrete solutions. This will allow for other important levers for decarbonisation, such as material innovation, accelerating our journey to net-zero.

The report focuses on the example of Europe, motivated by the fact that the region is particularly well placed to lead on low-carbon cement and concrete. Building upon a strong industry; having access to large quantities of cement substitutes, and being home to leading research institutes in the field, we have great potential for the rapid uptake of clean tech cement and concrete solutions. Adopting new performance-based standards will get us there, making-Europe in the process the global standard-setter for low-carbon cement.

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> *All the CO2 emitted now is a direct contribution to global warming and while we cannot reverse this, we can shape a sustainable future today. The Alliance for Low-Carbon Cement and Concrete believes that in order to meet Europe's climate goals of 55% reduction by 2030 and climate neutrality by 2050, we should be targeting zero emissions for cement and concrete by 2040. The Alliance is ready to take on the challenge of increasing the roll-out of existing solutions.*

CLINKER: THE EMITTER HIDDEN IN PLAIN SIGHT

Traditional cement — commonly referred to as Portland cement — is an energy- and carbon-intensive intermediate product. In itself, cement has no purpose: it is simply grey or white powder. However, mixed with various raw materials, including sand, water and potentially other aggregates such as gravel, it serves as the binding agent of concrete and mortar, indispensable products in the building sector. The billions of tonnes of cement made each year account for a staggering 7-8% of global CO_2 emissions — more than the combined emissions of aviation, trucking, and shipping. In Europe, the lion's share of cement ends up in concrete mixes, respectively ready-mix concrete (RMC) (56%) and prefabricated (or precast) concrete (20%). The remaining 24% is consumed in bags by retailers and contractors — again mainly to produce concrete — or is used by the mortar industry.[6] These proportions are similar in the rest of the world as well.

In terms of emissions, **cement — and particularly its key ingredient, clinker — is the main culprit of the negative environmental impact.** While cement makes up for approximately 12% of the total mass of concrete, it is responsible for 95% of its CO_2 footprint, of which 94% stem. directly from the production of clinker.

Clinker is the key ingredient of traditional cement, thanks to its binding properties.[7] These marble-sized grey balls are produced through a chemical process. This involves heating up crushed rocks and other raw materials — typically limestone and clay — in kilns at a high temperature (up to 1450°C), triggering a chemical reaction in which the feedstock is split into oxides and CO_2. These combine to form clinker, and once cooled, are ground into ready-to-use cement. Importantly, while about a third of the emissions of this process comes from the fuel consumption needed to heat up the kiln, the remaining two-thirds are intrinsically linked to the chemical reaction of the calcination of limestone.[8,9] **In other words, the problem with the emissions in the cement sector is essentially the problem with clinker.**

To meet the urgent decarbonisation needs, the industry must step up its game on clinker substitution - now. While all decarbonisation levers[10] will be essential to reaching net-zero, it is widely accepted that replacing clinker can be readily deployed at a large scale at "near zero costs" (IPCC, 2022), accelerating decarbonisation and complementing other levers with a lower technology readiness level (TRL) such as carbon capture, usage, and storage (commonly referred to as CCUS). This is very much in line with the principles of circularity and energy sobriety: first bringing down the amount of clinker used in cement as much as possible, thus reducing material and energy demands for energy production and CCUS.[11]

This decarbonisation pathway would be a timely effort for Europe as the EU's clinker-to-cement ratio (referring to the average share of clinker in the different cement mixes on the market) is traditionally much higher than in the rest of the world. In 2020, European cement had an average clinker-to-cement ratio of 78,1%, whereas the global ratio sits significantly lower at 72%.[12,13] Besides, recent years have witnessed all but a decline in the use of clinker in Europe (cf. Figure 1), as such seriously questioning the extent to which ongoing efforts on clinker substitution will be sufficient to bring the industry on track of net-zero.[14] More needs to be done.

