POLICY BRIEF

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Decarbonizing the Cement and Concrete Industry

Cement EU Policy Brief
by Future Cleantech Architects

Future
Cleantech
Architects

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Executive Summary

Cement is omnipresent and indispensable, but emissions-intensive to produce. It is the 'glue' that holds concrete together and, as such, is a critical part of almost all modern infrastructure: from buildings to bridges, from train tracks to future energy infrastructure such as wind turbine foundations or hydropower dams. At the same time, the cement industry is responsible for 7% of global CO_2 emissions and 4% of emissions within the EU. It stands as one of the highest industrial emitters alongside iron and steel. If the cement industry were a country, it would be the third largest emitter in the world, after China and the US. Moreover, demand for cement is expected to continue to increase at a rate equivalent to building a New York City's worth of concrete every month for the next 40 years. New cement technologies pioneered in Europe can therefore hope to meet demand of a global market.

Decarbonizing cement is challenging for two main reasons: a multi-faceted emissions profile and an undynamic industry. Emissions are multifaceted, requiring multiple solutions for decarbonization, with the majority of emissions (60%) from producing cement coming from the fundamental chemical reaction of producing clinker, in which CO2 is released from the limestone. The industry is dominated by a few major cement producers, plant lifetimes are long, and profit margins are low, leading to risk aversity and low R&D investments. Further downstream in the value chain, architects, engineers, contractors, and owners are also relatively reluctant to adopt new building materials and methods, given the high stakes involved in safety, reliability, financial risk, and regulatory compliance.

Transitioning from today's to tomorrow's market thus requires both innovative technologies and smart, incentivizing policies.

In terms of technologies, a number of innovative solutions are already known and exist, but need to be refined and scaled. When taking into consideration not only possible modifications at the cement plant level but also along the entire value chain, emissions can already be cut by up to 80%, even without the use of disruptive and costly technologies such as Carbon Capture and Storage (CCS).

In terms of policies, the European Green Deal and the Fit for 55 package aim to make Europe the first climate-neutral continent by 2050 through a combination of policy measures and technological innovations. The main EU policies, such as the Industrial Emissions Directive, the European Trading System, or the Construction Products Regulation, aim at regulating and monitoring emissions of pollutants such as CO_2, NO_x, and SO_2. The recently re-elected President of the European Commission, Ursula von der Leyen, has also sent a strong signal to European industry by announcing a Clean Industrial Deal in her first 100 days as well as an Industrial Decarbonization Accelerator Act. They will aim to channel investments into infrastructure and energy-intensive industries and will be backed by two financing pillars: a European Savings and Investments Union to mobilize private financing and support startups within Europe, and a new European Competitiveness Fund, particularly for cross-border European projects. President Von der Leyen also plans to increase the EU budget, especially for the post-2027 EU Research and Innovation Framework Program.

This new five-year mandate presents a unique opportunity to develop the enabling policy framework to transform the cement sector by **cutting** emissions and material use in today's market, **creating** standards and demand to outline tomorrow's market that the industry can work towards, and **catalyzing** the transition through both supply and demand side measures. Future Cleantech Architects welcomes the increasing emphasis on industrial decarbonization in the current policy plans. However, achieving total emissions reductions will require both better designed and more ambitious policies.

Recommendations

This policy brief outlines Future Cleantech Architects' five policy recommendations to ensure European cement production aligns with Europe's 2050 carbon neutrality objectives:

Cut: Enhance material efficiency through the adoption of policies geared at enhancing design and building practices, reuse of construction materials, and systemic innovation to significantly reduce CO_2 emissions in the cement and construction industry.

Cut: Leverage carbon pricing by accelerating the phase-out of free allowances, revising benchmarks under the EU Emission Trading System, and reinvesting auction revenues into low-carbon technologies.

Catalyze: Implement financing schemes to support green cement markets, retrofit old plants, and provide investment guarantees for first-of-a-kind facilities and technologies.

Create: Adopt green standards for cement and concrete by establishing performance-based standards to lower barriers for low-carbon options and reduce clinker use.

Create: Mandate green public procurement across the EU by developing harmonized systems for defining "green" products and revising the public procurement directive to incentivize sustainable construction.

Sector Overview

Cement is everywhere: it is the 'glue' that binds concrete and the second most used material in the world after water. Concrete – composed of cement, water, and other aggregates such as sand and gravel – is integral to societal development as an essential component in infrastructure (23% of cement end use), residential (20.5%), and commercial buildings (20.5%) (CemBureau). Importantly, concrete is also indispensable for the development of infrastructure required for the energy transition. The construction sector as a whole carries significant economic weight, providing 18 million direct jobs and contributing to 9% of the EU's GDP. However, the cement sector's environmental impact is substantial, representing 7% of global CO_2 emissions. In the EU, it accounts for 4% of emissions, making it the highest industrial emitter along with iron and steel and mineral oil refining (each accounting for over 20% of industrial emissions in Europe).

