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The 21st-century cement plant: Greener and more connected

The cement plant of the future will embrace digitization and sustainability trends to earn a competitive advantage and build resilience.

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There's never been a more important time to build resilience into the core of the cement value chain: the cement plant. The cement industry is being hit hard by the COVID-19 pandemic, with global demand for cement is expected to decline by 7 to 8 percent in 2020—though these declines have been unevenly distributed across regions.[1] In response, cement players around the globe have reduced production or even closed plants entirely. And while the plant is just one component of the cement value chain, its role in navigating disruption and setting up cement companies for future success is crucial.

The path forward for the industry is clear: embrace digitization and sustainability. Putting these two trends at the core of planning for the future will help cement players catch up to those in other heavy industries and achieve considerable productivity gains. In an industry where regaining lost revenues can take years, it is crucial to kick off now to both recover from the impact of COVID-19 and make cement players more resilient to future disruptions.

Indeed, the cement plant of the future will operate in a drastically different way than today's plants. In this article, we describe our vision for a resilient, agile, green, and efficient plant as well as the business impact and strategic considerations that senior leaders should consider when determining the industry's path forward.

Our vision: The leading cement plant of 2030

The cement plant of the future achieves considerably lower operating costs and higher asset value through higher energy efficiency, yield, and throughput. More targeted and effective maintenance lengthens the lifetime of equipment. Each plant's environmental footprint is minimized, securing its license to operate across locations and jurisdictions. The plant meets customer demand by dynamically adjusting production and logistics according to real-time customer data. Excited, engaged employees focus on value-added activities, and all non-value-added tasks are automated. Real-time information is available for managers remotely at all levels to make better decisions.

This future is not far off. Our analysis shows that pursuing digitization and sustainability levers are key to significantly boosting productivity and efficiency of a typical cement plant (Exhibit 1). The result is a margin gain of $4 to $9 per ton of cement,[2] which could shift a traditional plant to the top quartile of the cost curve for plants with similar technologies (see sidebar "Today's cement plant").

The required capital expenditure needed to make this transition will vary based on the lever applied. For example, implementing an advanced analytics (AA) pilot[3] for the burning process would require two to three months of expert work to gather and analyze historical data as well as model and train the system. Meanwhile, investing in an alternative fuel installation would require up to $20 million and up to one year to commission and operate. More innovative solutions will require additional money and time. Beyond that, though, some of these investments might be driven by requirements outside the typical operational excellence or compliance requirements to which the industry is accustomed.

Operational frontrunner: Enabling digital and advanced analytics

Unlike many other industries, cement has yet to embark on its comprehensive digital transformation journey. Of the 54 manufacturing plants designated as "lighthouses"—leaders in using Fourth Industrial Revolution (Industry 4.0) technologies—not one is a cement plant (see sidebar "Manufacturing 4.0: Lighthouse factories, as defined by the World Economic Forum"). However, stricter regulations, declining demand, and changes in the broader construction ecosystem will create the urgency this industry needs to pursue Industry 4.0 technologies to stay competitive.

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[1] Paul Roger, "Impact of COVID-19 on global cement markets," *Global Cement Markets*, June 2020, cemnet.com.
[2] Without taking into consideration the impact of innovative installations for carbon reduction.
[3] Eleftherios Charalambous, Robert Feldmann, Gérard Richter, and Christoph Schmitz, "AI in production: A game changer for manufacturers with heavy assets," March 7, 2019, McKinsey.com.

Exhibit 1

Applying digitization and sustainability levers together can increase margin by $4–$9 per ton of cement.[1]

Potential savings per ton of cement, %

■ High savings potential ■ Medium savings potential ■ Not quantified

Value-creation category/lever	Advanced analytics[2]	Process digitization	Automation and robotics	Traditional levers[3]	Innovation[4]	Total
Carbon emissions[5]						
Yield, energy, throughput	6–12%			2–6%		8–18%
Raw materials	1–3%					1–3%
MRO[6]	5–8%	~5%	1–5%			11–18%
Productivity		10–15%	10–15%			20–30%

Capital expenditure

$50,000 → $100 million

[1] Assuming an average production cost of $35–$40 per ton of cement; without taking into account the impact of innovative installations for carbon reduction.
[2] Includes asset optimization and reliability.
[3] Includes fuel-mix optimization, energy efficiency, and clinker substitution.
[4] Includes carbon capture, utilization, and storage (CCUS), solar power generation, electrification of logistics and mobile equipment, and micro-algae cultivation, among others.
[5] Currently, free carbon allocations are sufficient for cement players, and therefore no cost is directly associated with carbon-emissions reduction, but this may change in the future.
[6] Maintenance, repair, and overhaul.