The ambition of the European industry on clinker substitution — i.e. pursuing a clinker-to-cement ratio of 74% by 2030 and 65% by 2050[15]— **can be significantly improved.** Most notable are the ambitions laid down by FICEM, the association of the cement industry in Latin American Countries (LAC), representing key markets such as Brazil or Mexico. Indeed, while LAC already has a strong tradition of clinker substitution with a ratio of 66%, the ambition is to bring it further down t to 53% by 2030 and 51% by 2050.[16]

At a time when there is growing scientific evidence that **Europe is arguably the one that is best placed to pursue high levels of clinker substitution** due to a large availability of alternative materials[17], **it is time to fundamentally alter the way in which European cement and concrete is made.**

> *Cement — and particularly its key ingredient, clinker — is the main culprit of the negative environmental impact.*

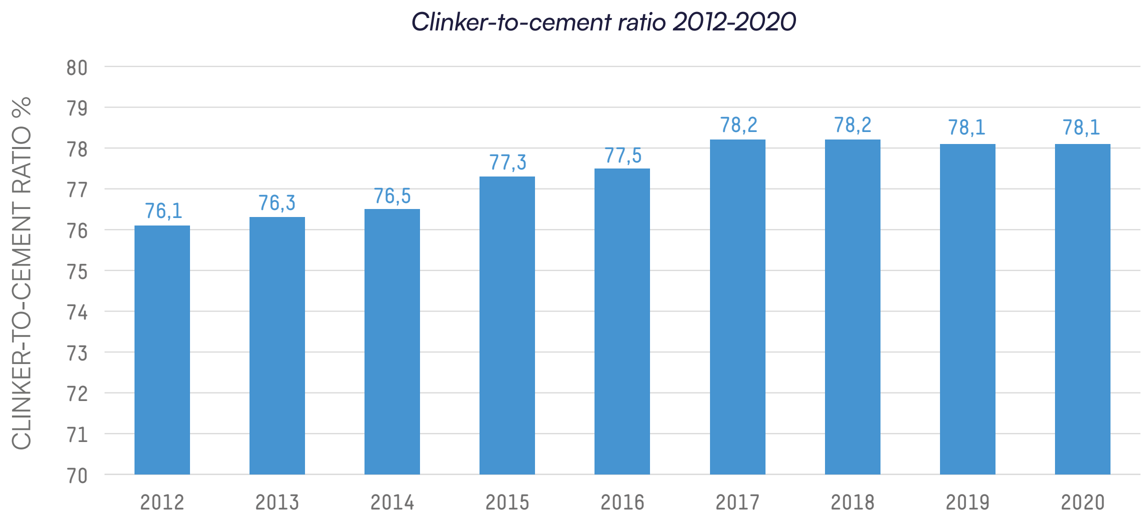

Figure 1: EU clinker-to-cement ratio, Jamcem Consulting — based on GNR and ERMCO data, 2023

CLINKER SUBSTITUTION: SOLUTIONS ARE ALREADY OUT THERE

Clinker and cement substitution can play a much bigger role in reducing GHG emissions than it does today. According to the latest IPCC report, **existing solutions can be scaled up at near zero costs, and when done successfully, cut the industries'** footprint by half.[18] The potential for abatement is even higher when we consider the fact that other technologies with high TRL levels are in full development, showing great potential to further bring down clinker use in cement due to more complex mixing designs or even substitute it altogether.[19]

At the risk of oversimplification, we can distinguish between two approaches allowing to reduce — or even fully eliminate — the use of clinker in cement and concrete. These include clinker-lowering technologies, and alternative-clinker technologies. Both cover a broad — and rapidly expanding — set of underlying solutions to reduce the carbon footprint of cement making.

Reducing the amount of clinker

Clinker-lowering technologies are currently the most dominant and have as a point of departure a shared belief that some (low) level of Portland clinker will be needed in cement and concrete mixes in the foreseeable future.

To reduce its impact as much as possible, research has largely focused on the use of supplementary cementitious materials (SCMs) and fillers in cement mixes, as well as improving the efficiency of cement used at the concrete level through the development of admixtures.

