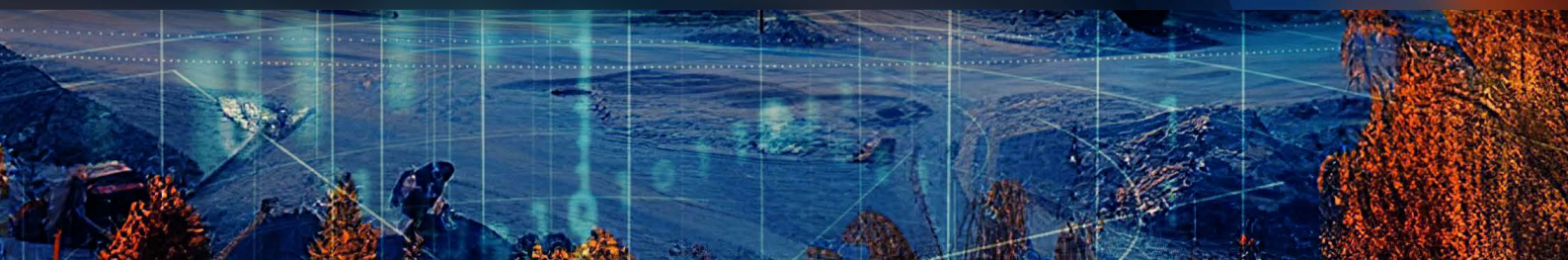
Carbon^Re

Digitalisation: the pathway to net zero

Unlocking the power of data in the cement industry.



Who we are

We are a company pushing the boundaries of artificial intelligence to accelerate the decarbonisation of cement and other foundational materials. Carbon Re's innovative AI-powered software optimises cement production, specifically targeting the pyroprocess stage to reduce fuel-derived carbon emissions by up to 5%.

Our solution integrates seamlessly with plant Advanced Process Control (APC) systems like ABB Ability™ and FLSmidth ECS/ProcessExpert®, using AI models that continuously adjust in closed-loop control to optimise fuel use and manage fuel-mix variability.

By integrating with Carbon Re, plants can utilise a broader set of their process, laboratory and chemical data. Our advanced machine learning models enable real-time, dynamic optimisation of process targets, automating repetitive manual tasks and allowing process engineers to focus on more impactful work.

Carbon Re requires no capital investment, new equipment, or plant shutdowns. It supports ongoing plant optimisation, adapting to changing inputs and external pressures such as volatile fuel costs and emissions regulations. The result is significant energy savings, allowing operators to run plants at peak efficiency and realise substantial cost reductions.

Find out more at carbonre.com/product/

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A foreword from Make UK

The manufacturing sector is currently facing an array of significant challenges that require attention in order to ensure its sustainability and growth.

One of the key challenges is to decarbonise the industry and its products to achieve net zero by 2050, as part of the global effort to combat climate change. The manufacturing industry is a significant contributor to greenhouse gas emissions, and therefore, it needs to take action to reduce its carbon footprint. This requires a shift towards cleaner and more efficient production methods, as well as the adoption of renewable energy sources.

Another crucial challenge is to increase productivity, which has become more critical than ever before due to the highly competitive market environment. Manufacturers need to find ways to optimise their processes and reduce costs to boost their productivity while maintaining quality.

The manufacturing industry has been struggling with labour shortages for a long time. The ageing workforce and the lack of skilled workers have made it difficult for companies to find the right talent to fill their vacancies. To overcome this challenge, manufacturers need to invest in training and development programs to upskill their existing workforce and attract new talent.

While these challenges may seem unrelated, the link between them is digitalisation. Many manufacturers are already investing in digital technologies to improve their operations and increase efficiency. However, to fully realise the benefits of digitalisation, manufacturers need to understand how it can help them address all these challenges simultaneously. Digital technologies can help manufacturers optimise their production processes, reduce energy consumption, and improve product quality. They can also help manufacturers attract and retain talent by offering flexible work arrangements and providing opportunities for upskilling.

There is still much work that needs to be in Industry 4.0. It's not just about the shiny robots or other exciting technologies like artificial intelligence that make the headlines. It is all about the exchange of data between machines and systems which is transforming the way we interact with things and leading to the development of new products, services, and business models.

Those who invest will reap the numerous benefits: data-driven decisions are more robust and less risky, encourage innovation and create new revenue streams.