Source: McKinsey analysis

Today's cement plant

When envisioning the cement plant of the future, it is important to understand the reference for a typical plant today. Our reference plant is a five-stage preheater-calciner kiln with a vertical raw mill and two cement ball mills. It has an annual production capacity of one million metric tons of cement and produces several types of cement. The plant has an average overall equipment effectiveness (OEE) of 90 percent, and it uses up to 15 percent plastics as an alternative fuel source. It has also recently implemented an advanced-process-control tool for kiln flame and cement mill management. The plant has a central control room for monitoring all plant operations, and operators huddle daily to review shift results on a digital screen. The maintenance department feeds manual inspection logs into a reliability tool, which notifies technicians of the next equipment inspection. The per-ton cement cost at such a plant is between $35 and $40.

In the cement plant of the future, value—not necessarily volume—is the key focus. Real-time, fact-based decision making is the norm, and continuous adjustments account for ecosystem variability. The product portfolio is increased five- to tenfold, and operations are managed with dynamic constraints and opportunities, with production parameters adapted in real time. Digital twins simulate and optimize the overall impact of external variability in operations ranging from complex processes such as burning to more structured activities such as maintenance.

Fewer workers are required to be on-site continuously, and interactive online dashboards allow managers to remotely collaborate, solve problems, and quickly make informed decisions with the rest of the team. Maintenance engineers are alerted of faults in equipment or of opportunities for maintenance immediately, and they receive step-by-step instructions on how to repair with the aid of augmented reality.

A strong technological base facilitates a fully integrated cement value chain, including within different functions. AA algorithms improve yield, throughput, quality, energy efficiency, and cement-to-clinker ratios.[4] Automated tracking of overall-equipment-effectiveness (OEE) loss and AA-enabled software tailor asset strategies to improve equipment reliability and lifetime (Exhibit 2).

A carbon-neutral cement industry: Pioneering the response to climate change

Cement production in 2017 was responsible for 7 percent of global CO_2 emissions. Increased pressure for more-stringent emissions standards and decarbonization from society and governments alike will have a major impact on the industry. This has the potential to disrupt the entire value chain, as cement producers will need to rethink their products, portfolios, and partnerships to achieve carbon neutrality.

[4] Eleftherios Charalambous, Thomas Czigler, Robert Feldmann, and Patrick Schulze, "AI to boost core assets," *International Cement Review*, February 2019, cemnet.com; Charalambous, Feldmann, Richter, and Schmitz, "AI in production: A game changer for manufacturers with heavy assets."

Manufacturing 4.0: Lighthouse factories, as defined by the World Economic Forum

Since 2018, the World Economic Forum (WEF), in collaboration with McKinsey, has been studying the characteristics that differentiate advanced-manufacturing frontrunners—or "lighthouses"—from the rest of the industry. WEF describes lighthouses as manufacturers that have been able to apply Fourth Industrial Revolution (Industry 4.0) technologies to achieve financial and operational impact by transforming plants, value chains, and business models. The concept of lighthouses is not restricted to individual plants, as it also accounts for the replicability of the model across multiple sites and the level of integration across the value chains.

As of September 2020, the global WEF lighthouse network consists of 54 leading factories in Industry 4.0. New end-to-end lighthouses use digital connectivity to scale up in-factory digital operations while removing barriers across functions in the value chain. Furthermore, end-to-end lighthouses continue to push the envelope of technological advancement, expanding beyond the factory site to drive exponential benefits and reshape the customer journey.[1]

[1] Kate Whiting, "These 10 new 'lighthouse' factories show the future of manufacturing is here," World Economic Forum, September 17, 2020, weforum.org.

According to our analyses, the cement plant of the future could reduce emissions by up to 75 percent by 2050 compared with 2017. Around 20 percent will come from operational advances, such as energy-efficiency measures and clinker substitution. An additional 10 percent will come from alternative fuels—however, the availability of alternative fuels varies by region and depends on the decarbonization efforts of other sectors, such as steel and energy. The same holds true for clinker substitutes, such as natural pozzolans or industrial by-products.[5]

A greener, more efficient plant is thus further enabled by innovation advances such as scaling of carbon capture, utilization, and storage (CCUS) technologies. In terms of scalability, CCUS is probably the most advanced option. Using this technology, cement players capture emitted CO_2 and can either pursue carbon-cured concrete (one of the few already available utilization options that locks in CO_2 in the end product) or store carbon in former oil and gas fields. Other blue-sky ideas, including electrolysis and utilizing bacteria that produce calcium carbonate, require significant investments to scale, with first movers gaining significant advantages over peers. It is paramount that the plant remains connected to the whole cement production value chain so its contribution optimizes the opportunity and also allows for emissions to be captured and offset in the most effective way. Ensuring traceability of emissions, end-to-end accounting, and full value-chain visibility paves the way to this optimal point.