Interestingly, such practices are all but new, going back all the way to antiquity and the construction of Roman temples, known for their impressive longevity, outperforming traditional concrete types.[20]

Recent years, however, have witnessed further breakthroughs in the development and use of SCMs and admixtures. Amongst others, we have seen a proliferation of SCMs and fillers, whereby clinker can be substituted with (by-)products for the built environment, agriculture, forestry, metals, waste and energy sectors. Additionally, technologies are in full development to optimise, for example, grinding techniques — allowing to use existing stocks of SCMs more effectively[21,22,23] and to engineer new SCMs altogether.[24]

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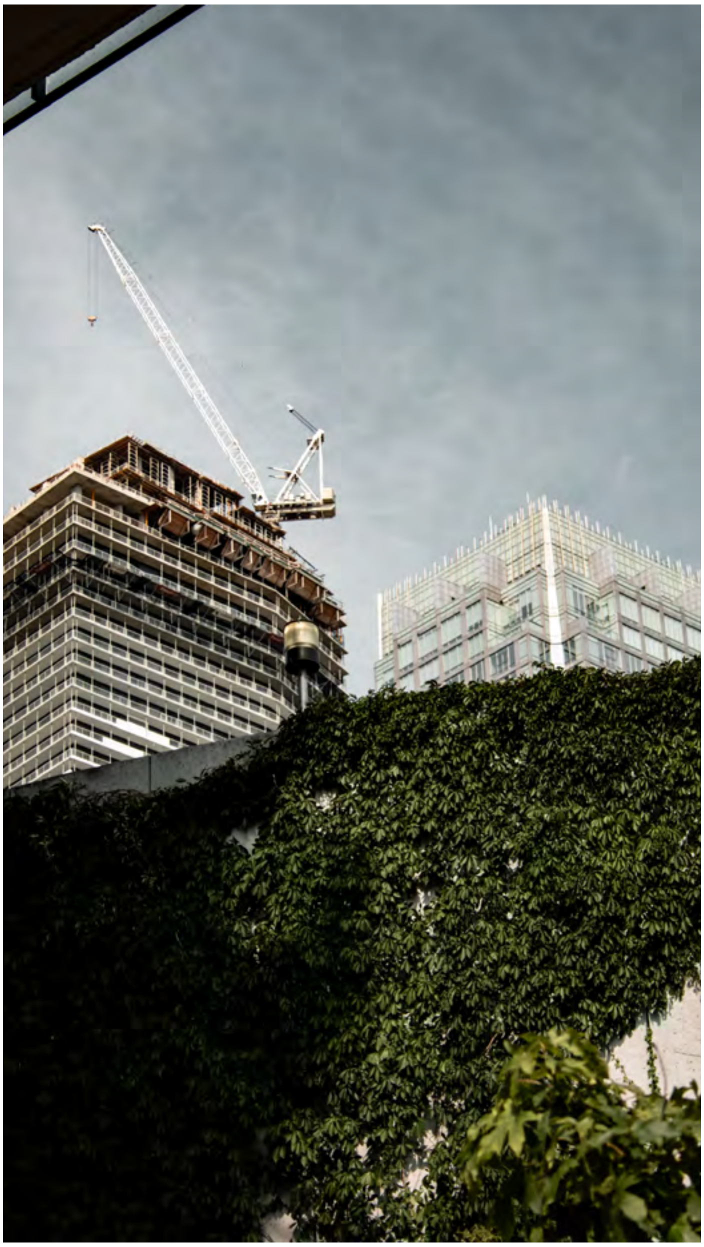
Replacing clinker

Alternative-clinker technologies are also in full development and seek to replace (Portland) clinker altogether.

They seek to — often radically — alter the raw material mixes, to come up with alternative clinker and binder types. These, in turn, have very different ways of production, typically relying on a different set of raw materials, generating much lower levels of process emissions (e.g. alkali-activated materials). Furthermore, various technologies also require much lower or even ambient temperatures (e.g. geopolymers), further adding to their GHG reduction potential.