Decarbonizing the sector is challenging due to two overarching factors: a multifaceted emissions profile and an undynamic sector nature.

- The majority of emissions come from the basic chemical reaction of turning limestone into clinker (60%), with the rest resulting from high-temperature heat (30%) and other energy consumption (10%). This multifaceted emissions profile makes it fundamentally harder to decarbonize, as there is no single drop-in alternative.
- Cement is a local, mass-produced, low-cost commodity with narrow profit margins and a strong safety culture in its use. These factors contribute to a highly regulated, risk-averse industry that lacks incentives to innovate.
- According to the IEA, the sector has underinvested in R&D (including for decarbonization) compared to other industries: around 0.6% of revenue is spent on R&D, compared to 1.3% for iron and steel, or 4.4% for the automotive sector. Moreover, cement kilns have a long asset life, typically 30-50 years, meaning that many emissions-intensive plants in operation today could still be running in 2050. Lastly, cement-making is as much a logistical business as an industrial one, with a tightly-knit value chain. As a result, changes that disrupt this chain are difficult to implement.

Innovative technological solutions must be refined and scaled in order to reach 100% emissions reductions. Considering the whole value chain, as opposed to just cement production, increases the potential of emissions reductions of up to 80% through just moderate changes and investments. The combination of low-hanging fruit in today's market and newer technologies in tomorrow's market opens up a wide solution space[1] with multiple options towards cement decarbonization that must be combined into a coherent pathway (see Fig. 1).

Finally, many stakeholders are involved within the construction and cement value chain, and although each of them can exert leverage in driving decarbonization in their own way, the overall complexity of their interactions has historically slowed this down:

- **Cement producers** can drive sustainability by optimizing production processes and adopting decarbonization technologies, along with alternative fuels and raw materials. Policymakers can provide the enabling conditions for the sector to transform through the use of push and pull policies.
- **Concrete producers** can incorporate sustainable materials, reduce water usage, and enhance the durability and energy efficiency of concrete products.
- **Demolishers and waste managers** can efficiently manage demolition waste, promote recycling and reuse of materials, and minimize landfill use.
- **Architects, designers, civil engineers, construction workers, engineers, and insurers** can design and construct energy-efficient, low-impact buildings using sustainable materials and ensuring resilience and longevity in their projects.
- **Urban planners, property owners, clients, and investors** can drive demand for sustainable buildings and infrastructure by prioritizing projects that incorporate green building practices, energy efficiency, and reduced environmental impact, thereby influencing market trends.

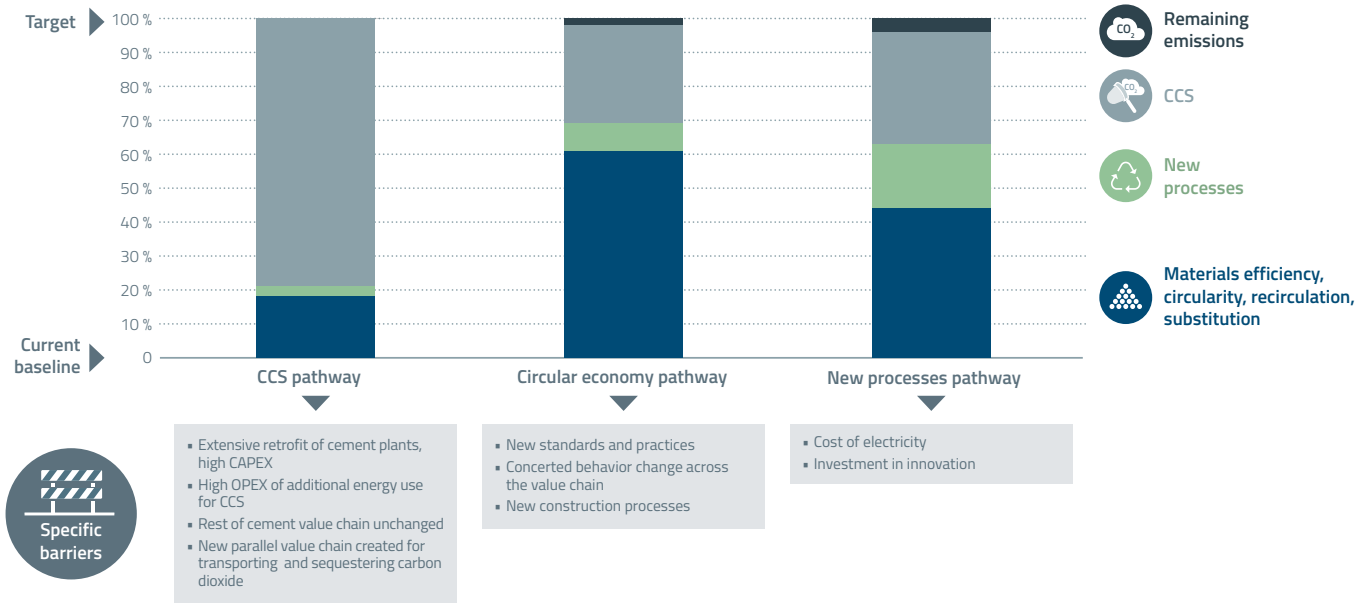


Figure 1: Pathways and their barriers to net-zero emissions for cement and concrete in Europe. Source: adapted from Material Economics.

