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Global innovations driving zero-carbon cement

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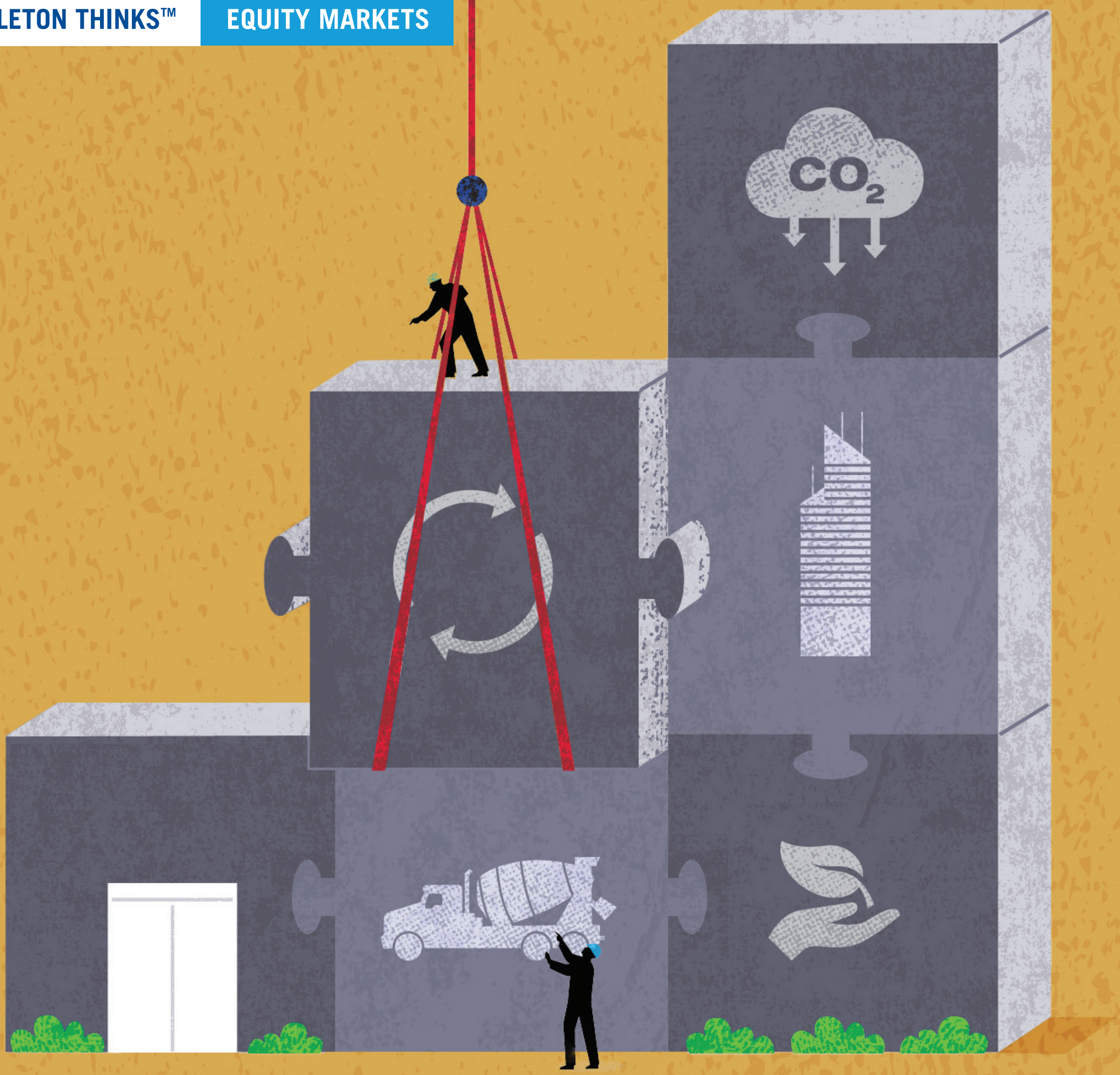

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Introduction

As the glue that binds sand and gravel to make concrete, cement is an integral part of our everyday lives. We build houses, skyscrapers, hospitals and bridges from it, and even use concrete to anchor wind turbines. Beyond infrastructure, cement is a cornerstone for nations seeking to improve the prosperity and quality of life of their citizens. Essential to China's modern urban landscape, cement is projected to play a similar role across regions, like India and Africa, making cement a high-profile sector for our emerging market equity analysts.