Importantly, recent years have also witnessed some significant breakthroughs in the development of technologies inspired by biomimicry. Most notable in this regard are the use of sequestered CO_2 as binder — mimicking the properties of natural limestone — or the deployment of bacteria in cement and concrete for strength development — mimicking the formation of corals and shells.[25,26,27]



Successfully used

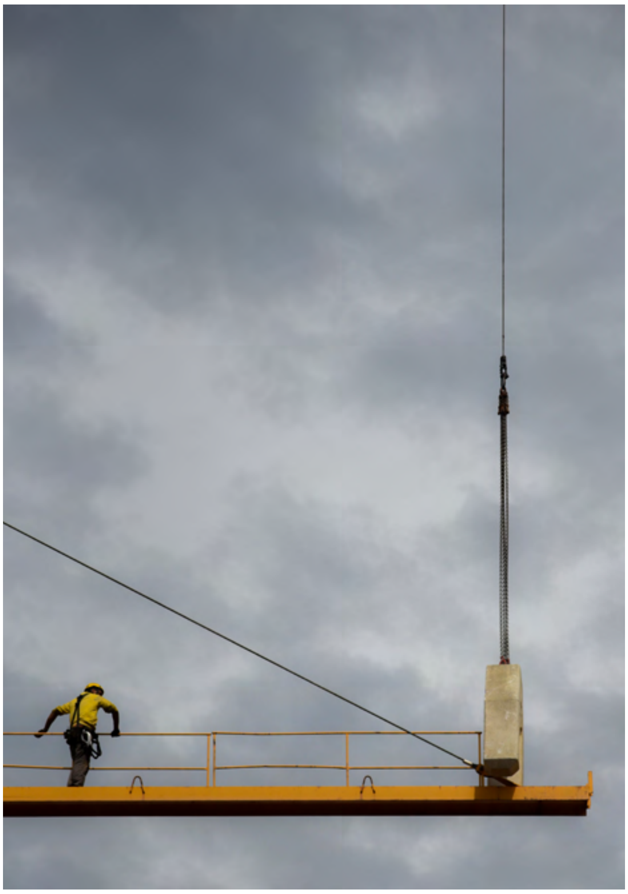
It is important to emphasise that most of the above technologies are well-established and commercially available on the European market. Indeed, **looking at some of Europe's most prestigious infrastructure projects (e.g. Grand Paris Express, H2S, Olympic Village), low-carbon cement and concrete solutions have earned their stripes over and over again.**

The challenge of clinker substitution is thus not only one of further technological development, but rather of **scaling-up the existing solutions on the market. To get there, the remaining barriers — cement and concrete standards — need to be addressed head-on.**

BARRIERS TO SCALING-UP OF LOW-CARBON SOLUTIONS

As with all new products and technologies, there are various factors that have an impact on the market uptake of low-carbon cement and concrete. On the demand side, awareness-raising is key to getting all actors in the construction value chain up to speed with the latest innovations. Measures such as green public procurement (GPP) are essential to help ensure a critical market size for low-carbon solutions, as such helping to bring down green premium costs due to economies of scale.

The supply side faces a far greater challenge: the existing standards prevent low-carbon solutions from entering the market at a large scale. **European cement standards are outdated and highly prescriptive in nature, rigorously outlining what ingredients can be used in the cement mixes — and in what quantities.**



These standards, however, were created at a time when decarbonisation was not yet a fundamental objective. As a result, they match the characteristics of Portland cement, creating a lock-in for high-carbon cement and concrete.

Today's European cement standards define six different cement families — ranging from CEM I to CEM VI — with a subset of specified mixtures that are allowed on the European market without any further conformity assessment. In doing so, the point of departure is always a fixed level of Portland clinker, which can be blended with other specified levels of SCMs and fillers. While some progress has been made in recent years (e.g. EN 197-5 and EN 197-6) to include new SCMs in the standards and/or increase the levels to which they can be used, there is a widespread consensus that progress is too small and too slow given the challenge we are up against. It simply makes no sense that standards require novel solutions to match the characteristics of Portland cement, as **various innovations have successfully been used as alternatives to traditional clinkers.**[28] The situation is no different at the level of concrete standards, where barriers to the uptake of low-carbon solutions also persist across the EU.