[1] For a more comprehensive overview, see the figure showcasing the solution space across the cement value chain on page 4.

The Cement Value Chain

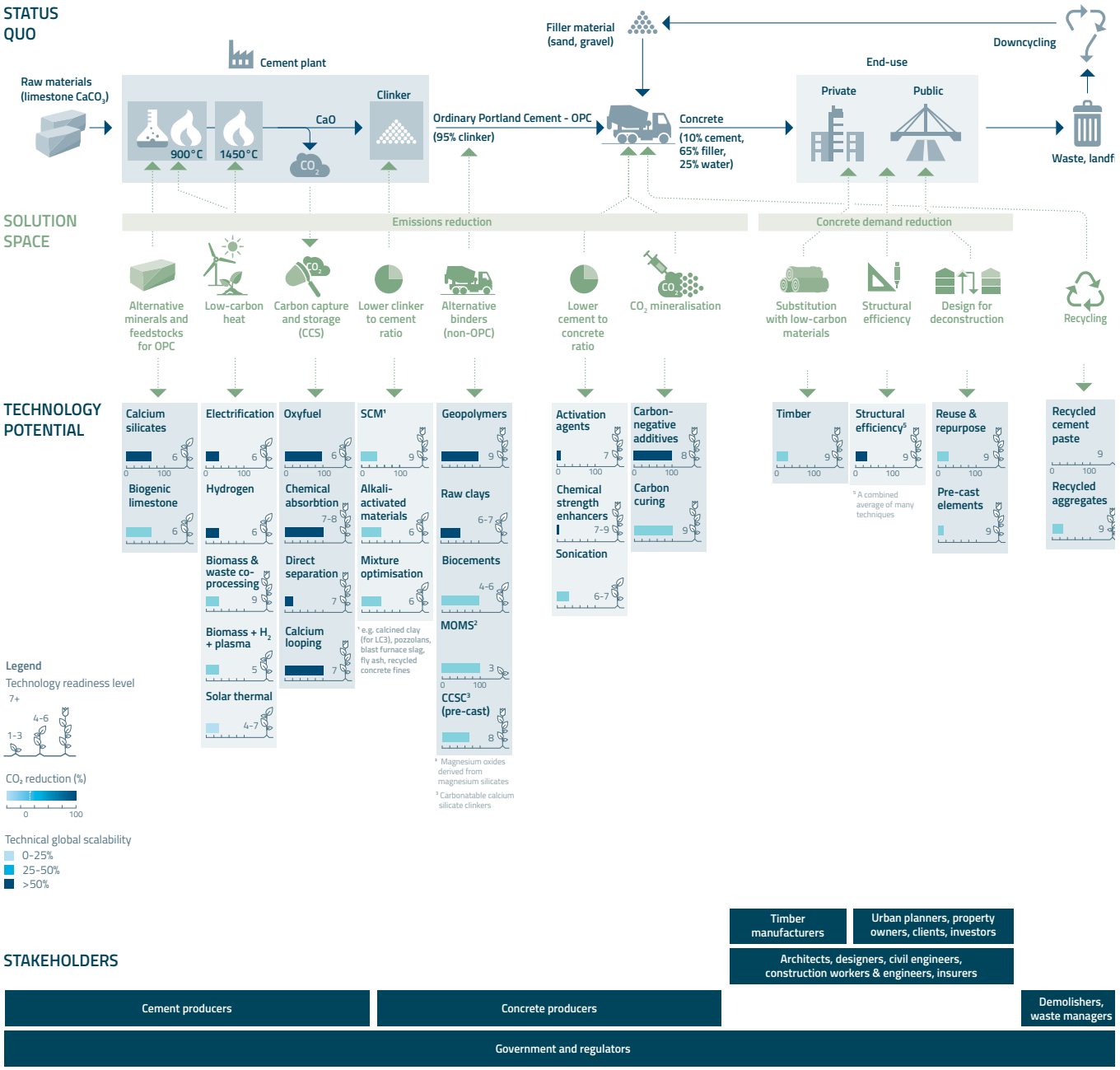
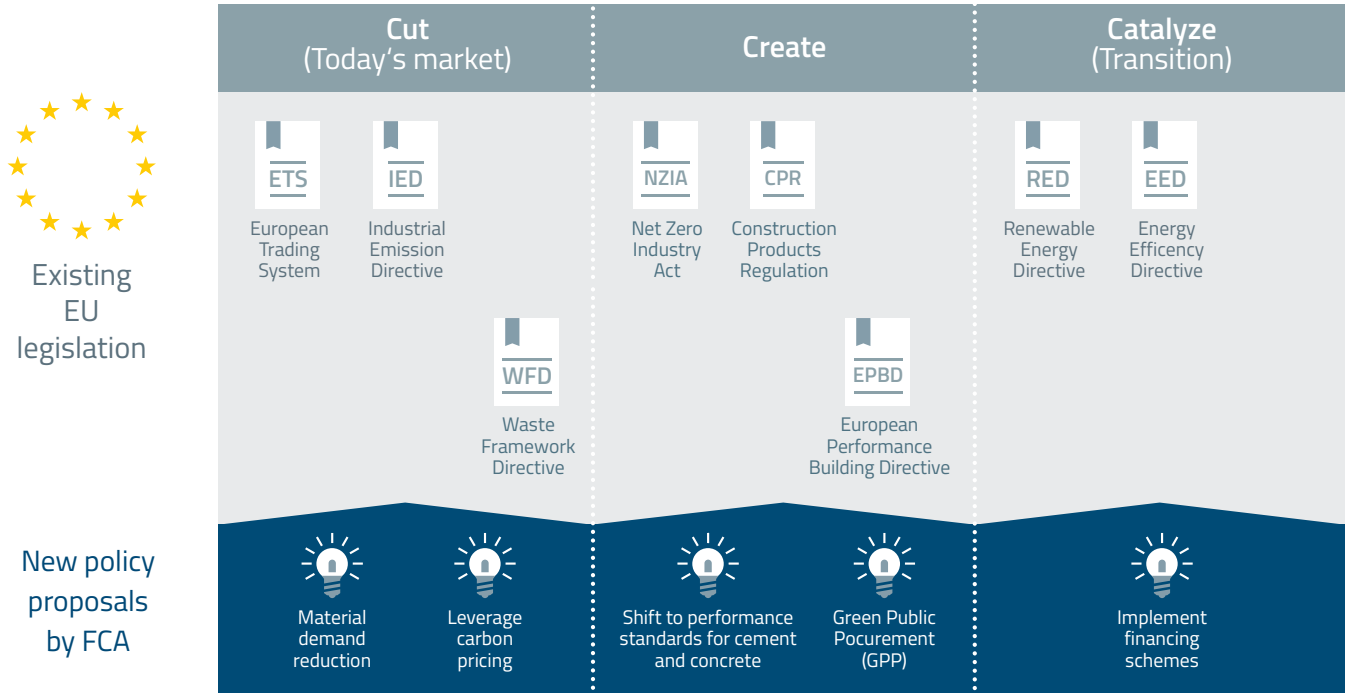