However, the benefits of digitalisation go beyond just increasing revenue. It helps to reduce costs by enabling raw material and waste efficiencies, as well as lower energy consumption. Additionally, digitalisation allows for better safety and quality of products, as well as greater visibility of the supply chain. It also connects the workforce and increases customer engagement, which leads to improved productivity and better service delivery. Moreover, digitalisation provides agility, competitive advantage, and overall resilience, which are crucial for businesses in today's dynamic marketplace.

The Carbon Re whitepaper makes it clear that digitalisation is not just a luxury, but a necessity for businesses looking to stay ahead of the curve and remain competitive in the long run.

Faye Skelton
Head of Policy, Make UK

MAKE uk
The Manufacturers' Organisation

Executive Summary

Cement is the backbone of modern life. Used to construct buildings, roads, bridges, and other critical infrastructure worldwide, its versatility, strength, and durability make it indispensable in meeting the growing demands of urbanisation and economic progress.

But cement is also responsible for 8% of global carbon emissions (greater than deforestation, global shipping and aviation combined), meaning that its impact on climate change is considerable.

This paper outlines how the future of the cement industry relies on the industry embracing digitalisation to be resilient, profitable and sustainable. It brings considerable opportunities and, thanks to Industry 4.0 initiatives, the cement industry has already progressed its digitalisation journey significantly.

These early investments now put producers in a strong position to take advantage of data-driven decision-making and advanced technologies such as artificial intelligence (AI) and machine learning (ML) for process control and automation.

However, to date these benefits have yet to be realised widely or consistently by the industry.

Below, we highlight case studies of digitalisation from within the cement industry, to derive key learnings,

including opportunities and roadmaps for success, the pitfalls to avoid, and where to prioritise action.

Additionally, our paper calls for a standardised approach to digital infrastructure across the cement industry. This already exists in the telecommunications, energy, healthcare, finance, and transportation industries, enabling effective data sharing, collaboration, and innovation across organisational boundaries. Data standards are key to enabling interoperability, which is achieved by defining common ontologies for data exchange so that data is consistent from one plant to another.

The adoption of a standardised digitalisation approach within the cement industry holds immense potential to revolutionise operations and drive unprecedented advancements. Integration with emerging technologies like AI and ML will further enhance decision-making capabilities, enabling proactive problem-solving and the discovery of innovative solutions. This digital transformation not only promises operational efficiency gains but also supports the industry's decarbonisation journey by enabling real-time monitoring and optimisation of energy usage, emissions reduction strategies, and the development of low-carbon cement formulations.

Ultimately, the convergence of digitalisation and sustainability efforts will pave the way for a more resilient, efficient, and environmentally friendly cement industry, driving benefits that extend beyond our current imagination.