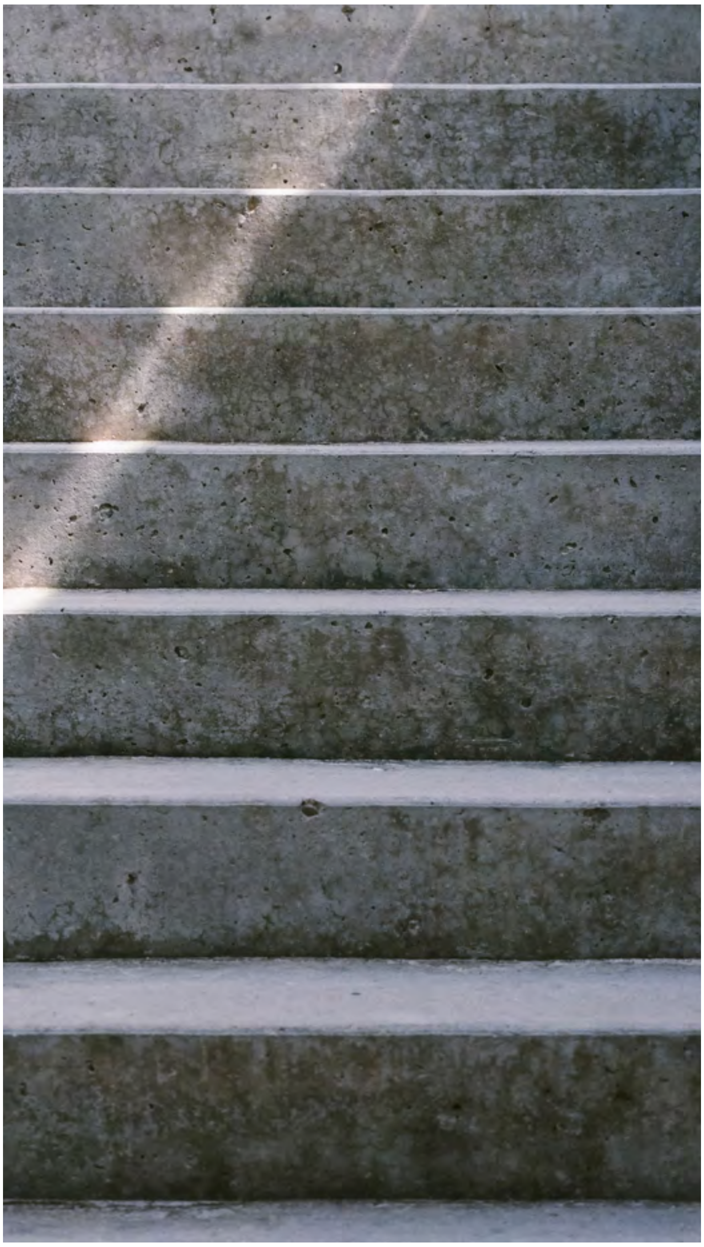
Unlike cement standards, concrete standards (EN 206) are non-harmonised across Europe, creating a situation in which each individual country can impose additional requirements for cement that is used in concrete mixes.[29,30] In addition, national concrete standards also contain requirements on, for example, minimum cement content per cubic metre, often pushing market actors to use more cement than needed.

While such provisions are — as with all non-harmonised standards in the EU — voluntary recommendations, the reality is that very few actors are willing to ignore standards, commonly seen as a way of showing due diligence towards partners. As a result, only bigger construction companies, with the capacity to extensively test new materials and self-insure, are able to use low-carbon cement and concrete.