Figure 2: The cement value chain, solution space, and stakeholders. Source: Future Cleantech Architects

An Eye on Recently Adopted European Legislation



To ensure the success of technological solutions, a well-rounded policy approach is needed that:

- **Cuts** the material use and emissions in today's market.
- **Creates** clear standards and demand to outline where the industry should be heading.
- **Catalyzes** the implementation of innovative solutions using both supply and demand-side measures to tilt the sector from today's to tomorrow's market.

Next Legislative Steps to Meet the Remaining Decarbonization Challenges

Cut	Update the Waste Framework Directive to endorse the reuse of construction materials.
	Update the 2013 Best Available Techniques document.
	Monitor the effective implementation of ETS reforms, the phase-out of free allowances, and the allocation of EU revenues for low-carbon cement and related technologies.
Create	Encourage standardization organizations to transition to performance-based standards that allow new types of cement.
	Revise the 2014 Public Procurement Directive to make GPP mandatory.
	Update the 2016 EU strategy on heating and cooling to tackle industrial (high temperature) heat.
Catalyze	Increase funding for the EU R&I Framework Program and the European Innovation Council (EIC) to enhance research and development in new types of cement and material efficiency and support pilot projects demonstrating cleantech at scale.
	Financial credit guarantees by the EIB and green conditionalities and contracts must be explored to make green energy more viable for industrial users.
	Earmark EU cohesion funds to support cement plant retrofitting and cleantech adoption in industrial facilities.

The following five policy actions address the remaining gaps in creating a holistic policy framework that aligns with the EU's ambitious climate targets: reducing GHG emissions by at least 55% by 2030, 90% by 2040, and achieving climate neutrality by 2050. Our policy recommendations focus first on deepening existing policies to reduce emissions and material use in today's market, then on creating more innovation-friendly standards for the market to work towards, and finally on catalyzing the transition from today's to tomorrow's market through more ambitious supply- and demand-side measures.

1. Cut emissions and material demand through material efficiency strategies

Between 2015 and 2022, the direct emissions intensity of cement production slightly increased. To get on track towards the IEA net-zero emissions scenario, the sector's global emissions must decrease by an average of 3% per year until 2030. While competing on price with the optimized production of conventional Portland cement is tough, reducing the use of emission – intensive materials through material efficiency strategies in today's market is the first – and often overlooked - step towards reducing the sector's emissions.