And yet, cement is also one of the most carbon-polluting industries. If we rank cement with the world's largest economies, it ties with India as the fourth-largest carbon dioxide (CO_2) emitter after China, the United States and the European Union (EU).[1] For climate-focused investors, cement is a thorny issue for the "E" in ESG analysis (Environmental, Social and Governance). There is currently no low-carbon replacement for cement's core ingredient—called clinker—that also matches the scale of growing global demand. This puts cement in a tug-of-war between two global trends: improving standards of living and decarbonizing national economies.

Luckily, there are well-known levers that cement operators are already pulling to reduce cement's carbon intensity—measured as CO_2 emissions per metric ton (MT) of cement. Total decarbonization, on the other hand, is quite difficult, though not impossible. With this backdrop in mind, our discussion dives into the mechanics of decarbonizing cement production, with a focus on recent developments and ESG research across the EU, China and India.

Key takeaways

- When analyzing the scope of cement carbon emissions, equity research typically hones in on ESG metrics like "clinker ratios"—which measure the percent of clinker in cement versus lower-carbon ingredients—and the ratio of "alternative fuels" used to heat cement kilns. Our on-the-ground analysts in China and India explain why some of these yardsticks can unravel upon closer inspection.
- To gauge prospects for zero-carbon cement, company-level metrics give you only half the picture. The economics of carbon capture technology, for example, don't work without national carbon pricing and publicly financed infrastructure. When grading country-level policies for capacity to decarbonize, our analysts think China may hold an edge in the coming years, compared with a more slow-moving EU.
- The EU plans to be the first carbon-neutral continent, with China pledging to decarbonize by 2060. Since India isn't following a similar glidepath (for now), two equity research shops recently predicted India could sell lower-priced (but higher-carbon) cement into Europe, benefiting from "carbon leakage." We explain why future carbon border adjustments will likely prevent this scenario from playing out.

Concrete steps to lower CO_2

Cement is one of the core pillars of our global economy. Over the past two decades—as the world's population grew 25% and gross domestic product (GDP) doubled—cement production skyrocketed from less than two gigatons (Gt) in 2000 to roughly 4.1 Gt annually during the last five years (one billion MT = one Gt).[2] Next to water, cement is now the second-most utilized substance on earth; if we divided cement by people, roughly half a MT of new cement is made annually per person on the planet.

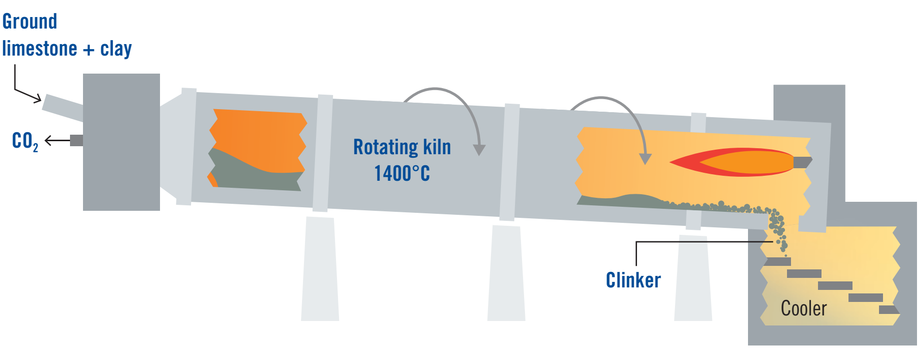
As a core building block, cement is part of most commercial and residential buildings, and a key part of critical infrastructure, including roads and bridges, and conduits for clean water and sanitation. Future demand is projected to jump another one billion MT before 2040, driven largely by population growth and infrastructure needs in regions such as India and Africa.[3] For governments aiming to improve quality of life for their citizens, cement is an irreplaceable ingredient for the hospitals, homes and renewable energy infrastructure that helps make socio-economic wellbeing a reality.

And yet, from a climate perspective, cement has a glaring Achilles' heel. On average, each MT of new cement emits well over half a MT of CO_2 during production. To get cement, just throw any decent-quality limestone into a coal-fired kiln, then heat it to 1400°C to produce clinker, cement's core ingredient. Roughly half of cement's CO_2 emissions occur when the carbon trapped in limestone is released in the kiln, while the remaining emissions come from heating the kiln, as seen in Exhibit 1.