Making it happen: Disrupting the existing model

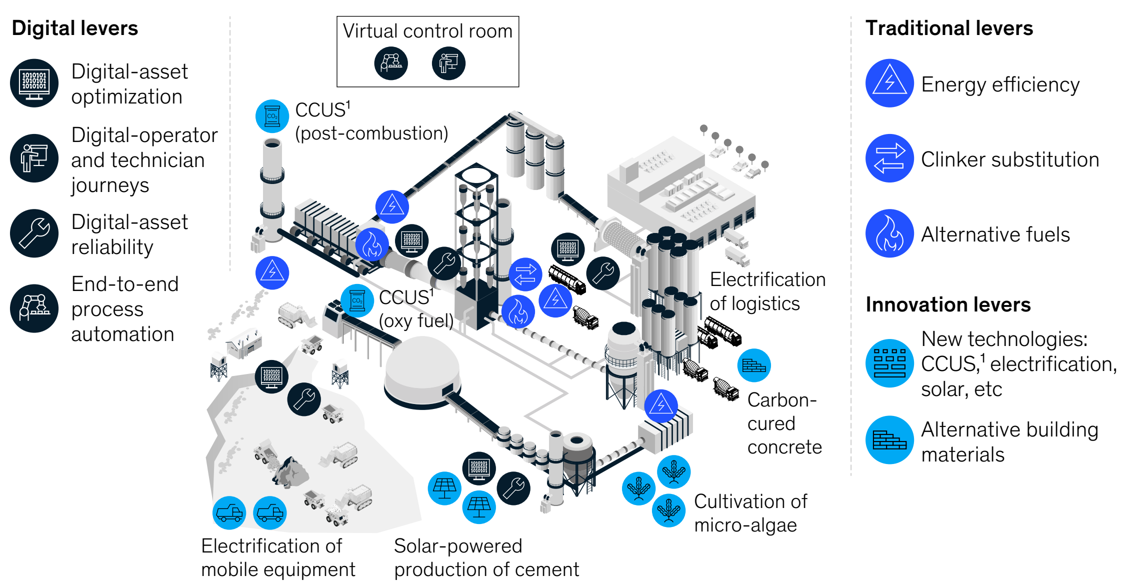
Today, most plants operate in a traditional, nonagile manner with manual or outdated technology infrastructure, and they struggle to acquire and retain skilled workers in important roles. A history

[5] Thomas Czigler, Sebastian Reiter, Patrick Schulze, and Ken Somers, "Laying the foundation for zero-carbon cement," May 2020, McKinsey.com.

Exhibit 2

The cement plant of the future integrates the latest proven digital and sustainability technologies and practices.

Integrated digital twin of cement plant enabling steering and optimized operations from end to end



[1] Carbon capture, utilization, and storage.
Source: McKinsey analysis

of mergers and capacity expansions has led to legacy investments that hamper the ability and appetite to make drastic changes. Moreover, while the cement industry has seen major advancements in IT infrastructure and operational technology over the past two decades, return has been below expectations. The efficacy of new enterprise-resource-planning systems, process-optimization tools, and even predictive maintenance has lagged behind due to change-management challenges and cultural differences between sites.

To understand the gaps and opportunities in each market subsegment, cement players should start by conducting an initial assessment of their plants and their entire value chain. Doing so will not only define realistic digitization and sustainability aspirations but also facilitate discussions of a comprehensive strategy that is codified into a detailed road map for each plant. Cement players can either define top-down targets for each plant or bottom-up targets depending on specific use cases for each plant. Either way, they can simultaneously build digital capabilities through a dedicated academy. They should then challenge themselves to focus on activities that will generate the largest margin gain for their business and customers.

Each plant will also need to establish an agile operating model that will include adjustments to the organizational structure, capabilities, infrastructure, processes, and partnerships. Local leaders need to be empowered to guide the way to achieve those goals, instilling transparency, customer orientation, and a sense of ownership within local teams. The plants also need to move away from being pure cost centers and focus on initiatives that generate high value while running day-to-day operations in a lean way. A stable organizational backbone ensures an organization has a common purpose, standards, platforms, culture, and set of values—allowing for open and simple knowledge sharing.

There is no single approach for success, and each plant should choose its own path depending on context, goals, desire for centralization, existing in-house capabilities, and so forth. The most important questions for cement players to answer before embarking on this journey are around value generation. More specifically: what use cases generate the most margin gain? Is it better to have peak efficiency or to maximize throughput? Can a fully integrated manufacturing process that has raw material–based production generate higher margins?

The COVID-19 crisis has forced cement companies to jump-start their digital transformation journeys sooner rather than later. Plants that realize a more digitized, sustainable vision of the future are more likely to ensure a long-term competitive advantage in productivity, operational efficiency, and resilience that far outweighs any investments made at the outset.

Greater efficiency and sustainability is just one aspect of this vision for the future. In the coming decade, companies must take action across the entire value chain to produce cement in a manner that is both economically and ecologically feasible.

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