- **Supporting a material efficiency mindset,** where buildings and infrastructure are designed to use materials more efficiently, is a low-hanging fruit that can reduce emissions by up to 50%. This can be achieved through structural efficiency (optimized design by architects and engineers of floors, central cores, foundations, etc.), requiring justification of inefficient designs, minimizing the material required without compromising strength and safety, or utilizing materials with superior performance characteristics that can reduce the volume of material required for construction. This approach requires the systematic collection and reporting of data on the structural efficiency of buildings (e.g. stress volume per m^2) in a similar way to the measurement of the energy efficiency of appliances. This would help to create benchmark metrics that could provide a basis for asking engineers to deliver not just a safe or cheap building, but a safe and efficient one.

- **The reuse of construction materials must be increased** when safety is guaranteed, as only 5-10% of the materials used in cement production are currently being recycled (or rather downcycled, typically for use as road filler). It involves the reuse of concrete elements from decommissioned structures into new construction projects without significant reprocessing. This practice aligns with the EU's Circular Economy Action Plan and the 2018 Waste Framework Directive, which encourage the reuse of construction and demolition materials, including concrete. **We urge the new Commission to start revising the Waste Framework Directive on construction and demolition materials to update the 2020 targets** for the reuse of construction materials and products, reduced waste generation, and sorting systems, a topic of current research and (demonstration) testing.

Impact of the recommendation: By 2050, rigorous material efficiency strategies could have the potential to reduce emissions by up to 65%.

A powerful EU scheme to rethink construction: the European Innovation Council (EIC) Box 1

The European Innovation Council (EIC), launched in 2021, is a key part of Horizon Europe's Pillar III, "Innovative Europe". It aims to decarbonize various sectors, including the cement industry, by supporting start-ups and SMEs with grants and equity investments. The EIC finances deep tech innovations across diverse sectors, from energy storage to low-carbon fuels and cement, through both open calls and targeted innovation challenges. These challenges encourage creative, out-of-the-box solutions aligned with EU policy objectives and market needs.

In 2023, the EIC launched a challenge under its EIC-Accelerator program with the goal of advancing beyond the existing costly carbon capture and storage solutions in the cement industry. This challenge focused on integrating cement-related projects into broader efforts, such as digitally enabled design and fabrication technologies that reduce or eliminate embodied building emissions by using less or alternative materials. Projects were required to align with the New European Bauhaus principles of sustainability, beauty, and community. A subsequent challenge in 2024 focused on the efficient use of cement, alternative low-carbon materials, and data-driven approaches.

Inspired by the US Advanced Research Projects Agency (ARPA), the EIC emphasizes transforming ideas into viable businesses from the outset. However, unlike ARPA, the EIC fosters collaboration among projects through a cluster portfolio approach, enhancing collective understanding of key issues. The EIC supports projects across all stages of development, from Technology Readiness Level (TRL) 1 to 9, through three distinct pillars: EIC-Pathfinder (TRL 1-4), EIC-Transition (TRL 4-6), and EIC-Accelerator (TRL 5/6-8/9).

The EIC's unique blend of grants and venture capital (through the EIC Fund) provides essential financing for high-risk, innovative projects that are not yet commercially viable. After rigorous legal and financial due diligence by the European Investment Bank (EIB), projects may receive equity financing, matched by the EIC Fund if additional investments are secured from other sources.

To further advance the sustainable transition and strengthen Europe's competitive edge, it is crucial to reinforce the EIC in the next EU Research and Innovation Program post-2027. This will support the development of more innovative, high-risk, and impactful projects across sectors, including the cement industry.

2. Realize the full potential of carbon pricing mechanisms in today's market

The EU Emissions Trading System (ETS) has not sufficiently triggered emissions reductions in the cement sector over the last decade. Instead, the cement industry – and in particular clinker plants – has benefitted from an overallocation of free allowances, due to the supposed risk of carbon leakage, that has led to additional profits for the industry of €3 billion between 2008 and 2019. Apart from a higher CO_2 price, fixing current design flaws in the ETS can increase the effect of cutting emissions and creating a level playing field in today's market.

- **Accelerate the phase-out of free allowances** to incentivize faster industrial decarbonization. Due to the low trade exposure and high share of transportation in overall costs relative to the sale price of cement, risks of carbon leakage in cement are lower than in other sectors that are also protected through free allowances, such as iron and steel. Long distances quickly become uneconomic, especially over land, with transport costs of 10-15 €/100km compared to sale prices of 60-80 €/ton. By increasing the cost of carbon-intensive traditional cement production, carbon pricing will make alternative, lower-carbon cement more cost-competitive.