Last year, variations of this production process added 2.4 Gt of carbon to Earth's atmosphere.[4] That's roughly a quarter of industrial emissions comprising sectors like steel and chemicals, and 7% of overall global greenhouse gases (neck-and-neck with global car emissions), as shown in Exhibit 2. Pressed by investors and governments to decarbonize, cement operators face a tough economic challenge, especially when compared with industrial peers; cement generates the most CO_2 per US dollar of revenue (6.9kg) versus 1.4kg for steel, 0.4kg for mining and just 0.3kg for chemicals.[5]

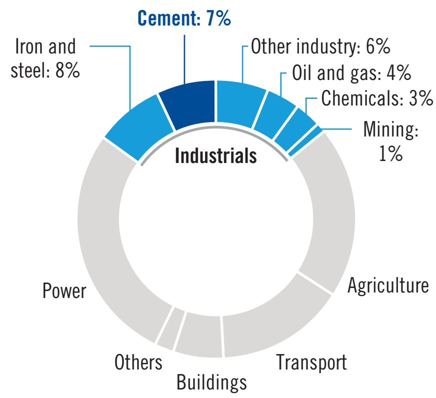
LIMESTONE + HEAT = CEMENT'S CO_2 FOOTPRINT

Exhibit 1: Clinker production illustrated



CEMENT'S 7% SHARE OF GLOBAL CO_2 EMISSIONS

Exhibit 2: Global CO_2 emissions by source with a focus on industrials



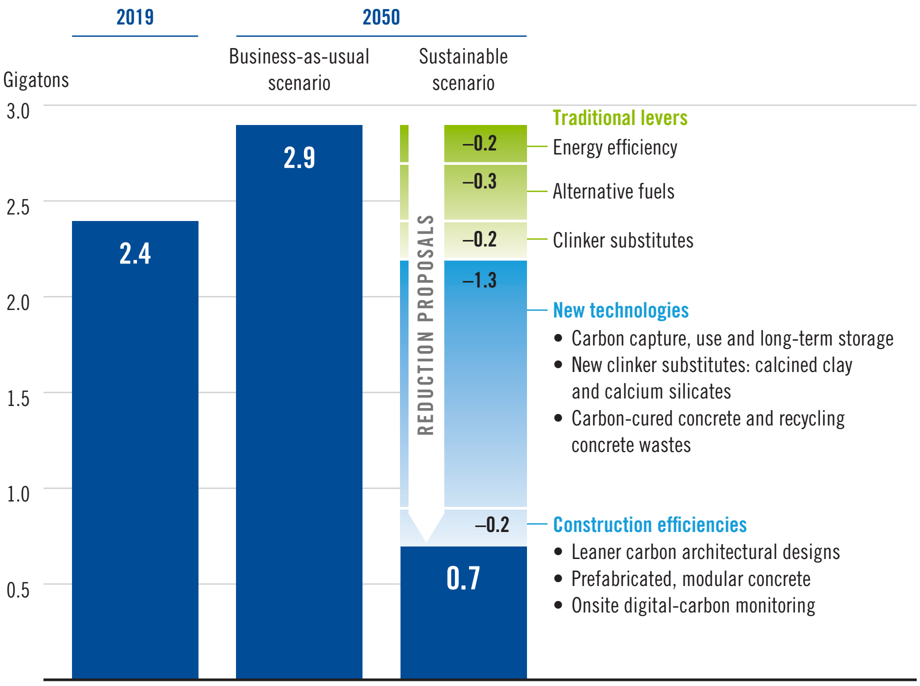
Source: McKinsey & Company. As of 2017.

ESG reports on cement often focus on three clear-cut steps for reducing cement emissions—see "traditional levers" in Exhibit 3 (on the next page). For example, you can shrink cement's clinker ratio by mixing in pozzolana (volcanic ash) or industrial byproducts, like blast furnace slag, or offset the coal for heating kilns with greener fuels, like sewage sludge. But these steps only go so far, and often don't match the scale of demand in countries like China. Other solutions, like replacing some clinker with fly ash from coal-fired power plants, are short-term remedies; supplies of fly ash will diminish if nations decarbonize their energy systems.