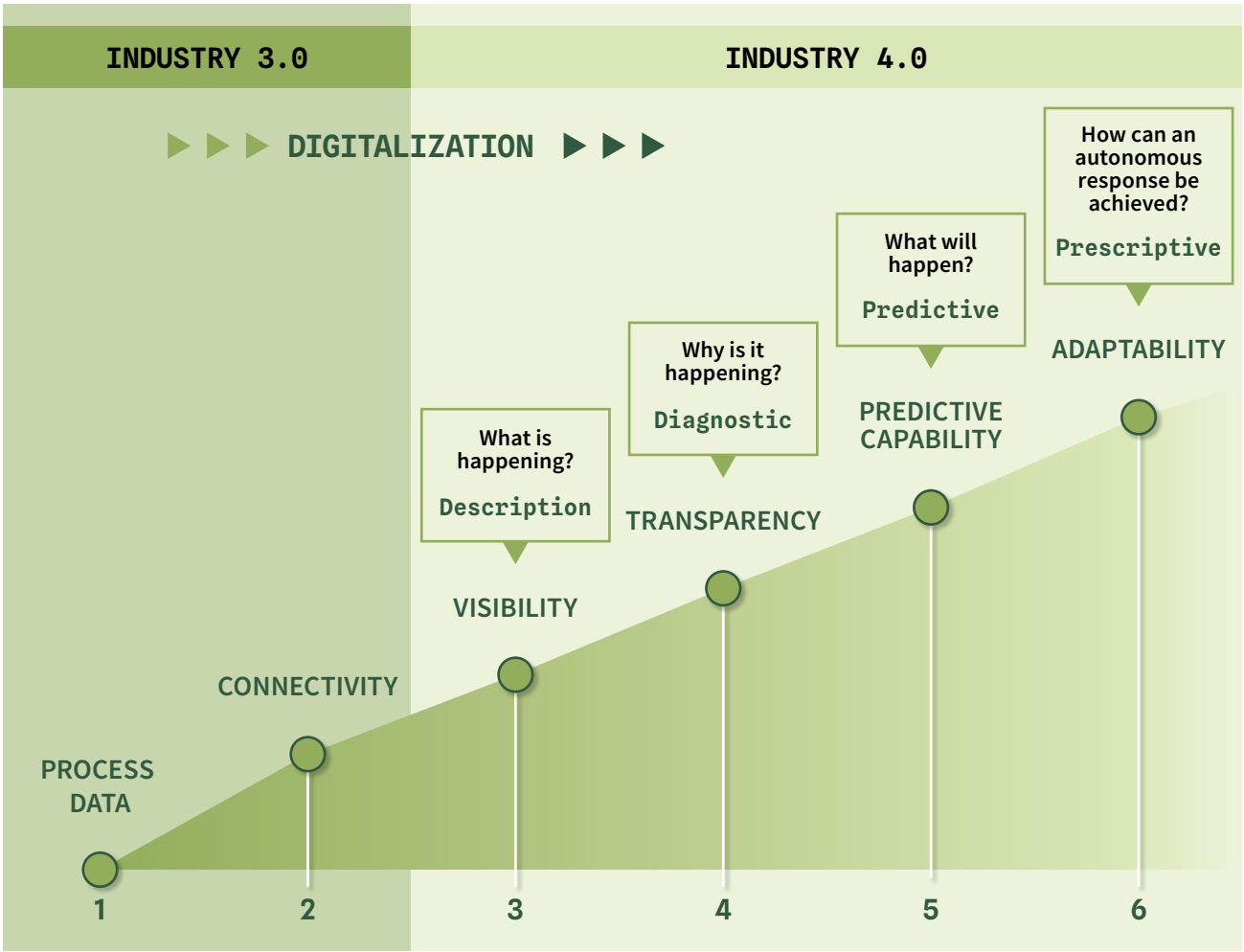
We hope that this paper inspires cement producers to advance their digitalisation efforts to reap the commercial and environmental benefits that can follow.

Why is digitalisation important for decarbonisation?

Digitalisation involves integrating digital technologies and data to create business value. In manufacturing, this includes deploying sensors, automation tools like DCS or SCADA, data historians, and facilitating cloud-based data access.

These technologies yield broad benefits such as enhanced operational efficiency, safety, customer experience, agility, data-driven decision-making, analysis, new revenue streams, innovation support, and cost reduction. Essentially, digitalisation serves as the foundation for both Industry 3.0 (the computer age) and Industry 4.0 (the age of the Internet of Things (IoT) and AI).

Digitalisation also offers a significant opportunity to increase sustainability outcomes and reduce greenhouse gas emissions, which is yet to be fully realised by the cement industry. According to Paul S. Fennell in his 2021 paper Decarbonising Cement Production[1] the benefits from improvements in operational efficiency enabled by digitalisation and



1 FENNELL, P., et al., 'Decarbonising Cement Production', Joule, 2021 https://www.sciencedirect.com/science/article/pii/S2542435121001975

next-generation measurement devices could reduce emissions in the cement industry by an estimated 10%. This is further supported by World Economic Forum research which shows the materials sector can reduce emissions by an additional 4-10% in 2030 by accelerating the adoption of digital technologies.[2]

While digitalisation efforts have been advancing in the cement industry for years, it still lags behind other sectors, and many players have yet to fully leverage its potential or witness its tangible benefits. There is now a tremendous opportunity for the industry to learn from the efficiency gains and increased profitability in sectors like retail, transportation, and energy, where digitalisation has already proven successful.

The World Economic Forum's Global Lighthouse Network, designed to recognise and share insights from companies integrating Fourth Industrial Revolution technologies, serves as a valuable resource. It showcases how technologies like AI and IoT enhance daily manufacturing and supply chain operations, leading to improved performance, resilience, and achieve success that extends beyond the bottom line.

It's notable that among the 153 'lighthouses' (shining examples of companies that have adopted these technologies) in this network, only one is a cement producer. This reflects the current state of digitalisation in the cement industry—a fragmented landscape with no consensus on best practices or minimum standards for adopting the latest digital technology.