- **Revise the allocation benchmark under the ETS:** Benchmarks reflect the performance of the most efficient installations. The current annual improvement rates are set at a minimum of 0.2%, which is significantly lower than the actual possible improvement rates of at least 1.6%. Revising these rates upwards will ensure that benchmarks reflect the true potential for emissions reductions. Further, free allowances are based on clinker production efficiency and reward only a more efficient clinker production[2]. This approach effectively penalizes reducing clinker content in cement and reducing concrete usage overall. Transitioning to a more comprehensive benchmark that considers the entire cement or concrete value chain will reward innovative solutions across the entire value chain. When considering the whole value chain, reductions in emissions of up to 80% can be achieved without breakthrough technologies.

- The revenues generated from auctioning current allowances can **be reinvested in innovation and research on alternative cements** that produce fewer emissions at national level and, through the Innovation Fund, at the European level.

Impact of the recommendation: The projected cost of the current free allocation system across all sectors from 2023 to 2033 stands at €331 billion. In parallel, moving to full auctioning of allowances for sectors covered by the CBAM by 2026 would be expected to generate an estimated €5 billion a year. These funds could be channeled into research and development in low-carbon cement.

Carbon leakage

Box 2

Carbon leakage occurs when companies relocate production to countries with looser greenhouse gas emission regulations or import from them, leading to higher overall emissions. The EU counters this using free allowances and the Carbon Border Adjustment Mechanism (CBAM):

- Free allowances: High-risk sectors receive free emission certificates based on benchmarks that describe expected emissions of a given production amount using the best available techniques.
- Carbon Border Adjustment Mechanism: Levels the playing field by imposing a carbon cost on imports equivalent to the EU's carbon price.

From 2026 to 2034, free allowances will be gradually phased out while CBAM is phased in.

3. Outline tomorrow's market with green standards for cement and concrete

Current prescriptive standards dictate cement and concrete compositions that discourage optimization and innovation. For decades, low raw material prices, cheap energy, and weak environmental regulations have led to overuse of clinker in cement and overuse of cement in concrete. Clinker, the main source of CO_2 emissions in cement production, has been overused without improving concrete strength, leading to inefficiency and higher emissions. For example, increasing the amount of cement in concrete from 296 kg/m³ to 415 kg/m³ does not improve strength, but can increase risks such as cracking, alkali-silica reaction, and higher embodied CO_2. Alternative best practices exist: in Denmark, concrete with 150 kg cement/m³ of concrete is used, much less than the EU average of 300 kg/m³. Moving to harmonized, performance-based standards that focus on end results rather than processes is in line with the Construction Products Regulation (CPR) and can outline what the market must work towards.

- **Do not limit the amount and type of Supplementary Cementitious Materials (SCMs)[3] in concrete.** According to a 2015 US survey, this was the case in ~85% of the examined specifications, with an average of 18% SCM content used in the investigated projects. In some cases, SCM limits can be a drag on performance and SCM could be used in greater quantities to reduce embodied CO_2. As currently common SCMs are in short supply (e.g. fly ash and blast furnace slag) and the new materials that are emerging do not fall under existing specifications, approving a greater variety of SCMs would be beneficial. A standard similar to the SCM specification currently being developed in the United States (WK70466) could be implemented at the EU level.

- **Abandon maximum water-to-cement ratio requirements in concrete.** Performance can also be achieved with varying water-to-cement ratios, depending on the mix. For instance, concrete with 50% fly ash can achieve similar strength and lower permeability compared to traditional Portland cement, demonstrating that performance measurement should not be based on water content.

- **Adopt performance-based cement standards, harmonized across the EU.** CEN CENELEC (the organization mandated by the European Commission to develop standards) should make efforts to transition to technology-neutral, performance-based standards that use a coherent set of performance parameters, efficiency, quality, and sustainability criteria, and easy, reliable testing methods that focus on end results and key performance assessment criteria such as strength, permeability, shrinkage, sulfate resistance, and resistance to alkali-silica reaction. Harmonization is crucial to reduce complexity and enables broader adoption and scaling of innovative materials.

Impact of the recommendation: Adopting performance-based standards ensures performance while maximizing the use of existing low-carbon solutions and incentivizing further material innovation, which is discouraged by current standards. For example, if the widespread use of all SCMs were normalized, emissions could be reduced by at least 50%. Performance would be assured for project owners, consistency assured for contractors, and manufacturers would have an aligned authority and responsibility to improve performance. Similar standards are currently being developed and implemented in the US and in Latin American markets.

[2] All installations are allocated free allowances up to the benchmark clinker level, which is set by calculating the average emissions of the most efficient 10% of clinker producers. Installations with less intensive emissions than the benchmark receive additional allowances, while installations emitting more must purchase additional pollution permits.

[3] SCMs are a set of materials – often industry by-products – that serve as partial replacement of traditional clinker in cement, or as partial replacement of cement in concrete mixes.