Achieving far larger emission cuts requires "new technologies," like injecting liquified CO_2 into wet concrete to sequester carbon while it hardens. Getting these innovations off the ground, however, requires new building codes which regulate design and stipulate approved materials. Other zero-carbon innovations like carbon capture are still decades from large-scale deployment and will require public investments in new infra-structure to transport and store liquified CO_2 underground.

NEW TECHNOLOGIES DOMINATE CO_2 REDUCTIONS

Exhibit 3: Potential CO_2 emissions and reductions, annual gigatons CO_2



Sources: "Getting the numbers right," Global Cement and Concrete Association, 2017, gccassociation.org; Global Cement, fifth edition, Freedonia Group, May 2019, freedoniagroup.com; The Global Cement Report, 13th edition, CemNet, cemnet.com; Umweltbundesamt (German Environment Agency); McKinsey 1.5-degree-pathway model 2020; McKinsey Cement Demand Forecast Model emissions 2020. There is no assurance that any estimate, forecast or projection will be realized.

EU carbon pricing

To help speed up the testing and deployment of zero-carbon innovations, the EU's European Commission announced in September 2020 it plans to reduce the number of carbon permits in the EU emissions trading system (ETS). This could double the price of carbon from €30/MT (US$36/MT) this year to upwards of €59/MT (US$70/MT) by 2030.[6]

As the world's biggest cap-and-trade carbon market, the ETS provides economic incentives to invest in new carbon solutions by making CO_2 emissions more expensive. The EU proposal, which has yet to be approved by the EU Council of Ministers, aims to cut EU greenhouse gas emissions 60% below 1990 levels by 2030.[7] Negotiations could be dicey as center-right lawmakers think the new carbon caps are too costly for Europe's industries and may endanger jobs.

The International Monetary Fund (IMF) applauds the EU carbon proposal but points out higher carbon prices alone aren't nearly enough to reach EU carbon neutrality by 2050. Zero-carbon technologies like green hydrogen for steel and carbon capture for cement will require additional spending from EU governments and public-private financing for infrastructure.[8]

Carbon border adjustments

In late January 2020, just as COVID-19 began shaking global markets, the Financial Times reported on new equity research forecasting a sharp rise in European cement prices.[9] The main culprit: expensive carbon capture technology necessary to decarbonize.

The research claimed the costs of retrofitting cement plants with carbon capture would eat away corporate profits, evaporate shareholder dividends and ultimately force cement price hikes. In turn, higher cement prices would expose EU cement makers to "carbon leakage" via cheaper higher-carbon imports from outside the EU. The "buy or sell" recommendations for Europe's largest cement makers, Germany's HeidelbergCement ("Heidelberg") and Switzerland's LafargeHolcim ("Lafarge"), were promptly downgraded.

A more recent ESG report from Investec that crossed our desk makes a similar prediction, pinpointing India cement makers as the primary beneficiary of new seaborne trade into Europe.[10] A quick aside: cement is largely made and consumed locally, and isn't traded internationally, yet. The ESG study accurately notes India's cement makers score well on a range of ESG metrics, including lower clinker ratios and carbon intensity. Because India isn't pursuing net-zero emissions, its companies can avoid the costs of carbon capture and may undercut EU cement makers on price.

For economies using carbon markets to reach zero-carbon more quickly, carbon leakage via seaborne trade has a solution: carbon border adjustments. For cross-border trade, new ecolabels that quantify the "embodied carbon" of imports will make it easy to adjust prices to match the values assigned by local carbon markets. Cement makers in India are still free to avoid the costs of zero-carbon technology. However, they could face price adjustments when selling into regional carbon markets. With China's national carbon market kicking off in 2020, we think carbon border adjustments are poised to gain momentum.

Shareholder pressures

For climate-focused investors, the January 2020 cement downgrades may seem misguided. Shareholder groups like the Institutional Investors Group on Climate Change (IIGCC) have been pushing Heidelberg and Larfarge to increase investments to speed up CO_2 reductions. ShareAction, a UK lobby group, went even further by encouraging bondholders to boycott new issuances from "climate laggards" in Europe's cement industry.[11]

Responding to investor pressures and EU carbon pricing, Lafarge recently announced it's stepping up its climate efforts. By mixing in more low-carbon ingredients, Lafarge intends to reach 475kg of CO_2/MT of new cement by 2030, roughly 15% less CO_2 than 2019.[12] As for Heidelberg, it is fast-tracking its 2030 carbon reductions, aiming for 525kg of CO_2/MT of cement by 2025.[13]

To be clear, low-tech methods to reduce carbon intensity won't likely squeeze profit margins too hard for Lafarge and Heidelberg. The dilemma, however, is reaching Europe's net-zero goals by 2050. Even with the EU's proposed carbon price hikes, the economics of carbon capture still don't add up. To make the math work, cement companies need to see CO_2 prices as high as €68/MT (US$81/MT) to €110/MT (US$131/MT) to implement carbon capture, according to estimates from the International Energy Agency (IEA).