Fortunately, there is an easy way out of this conundrum. As advocated by the United Nations Environment Programme (UNEP) and many others, **there is an urgent need to switch to performance-based approaches in cement and concrete standards.**[31,32] Performance-based standards would define the final properties of a product on the basis of key characteristics (e.g. strength, durability, fire resistance, sustainability), in line with current practices. However, this would be done in a much cleverer way, no longer locking in specific carbon-intensive cement compositions, or characteristics that are specific to Portland cements only.

Performance-based standards are vital for creating a level-playing field for low-carbon cement and concrete, paving the way for the much-needed accelerated decarbonisation of the industry. What is more, several countries are already taking steps in this direction, inspired by the successful examples set by many LAC countries — having performance-based standards for all cements on their market; as well as the US with its well-functioning performance-based standard for hydraulic cement (ASTM C1157).[33]

If the EU is serious about its ambitions to become the world's first climate-neutral continent, there is an urgent need to follow and leapfrog this trend by mandating European standardisers, CEN, to ensure performance-based cement standards become the new normal, replacing the existing prescriptive approach.



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PERFORMANCE-BASED STANDARDS CAN HELP OUR CLIMATE GOALS

Clinker substitution is arguably the most important lever for achieving large-scale emission reductions in the short- and mid-term future. This is especially true for the EU cement industry, due to a combination of factors, including the widespread availability of SCMs (including building stock) and our strong tradition of research and development on cement and concrete.[34]

Replacing clinker for the climate

A recent study by the New Climate Institute calculated how a large-scale market uptake of low-carbon cement could contribute to CO_2 mitigation in Europe. The analysis assumed that current recipe-based cement standards were replaced by performance-based ones, leading to an acceleration in the uptake of SCMs and novel binders from 2025 onwards.

Different mitigation scenarios were modelled, in which the clinker-to-cement ratio in Europe reaches, respectively, 60%, 50%, or even 40% by 2050.

Such new approach to standards would allow the EU to meet the global targets, put forward by the UNEP in 2018 (i.e. LCS scenario of 60% by 2050)[35], catch up with more recent prognoses[36] and targets set by today's most ambitious regions (i.e. MCS scenario of 50% by 2050)[37], or even leapfrog other regions and become a global leader in clinker substitution (i.e. HCS scenario of realising the potential of 40% by 2050).

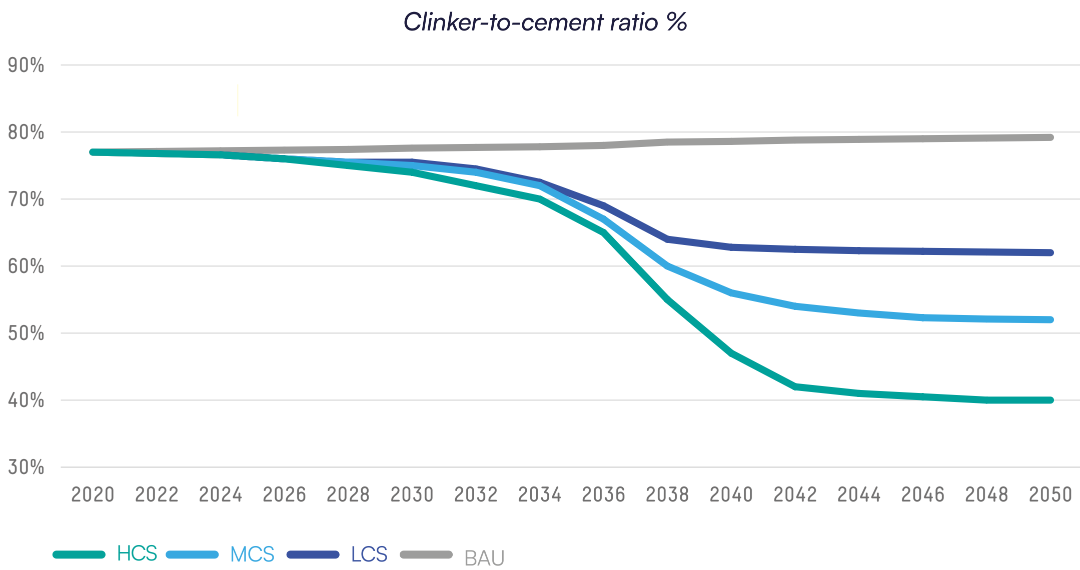

Figure 2: Clinker-to-cement ratio models — New Climate Institute, 2023

These scenarios were modelled against a business-as-usual scenario, in which standards continue to follow a prescriptive approach, allowing no real progress towards low-carbon cement solutions.