2 *Digital for Climate Scenarios*. World Economic Forum (accessed April 2024) https://initiatives.weforum.org/digital-transformation/climate-scenarios

Digitalisation in the cement industry today

Historically, the cement industry has been slow to adopt digitalisation compared to other sectors – many plants are still manually operated and use outdated technology. Recent research from Rockwell Automation indicated that over 60% of cement plants have yet to undertake a single digital transformation initiative.[3]

However, there have been notable advancements in recent years, with plants increasingly adopting Industry 4.0 technologies and advanced solutions such as AI and ML. Among top producers, digitalisation priorities vary, with companies like Holcim, Heidelberg Materials, Votorantim Cimentos, and TITAN integrating it into their strategies, while others make no mention of digitalisation in their strategies at all.

While initial digitalisation projects often target individual plant use cases, industry leaders are swiftly scaling pilots to encompass processes across multiple sites or entire factories. Holcim's *Plants of Tomorrow* initiative exemplifies this trend, rolling out Industry 4.0 technologies to over 270 cement plants worldwide.[4] Similarly, OYAK Cement's *Cement 4.0 Project* harnesses the potential of big data and AI across 10 facilities in Turkey. China Resources Building Materials Technology is also implementing its intelligent industrial internet platform to manage industrial operations in real-time across 35 sites. These initiatives are yielding significant benefits for the plants involved, marking an inflection point for the industry.

Numerous opportunities exist for digitalisation projects throughout the cement value chain, spanning business operations, production and logistics. However, prioritising the digitalisation of the production process is crucial for producers due to its potential to decrease carbon emissions (and hit industry Net Zero targets), improve overall operational efficiency and lower operating costs.

Below we showcase various Industry 4.0 projects in production implemented by digitalisation leaders in the cement industry, providing insights for producers embarking on their digitalisation journey.

Collecting and storing data

Data collection and utilisation form the foundation of digitalisation, revolutionising various industries like retail, transportation, logistics, and energy by enhancing efficiency and profitability. Thanks to Industry 4.0 initiatives, cement plant operations generate extensive data from installed sensors, measuring crucial variables such as fuel flow, temperature, pressure, atmospheric conditions, mechanical speed, electricity consumption, chemical analysis, and quality data. These variables are sampled at various time resolutions, ranging from 500 milliseconds to hourly or daily intervals.

To realise the potential of this abundant data, producers must adopt data standards to ensure structured, accessible, interoperable, and coherent data across their plant estate. Aligning data aggregation and storage with the FAIR principles, as discussed below, presents challenges. Nonetheless,

3 *Unlocking potential: the connected cement plant.* Rockwell Automation (June 2020). https://literature.rockwellautomation.com/idc/groups/literature/documents/wp/cement-wp001_-en-p.pdf

4 *Plants of Tomorrow.* Holcim (accessed April 2024) https://www.holcim.com/what-we-do/green-operations/plants-of-tomorrow

standardised and consistent data are crucial for facilitating data-driven decision-making at the individual plant and group levels within the organisation. The shift from on-premises solutions to cloud-based platforms is crucial to deliver this objective (see next section).

OYAK Cement, Turkey's largest cement and concrete brand, embarked on a digital transformation journey centred on data infrastructure and cleansing. In their annual report (2022) OYAK cement highlights that correctly defining and processing data will enable the cement industry to achieve increased productivity, efficiency, reliability and sustainability. Managing over 800 billion data points annually across 18 plants required OYAK Cement to adopt an adaptive, compatible, and manageable data infrastructure.[5] Consolidating data from all their plants and cleaning 'messy' data to ensure synchronisation of process, quality and maintenance timestamps has been key to this success and with this data infrastructure established, OYAK has been able to utilise AI optimisation. The OYAK *Cement 4.0 project* has resulted in nearly 140,000 tons of CO2 reduction in a year.[6]

The OYAK *Cement 4.0 Project* has resulted in nearly 140,000 tons of CO2 reduction in a year

The OYAK Cement 4.0 case study demonstrates the advantages of digitalisation strategies that extend beyond individual plants, and ensure coherence and unity of data across a cement plant fleet. Adopting FAIR Principles for data standards facilitates interoperability, ensuring consistency across plants. While initially designed for scientific and open source data, these FAIR Principles can be applied to companies implementing a unified digitalisation strategy across their entire group:

- **Findable:** Data must be easy to find for both humans and computers.
- **Accessible:** Data must be accessible and secured through authentication & authorisation.
- **Interoperable:** Data must be capable of being matched and reused across different use cases.
- **Reusable:** Data must be richly described so they may be replicated and/or combined in different settings.