Five recommendations to policymakers

4. Implement Green Public Procurement across the EU

The public sector represents 60% of global cement and concrete demand. In the EU, despite guidelines and initiatives promoting innovation and sustainability, a large proportion (55%) of public procurement decisions still prioritize the lowest price over other criteria, with big differences within the EU. In the Netherlands and Sweden, most procurements (67% and 58% respectively) included at least one environmental consideration, whereas in the first half of 2021, only 12.4% of procurement awards in Germany included sustainability criteria. The practice often overlooks the potential long-term benefits and cost savings associated with sustainable and innovative products and services, neglecting other important factors such as environmental impact and lifecycle costs. While Green Public Procurement (GPP) is identified as a key priority by the European Commission, its implementation remains voluntary. GPP is essential in creating tomorrow's market that incentivizes further innovation today.

- **Make Green Public Procurement requirements mandatory in the EU, despite cement's green premium, and revise the 2014 public procurement directive.** Since 2014, the Most Economically Advantageous Tender (MEAT) criteria make the inclusion of environmental considerations in public procurement possible, yet they remain underused due to legal uncertainty, lack of EU guidance, and expectations of significant cost increases. The latter fear of cost increases, however, does not reflect reality, as cement makes up just a fraction of the final building cost (see box 3). The introduction of mandatory quotas for green public procurement, instead of remaining voluntary, can be a good option to trigger the use of sustainable materials in public construction and infrastructure projects.

- **Develop EU-level harmonized systems with uniform definitions and methodologies for calculating what is "green".** The precondition for GPP is uniform standards and certification, aligned with EU taxonomy and considering the full life cycle of the product. High-resolution data across the full supply chain is necessary to increase transparency with suppliers to enable competition for GPP and help buyers make sustainable buying decisions. Developing EU-level harmonized systems for GPP definitions and methodologies for monitoring and reporting (including on embodied emissions) would be highly proficient. Existing best practices in bids in Member States could serve as a basis and allow measurement of the environmental impact of GPP.

- **Support and train local and regional governments**. One of the biggest barriers to GPP is the lack of capacity and training of procurement offices. A large share of public procurement occurs at the local and regional levels. Central government coverage of the added costs to alleviate financial pressures on local governments would be needed, as these offices usually have higher financial constraints and lower willingness to burden tax revenue. Proper training and information on green public procurement and standards could enhance collaboration between procurement officers at the national level across the EU.

Impact of the recommendation: If 40% of cement in the EU is used for public construction, even light Green Public Procurement (GPP) criteria (e.g. requiring 10% emission savings) could already cut the sector's emissions by 4%, or 4.4 Mt of CO_2 annually. More ambitious GPP criteria (50% emission savings) could reduce emissions by 20%, or 22 Mt of CO_2 per year. Best practices already show the benefits: Vienna saved €44.4 million and cut CO_2 emissions by over 100,000 tons between 2004 and 2007 through effective GPP. A 2015 study found that Berlin reduced GHG emissions by 47% and cut costs by 3.8% (€38 million annually) using GPP across 15 product categories. Catalonia increased GPP from 14% in 2017 to 40% in 2020, aiming for 50% by 2025. Similar standards are currently being developed and implemented in the US and in Latin American markets.

Green premium cement

Box 3

The green premium for cement (60-100%) is significantly higher than in sectors such as electricity generation, where the LCOE of renewables is already competitive compared with fossil fuel generation. However, cement's green premium is much lower than in other hard-to-decarbonize sectors such as shipping, where the premium for sustainable fuel compared to bunker fuel is between 350-600%. Most importantly, however, the impact of cement's green premium on the final cost of the product is relatively small. **In construction, even the 60-100% increase per ton of cement adds only 1-3% to the final cost of the building**. This allows for a much bolder approach in embracing the green premium.

Percentage cost increase

*The green premium will be higher in infrastructure projects with high concrete content and global south markets.

Note: Scenario based on the Net-Zero Scenario, using 1.6 Gt of carbon capture.
Ranges driven by variation in underlying product and abatement costs. The cost premium includes CapEx and OpEx.

Source: MPP analysis (2022)

Five recommendations to policymakers

5. Implement financing schemes to catalyze the transition to tomorrow's market

Old industrial regions often face outdated infrastructure and equipment, high energy consumption, and environmental impacts from legacy industrial practices. Transitioning to alternative cement production requires substantial investment in new facilities or retrofitting existing plants, which can be a deterrent for manufacturers. Catalyzing the transition to tomorrow's low-carbon cement industry will therefore require significant capital-intensive investment in building new facilities and retrofitting existing ones.

- **Broaden the focus of EU funds** to include innovation in alternative materials and structural efficiency, rather than concentrating mostly on CCS. Currently, CCS dominates funding from the Innovation Fund, with eleven large-scale projects receiving €1.931 billion, while only one project for clinker substitutes and one for fuel switching receive minimal support (€0.0045 billion and €0.0044 billion, respectively).

- **Boost regional development:** Additionally, retrofitting for improved efficiency and reduced operational costs can boost the competitiveness of cement plants in older industrial regions, often a major employment pool, thus driving employment, investment, and economic growth. Ensuring the earmarking of European Structural and Investment Funds and a follow-up of the Just Transition Fund post-2026 are essential for the development and competitiveness of old industrial regions.