The world's cement colossus

Despite the recent focus on European cement makers, to really grasp the big picture one needs to look at cement production globally. Today, over half of the world's cement is made and consumed in China, with India coming in a distant second, as shown in Exhibit 4. Since 2000, the surge in demand for cement has largely been fueled by China's spectacular economic transformation, moving hundreds of millions of people out of poverty and into a modern urbanized landscape. Consider the following: China poured more concrete between 2011 and 2013 (6.6 billion MT) than the United States poured during all the twentieth century (4.5 billion MT).[14]

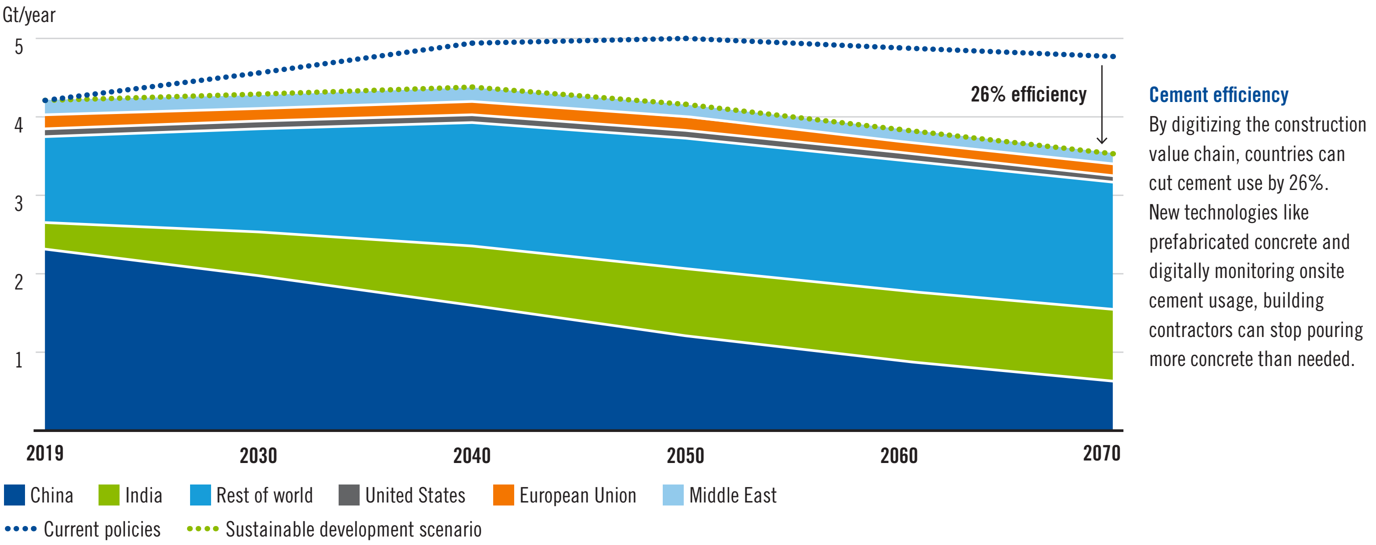
With well over half of today's cement coming from kilns in China and India, it's worthwhile examining how companies like Anhui Conch ("Conch") in China and Ultratech in India are grappling with CO_2 emissions. Like their counterparts in Europe, these firms focus on the traditional carbon-abatement levers found in most ESG reports: energy efficient kilns, replacing coal with alternative fuels, and blending cement with clinker substitutes. Each approach can move a company closer to lower-carbon cement. However, our on-the-ground inspections reveal some methods are outmatched by the scale of China's cement production, and others appear likely to disappear in a carbon-neutral economy.