Cloud vs on-premise solutions

Cloud-based solutions enable companies to outsource their infrastructure to third-party servers such as; Amazon Web Services, Microsoft Azure and Google Cloud, with the company connecting to the service via the internet. This approach contrasts with the traditional 'on-prem' model, where servers operate entirely within local area networks on-site. The National Institute of Standards and Technology provides the most widely used formal definition of cloud computing:

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

Cloud-based solutions offer several advantages over on-premise models.

Primarily, cloud solutions offer flexibility, enabling remote access to centralised data and applications from anywhere with an internet connection – particularly

5 *Presentation: Digital transformation in cement manufacturing: OYAK Cement 4.0.* AVEVA (2021). https://resources.osisoft.com/presentations/digital-transformation-in-cement-manufacturing--oyak-cement-4-0/

6 *Presentation: Digital transformation in cement manufacturing: OYAK Cement 4.0.* AVEVA (2021). https://resources.osisoft.com/presentations/digital-transformation-in-cement-manufacturing--oyak-cement-4-0/

helpful in an age where work-from-home arrangements are on the increase. Cloud service users can also access a variety of services, ranging from Business Intelligence platforms to machine learning systems, which can utilise cloud-stored data seamlessly, without requiring intricate integration projects.

Additionally, the pay-as-you-go model allows companies to easily adjust resources based on demand without the need for extensive hardware investments and the associated upfront costs and long lead times. They also reduce operational costs by eliminating the need for onsite infrastructure maintenance and updates.

By deploying Carbon Re, a leading cement producer in South America has reduced clinker quality variance by 25% achieving a tangible ROI in 1 year.

Concerns raised about cloud solutions usually relate to data security and vulnerability to cyber-attacks as well as latency and downtime. However, cloud-based solutions typically offer enhanced security measures, with data stored in highly secure data centres with regular security updates provided by the cloud service provider. Without the 'single point of failure' risk of on premises solutions cloud solutions are more secure than on-site solutions.

Opportunities for predictive quality analysis using machine learning

Throughout the cement production chain, continuous quality checks are performed to ensure the final product meets specifications and standards.

Clinker quality is assessed during the pyroprocess with samples from the kiln taken at intervals to measure the content of free lime, C3S (alite) and other quality parameters. Currently, the lag time between samples is typically 1-4 hours – or longer when erroneous results require resampling and testing. With Industry 4.0 capabilities, producers can develop software sensors using process and lab data, to enable continuous monitoring between real samples. These software sensors can also substitute hardware sensors when an installed sensor fails, or use corresponding data to simulate a sensor even when no sensor has been installed.

Cement strength, a crucial quality indicator, is measured through physical tests at 2, 7 and 28 days. Typically, without a method to estimate cement strength during production, producers are encouraged to either increase the clinker content using more expensive and higher-quality clinker or to conduct more extensive grinding to ensure the final product's strength. Both techniques drive product quality but both also increase the carbon footprint of the final product, while failing to address any other production variables that may impact quality.

With ML capabilities, producers can now accurately forecast the future strength of their cement. They utilise historical and real-time data from chemistry, mineralogy and particle size distribution to model quality throughout the production process.

Examples of this approach include Holcim's Volos plant in Greece which has saved 13,000 tonnes of CO2, annually, with their in-house solution, CemQ.[7] Similarly, Dyckerhoff, a Buzzi SpA company, has achieved cost savings and reduced clinker content with 'alcemy for cement', Alcemy's machine learning powered software solution.[8]

By taking this approach and deploying Carbon Re's AI software sensor for free lime, a leading cement

7 *CemQ – Real-Time Cement Quality Prediction.* Holcim (accessed April 2024) https://www.holcim.com/sites/holcim/files/2022-04/holcim_pt_case_study_cemq.pdf

8 *Product: alcemy for cement.* Alcemy (accessed April 2024) https://alcemy.tech/en/produkt/zement

producer in South America has reduced clinker quality variance by 25% achieving a tangible ROI in 1 year.

Process optimisation with digital twins and AI

Process optimisation is an established tool in the cement industry for enhancing production goals while reducing carbon emissions and costs. Utilising advanced Industry 4.0 technologies such as digital twins and AI for process optimisation can significantly boost production goals while achieving unprecedented energy efficiencies, cost savings, and carbon emissions reductions.