- **Implement financial guarantees** to make green power more economically viable and mitigate risks for industries transitioning from natural gas to electrification. Adjust grid fee structures to reduce costs for industries using renewable energy and explore the use of virtual Power Purchase Agreements (PPAs) – without grid fees – to secure clean energy at competitive prices for industrial users.

- **Design and launch competitive, two-sided Carbon Contracts for Difference (CCfDs)** across EU member states to help bridge the gap between today's volatile carbon prices and the high upfront costs and risks of building first-of-a-kind cleantech that currently deter private investors. CCfDs mitigate investor risks by covering the additional upfront capital expenditure (CAPEX) and operational expenditure (OPEX) in relation to the CO_2 price. If CO_2 prices rise above the agreed strike price, making traditional production more expensive than sustainable alternatives, project owners repay the difference to the government. This both rewards governments for the initial risk-taking, making more such investments possible, and protects against subsidized windfall profits. CCfDs could focus on mature technologies with significant carbon reduction potential in the next 15 years, such as limestone calcined clay cement (LC3) or CCUS. Meanwhile, regulatory sandboxes, such as those in the Net Zero Industry Act, can provide testing grounds for less mature technologies in real-world conditions. In Germany's current CCfD scheme, companies compete to offer the lowest-cost, low-emission production across various industries, with a 15-year green premium guarantee.

- **Invest in alternative cements** which are more expensive to produce due to higher raw material costs, additional processing requirements, or smaller economies of scale. The EU should continue to invest in R&D to improve their performance and reduce costs, including pilot projects to demonstrate their real-world benefits. Encouraging the use of alternatives will in parallel require governments to revise building codes to support the use of sustainable materials, making CO_2 disclosure mandatory.

Impact of the recommendation: The discussion on CCfDs is still emerging, so quantitative estimates of their impact are currently limited. An analysis on the German cement industry shows that a strike price of 80 €/tCO_2 would be sufficient to cover the green premium for decarbonizing clinker through oxyfuel CCUS. With the current CO_2 price of around €70 /tCO_2, governments would only have to cover an additional €10 per ton of CO_2 avoided. Another analysis estimates that decarbonizing 20% of industrial installations in the EU could require annual support of €4-16 billion, depending on strike prices of €70-150 and assuming a CO_2 price of 45 €/tCO_2. A scenario analysis for achieving 30% decarbonization of selected materials in Germany through CCfDs estimated the cost to the government to be between €13 and €17 billion, with potential benefits assuming a CO_2 price of €50. Overall, the cost of CCfDs for the EU cement industry appears to be low compared to other policy instruments, such as subsidies, and even profitable in the long term given the expected increase in CO_2 prices.

Carbon Capture, Utilization, and Storage (CCUS)

Box 4

CCUS involves capturing CO_2 from large sources like power plants or industrial facilities. The CO_2 is then either used on-site, transported by pipeline, ship, rail, or truck for various applications, or injected into deep geological formations such as depleted oil and gas reservoirs or saline aquifers. 80% of emissions from cement production can be reduced without using CCUS when considering solutions across the entire value chain. However, given the high amount of process emissions which are unavoidable today, the cement sector is one of the priority sectors for CCUS deployment, and, given its high costs, should be prioritized in Carbon Contracts for Difference to ensure a consistent revenue stream to operators.

Conclusions

To meet the EU's ambitious decarbonization targets of reducing greenhouse gas emissions by 55% by 2030 and achieving climate neutrality by 2050, the cement sector must urgently adopt sustainable practices.

Policymakers have a crucial role in cutting today's market, creating tomorrow's market, and catalyzing the transition by designing an effective policy framework.

Future Cleantech Architects advocates for the adoption of the following measures:

1.	2.	3.	4.	5.
Cut emissions and material demand through material efficiency strategies	**Realize the full potential of carbon pricing mechanisms in today's market**	**Outline tomorrow's market with green standards for cement and concrete**	**Implement Green Public Procurement across the EU**	**Implement financing schemes to catalyze the transition to tomorrow's market**
By 2050, rigorous material efficiency strategies have the potential to reduce emissions by up to 65%.	Ending free ETS allocations (2023-2033) will save €331B, while full auctioning by 2026 will generate €5B/year for low-carbon cement R&D.	Performance-based standards can cut emissions by 50%, boost innovation, and align responsibility along the value chain.	40% of EU cement is used in public construction; GPP could cut emissions by 4-20%, saving up to €44M and 100k+ tons CO_2.	CCfDs for EU cement require €4-16B/year for 20% decarbonization, with government support of €10/ton CO_2 avoided.

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The contents of this report represent the views of Future Cleantech Architects and should not be taken to represent those of the reviewers or the organizations to which they are affiliated.

About Future Cleantech Architects:
We are a climate innovation think tank. We exist to close the remaining innovation gaps to reach net-zero emissions by 2050. To reach this objective, we accelerate innovation in critical industries where sustainable solutions are still in very early stages.

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