Three roads to greener cement

From an energy perspective, the cement kilns in China and India are already among the most efficient commercially available—many built in the last 10 years. Known as dry kilns, the majority pre-heat raw materials, like limestone, before entering the kiln for better energy efficiency. And hence, lower carbon emissions. By contrast, more energy-intensive wet kilns, which add water to the cement ingredients fed into kilns, are still common in countries like Russia and throughout the Caspian region.

CHINA: CEMENT'S GOLIATH

Exhibit 4: Expected cement production by region in Gt/yr



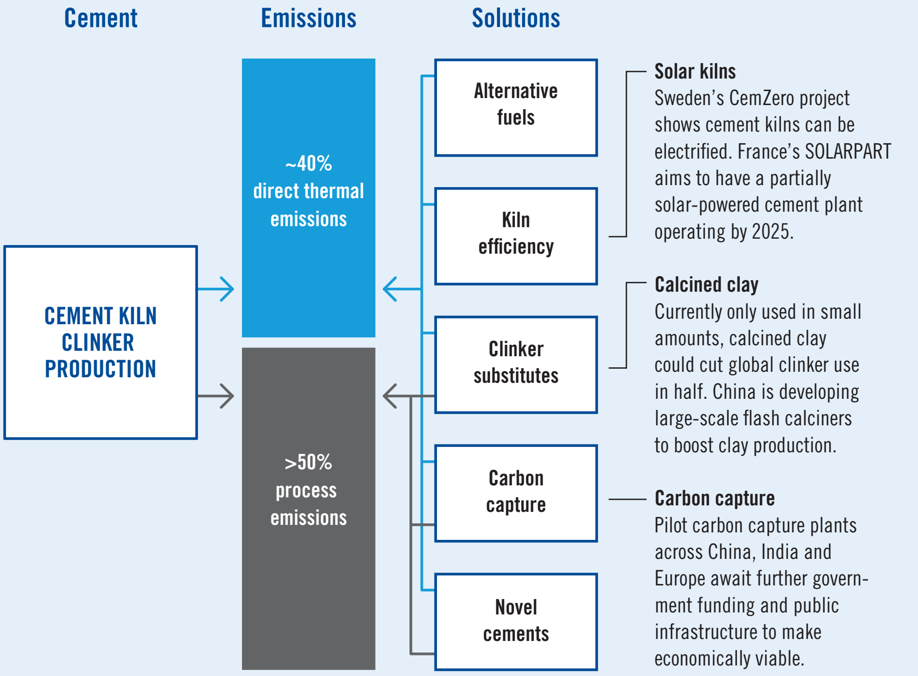
Sources: Energy Technology Perspectives 2020, IEA, September 2020. There is no assurance that any estimate, forecast or projection will be realized.

As for heating kilns, coal remains one of the cheapest (and dirtiest) fuels, accounting for about 40% of cement's thermal CO_2 emissions—see "Cement CO_2 Solutions" illustration. To cut thermal emissions, operators can switch to alternative fuels like solid wastes or green biomass. Conch, for example, converted 11 cement plants to municipal waste, with one 14 million MT cement plant in Tongling incinerating all the trash produced by that city's residents.[15] That's still just a drop in the bucket; Conch has more than 150 cement plants that produced 359 million MT of cement in 2019.

Even if Conch increases alternative fuels by 20–30% like many European operators (cement companies in China and India average 3–5% green fuels, according to the IEA) this isn't a zero-carbon solution. Burning biomass, for example, still produces CO_2 emissions, and supplies hardly match the scale of China's demand. As for non-renewable wastes such as tires, plastics and types of municipal waste, these sometimes have higher CO_2 emissions than coal in addition to pouring toxins into the air. Green fuels can help, but they aren't a zero-carbon panacea.

This leaves tackling clinker. Globally, cement's average clinker ratio is 70%, although it varies widely by region. At 65%, China's cement makers already boast the lowest clinker ratios globally, on average. Driving that lower with substitutes like slag is tricky; the volume of slag from China's steel mills is insufficient. As for fly ash from coal-fired power plants, those supplies need to start shrinking exponentially if China is serious about meeting its zero-carbon pledge; coal-fired power generates one-quarter of global CO_2 emissions annually.[16] To drive cement's carbon intensity even lower, China is researching new innovations like calcined clay, which we turn to shortly.

Cement CO_2 solutions



Source: Based on Chatham House, 2017. For illustrative purposes only.