The results of the study show a significant potential for CO_2 reduction, with annual emission savings of up to 52% in the most optimal scenario. By 2050, this would result in a cumulative mitigation potential of 797 Mt of CO_2.

Scenario	Year	Mitigation potential	Equals annual footprint of
LCS	2050	- 28%	Slovakia
MCS	2050	- 40%	Ireland
HCS	2050	- 52%	Romania

"Different mitigation scenarios were modelled, in which the clinker-to-cement ratio in Europe reaches 60%, 50%, or even 40% by 2050. The study shows a significant potential for CO_2 reduction, with annual emission savings of up to 52% in the most optimal scenario.

Best-case scenario could be even better

Importantly, these findings correspond to the figure put forward by IPCC. Moreover, and still in line with IPCC, it should be pointed out that the mitigation potential is likely to be even greater. The above estimations can be considered conservative as the different mitigation scenarios focus on the adoption of performance-based approaches at the level of cement standards, whereas additional gains are also possible at the level of concrete standards.

Another way in which the study remains rather conservative is that it assumes the energy input of calcined clays for all novel SCMs (due to data availability issues), whereas different novel SCMs require much lower or even no additional energy input. Furthermore, the timeline for the development of performance-based standards can be significantly shortened with a high level of political buy-in, resulting in a much faster market-uptake of low-carbon technologies and products.

Lastly, the impact of new standards on innovations has not been factored in, even though it is widely acknowledged that shifting from prescriptive to performance-based standards triggers large-scale innovation in industrial sectors.[37]

Therefore, we are confident that the actual mitigation potential can go as high as 60% as long as EU policy makers and industry are committed to fast-tracking performance-based cement standards. The European Union is particularly well placed be at the forefront of this transition, living up to its aspirations to become the global standard-setter for low-carbon innovations.

THE TIME IS NOW: KEY RECOMMENDATIONS

Standards will play a key role in decarbonising the cement sector. Even though today they effectively lock in the consumption of high volumes of clinker, they can be turned into a vector that drives innovation and the rapid market uptake of already existing and scalable low-carbon solutions.

Performance-based standards should become the new normal, replacing the existing prescriptive approach.

This requires:

1

The European Commission to urgently adopt a standardisation request for the development of a performance-based standard for common cements, replacing the existing (harmonised) cement standards EN 197-1, EN 197-5 and prEN 197-6. This must be done in close consultation with all relevant stakeholders, building upon scientific evidence and experiences from other regions and countries in the world.

2

CEN should fast-track the development of this new standard, upon acceptance of the standardisation request. The Technical Committee in charge, CEN TC 51, should prioritise the drafting of this new standard. Amongst others, this can be achieved by shifting resources from ongoing work on the incremental improvement of recipe-based standards.

3

CEN should revise and align cement testing standards with performance-based approaches. Priority should be given by CEN TC 51 to the development of sound and workable testing methods which do not discriminate against low-carbon cement types.

4

CEN and National Standards Bodies should revise concrete standards so that they allow for the use of all low-carbon constituents. The Technical Committee CEN TC 104 should prioritise the revision of the EN 206 standard. Particular attention should be paid to the prescriptive parts of the standard, including the provisions on minimum cement content. Also at the national level, National Standards Bodies should revise their annexes to EN 206, finally creating a level-playing field for low-carbon concrete solutions.

ENDNOTES

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The Alliance for Low-Carbon Cement and Concrete is ready to take on the challenge of increasing the roll-out of existing solutions! Join us and let's build our future together.

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