Cross-country comparisons

After factoring in these three carbon-abatement levers—kiln efficiency, greener fuels and lower clinker ratios—we see in Exhibit 5, on the next page, that carbon intensity across some of the biggest cement companies in the EU and India are roughly in the same ballpark. Carbon intensity is somewhat higher for large China companies due mostly to the higher-strength cement (81.5% clinker ratios) needed for big infrastructure projects. Relative to Europe, both China and India benefit from modern fleets of energy-efficient kilns and lower average clinker ratios. In Europe, in Germany in particular, cement companies stand out by using more alternative fuels.

As we've outlined, it's important to know what's underneath ESG metrics like clinker ratios to understand if the clinker substitutes have long-term viability. In our opinion, using fly ash does not. These metrics also don't reflect the new innovations that make zero-carbon achievable. Deploying these technologies at scale requires country-level policies, like public investments to help bridge the "valley of death" between early prototypes and mass deployment. If zero-carbon cement ever becomes a horse-race among the world's largest economies, we think China could soon give its peers a run for the money.

CEMENT CARBON INTENSITY

Exhibit 5: 2019 emissions of CO_2 per MT of cement across six large cement companies

CO_2 intensity (kilograms per MT cement)	561	590	619	505	683	690
Cement capacity (2019 million MT)	286	187	108*	33	359	104
Company	**LafargeHolcim**	**Heidelberg**	**Ultratech**	**ACC**	**Anhui Conch**	**China Resources**
Country	Switzerland	Germany	India	India	China	China

Sources: 2019 shareholder reports; *Ultratech cement capacity based on FY2020 rather than calendar year 2019. CO_2 cement intensity figures for Anhui Conch and China Resources are derived from clinker intensity (standard reporting in China) and an average 81.5% clinker ratio to determine cement CO_2 intensity. As of December 2020.

China's carbon declaration

President Xi Jinping's surprise carbon-neutral pledge at the 2020 United Nations climate meeting gave new energy to keeping Earth's climate from rising above 1.5°C. With Xi's commitment, four of the world's six largest economies (by nominal GDP) now have specific end dates for carbon-neutral emissions: as the second-largest economy, the EU is followed by China, then Japan and California as the fifth largest. The national US economy (ex-California) and India remain outside of this climate consensus, for the time being.

For the cement industry, Xi's carbon pledge is especially relevant given that China is the world's largest producer of cement. China, however, can't reach its ambitious carbon goal by simply pushing traditional carbon-mitigation levers. Large supplies of natural clinker substitutes like pozzolans, for example, aren't available in China. Instead, it must rely on new innovations to reach net-zero emissions.

Fortunately, the cement industry has been busy researching new low-carbon technologies. Achieving net-zero emissions in 30–40 years will require fast-tracking several prototype inventions well before 2030. Only through rapid scaling can today's early-stage inventions reach the commercial viability needed to replace and retrofit the cement industry's production capacity. We offer a high-level summary of some pioneering innovations.

Novel cements

In a partnership with Lafarge, Solida Technologies is using calcium silicates to replace limestone. Its unique recipe can reduce concrete's carbon footprint 70% by lowering kiln temperatures and curing concrete with waste CO_2.[17] Its main flaw is that curing must take place inside an enclosed CO_2 chamber, making it highly impractical for large infrastructure projects that pour concrete directly onsite. Other companies, like CarbonCure, are reducing clinker ratios by injecting liquified CO_2 into wet concrete as it's being mixed.[18]

Perhaps the most promising clinker replacement is calcined clay. Naturally abundant, clay is a good match for cement's sky-high demand in China and across the developing world. Research shows using a combo of calcined clay and ground limestone makes it possible to reach clinker ratios of 50%, and potentially cut production emissions in half.[19] There are some hurdles, including longer periods for the concrete to fully set, which could lengthen onsite construction times.[20] That said, calcined clay is an economical carbon solution for cement companies. China is busy testing two energy-efficient flash calciners that can process 300 MT of calcined clay per day.[21]

Carbon capture

If there's one cement gamechanger, it's carbon capture. In 2018, China's Anhui Conch spent RMB¥60 million (US$9 million) building a pilot carbon capture plant in the city of Wuhu in Anhui province. It separates and purifies 50,000 MT of CO_2 annually, which is just a fraction of the 1.5 million MT of CO_2 a typical plant produces in China. Meanwhile in India, Dalmia Cement is partnering with the Carbon Clean UK to build a carbon capture demonstration project in Tamil Nadu, India.

In Europe, the Norcem subsidiary of Heidelberg awaits funding of €1.5 billion (US$1.8 billion) from Norway's government to start building the world's largest carbon capture and storage project. With capacity to capture 400,000 MT of CO_2 annually from Norcem's Brevik cement factory, this demonstration project includes underwater infrastructure that can transport 1.5 million MT of liquified CO_2 annually for long-term storage underneath the North Sea. The project is part of Norway's pledge to reach carbon neutral by 2045. It's an ambitious endeavor, and yet still only scratches the surface. The IEA estimates that for the global cement industry to reach zero-carbon emissions by 2050, we would need to see five carbon capture facilities at 1 million MT capacity built monthly.[22]

For the time being, many cement companies are taking a wait-and-see approach to ascertain if carbon capture projects work, and if governments are willing to absorb the costs. As for carbon capture driving up cement prices, cement typically accounts for a small portion of costs (less than 2%) for large infrastructure and property development projects in China. Even if cement prices double, it would still be less than 5% of total construction costs.

The race to zero-carbon

The technologies we need to achieve zero-carbon cement are, for the most part, already known. Very few, however, are ready for mass-scale deployment. Meanwhile, security analysts can rank cement companies using ESG metrics like carbon intensity. It's difficult, however, to gauge the speed of zero-carbon trajectories. That's because decarbonization glidepaths depend on national industrial policies, like carbon pricing, and public-private financing.

There are only two economic transformations in history that approach the scale and speed theoretically required to avoid breaching the 1.5°C climate threshold. The first is China's explosive growth over the last 20 years, followed by the United States—more specifically, its rapid industrial and technological mobilization preceding the second world war.[23] In both examples, substantial government investments in research, infrastructure and training were critical to jumpstarting rapid national transformation. Some economists describe these two time periods as top-down "command economies." We think that description short shrifts the entrepreneurial spirit that was present in both time periods.

For regions like India and Africa that might not commit to net-zero emissions, there are still ample contributions to make toward reducing cement CO_2 emissions. Besides deploying calcined clay, the IEA estimates countries can

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cut cement demand 26% by simply not pouring more concrete than needed—refer back to Exhibit 3.

By digitizing the construction value chain, contractors can reduce cement wastage with more optimized building designs, and new construction techniques like prefabricated concrete and digitally monitoring embodied carbon on the building site. All combined, these efficiency practices could eliminate any cost increases from using zero-carbon cement. Extending the lifetime of buildings and infrastructure with higher renovation rates is also key, along with reusing and recycling concrete. It's important to note that all of these innovations lie outside the purview of cement companies and point toward new construction and engineering policies.

In terms of 2030 carbon reduction goals, European cement makers are currently on track to outpace companies in China. With the EU's recent approval of a €500 billion (US$594 billion) green stimulus plan (it includes projects like scaling up green hydrogen and sustainable agriculture), we expect to see continued CO_2 cement reductions from Lafarge and Heidelberg. That said, given Xi's new carbon-neutral pledge, China's cement makers may catch up with Europe in short order. European Commission President Ursula von der Leyen certainly seems to think so—she's asked China to join a new "high ambition coalition" for tackling climate change.[24] With a new US administration coming to Washington in January, von der Leyen's high ambition alliance may welcome another member.

Both sides of a coin

Standing back to examine cement's tug of war between improving standards of living and decarbonizing national economies, we end this discussion with our opinion that divesting from cement makers doesn't make sense from an ESG perspective. Cement remains essential to improving the quality of life for millions of people, especially in developing economies. Achieving zero-carbon cement will require both company-level innovations and country-level carbon policies, both of which are rapidly evolving as we get closer to global temperatures above 1.5°C. Active on-the-ground monitoring by our equity analysts across the globe remains key to successful ESG investing.

Endnotes

1. 2017 CO_2 in gigatons (Gt): China 10.9 Gt, United States 5.1 Gt, European Union 3.5 Gt, India 2.4 Gt. EDGAR database 2018.
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21. Source: Sui, T. 2020. Progress of low carbon cement in China. *Institute of Concrete Technology Yearbook, 2019–20*, 24th ed., 21–27.
22. Source: IEA. *Energy Technology Perspectives 2020*, September 2020.
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