A digital twin is created using data collected from a plant's sensors to digitally mirror the production process, allowing AI to simulate and offer insights in real time to maximise process efficiency. An early example of a digital twin in the cement industry is from Holcim's Plants of Tomorrow initiative. The company has built a virtual model of one of its Swiss plants to increase operational efficiency and has plans to roll out the project to other European plants.[9]

Carbon Re uses digital twins to facilitate decarbonisation and operational efficiency enhancements in cement production by providing operators with clear, actionable recommendations for process set points and optimal equipment settings. An illustration for this approach is from Carbon Re's collaboration with an innovative European cement producer, which is aiming to accelerate its digitalisation efforts and leverage data effectively in alignment with its business strategy. Building on the plant's existing advanced process control system (APC), the company has integrated Carbon Re with its kiln. By deploying our cutting-edge AI models in 'closed-loop control' Carbon Re optimises the pyroprocess at the plant continuously, and in real-time. While latency and downtime represent a particular issue to plant operations, this risk can be mitigated by ensuring cloud solutions are designed with high availability and disaster recovery in mind.

China Resources Building Materials Technology's Tianyang plant, the sole cement producer represented in the Global Lighthouse Network, has also implemented AI optimisation in their production process, achieving an 11% reduction in coal consumption per tonne of product.[10]

AI-enabled predictive maintenance

Industry 4.0 technologies are paving the way for predictive and prescriptive maintenance solutions in the cement industry. Like AI for process optimisation, predictive maintenance leverages historical sensor data, including temperature, pressure, vibration and lubrication, to analyse operations and offer real-time insights into equipment operational status and availability. Predictive maintenance solutions significantly reduce downtime and cut maintenance costs.

Building on the plant's hardware upgrades – a new set of high-resolution sensors, TITAN America's Pennsuco plant employs CemAI's AI solution to reduce idling and restarting time of major equipment and improve the reliability and efficiency.[11]

9 *Holcim launches world's first cement plant digital twin*. Holcim (2023) https://www.holcim.com/media/company-news/first-cement-plant-digital-twin

10 *Global Lighthouse Network: Adopting AI at Speed and Scale*. World Economic Forum (2023). https://www3.weforum.org/docs/WEF_Global_Lighthouse_Network_Adopting_AI_at_Speed_and_Scale_2023.pdf

11 *Our future with predictive maintenance*. World Cement (2024) https://www.worldcement.com/the-americas/22022024/our-future-with-predictive-maintenance/

A blueprint for success

Although there's no one-size-fits-all method for digitalisation, successful projects share common strategies and technologies. In this paper, we have highlighted the lessons that producers can draw from to ensure your initiatives not only launch effectively but also thrive as they scale.[12, 13, 14] These are summarised below.

Baseline the current state of digitalisation

Understanding your digital readiness is essential to determine the starting point and scope of your digitalisation project. A data audit and establishing a digital readiness level is a good place to start:

	Accessibility	Connectivity	Historical Records
Level 1	Inaccessible – data is stored on a DCS system	Only data signals used for direct control are connected	Only contains limited historical data – approx 1 month
Level 2	Not easily accessible – data is accessible internally but difficult to access remotely e.g. data stored on a local historian	All process data signals are measured and collected. Lab and process data are stored in the same place	Extensive historical records are available – 6 months to 10 years
Level 3	Very accessible – data is accessible locally and remotely to all parties e.g data is stored on a cloud historian	Extra data such as kiln shell scan temperatures, kiln imaging, and APC control settings are available	All historical data available

Set bold strategies

Your company needs a realistic yet ambitious strategic roadmap outlining key priorities at both the company and site levels, with digitalisation at its core. Each specific project should have a defined strategy and priority. Your company-wide strategy should encompass adopting data standards such as FAIR data principles.

12 *How digital and analytics can unlock full potential in steel.* McKinsey & Company (2021). https://www.mckinsey.com/industries/metals-and-mining/our-insights/how-digital-and-analytics-can-unlock-full-potential-in-steel

13 *Why Cement Producers Need to Embrace Industry 4.0.* Boston Consulting Group (2018) https://www.bcg.com/publications/2018/why-cement-producers-need-embrace-industry-4

14 Global Lighthouse Network: *Adopting AI at Speed and Scale.* World Economic Forum (2023). https://www3.weforum.org/docs/WEF_Global_Lighthouse_Network_Adopting_AI_at_Speed_and_Scale_2023.pdf

Invest

Recognise data and digitalisation as competitive advantages and allocate budget resources to ensure success – studies indicate that success in digitalisation programs correlates with investment.[15] While initial implementations may require patience and take several years to yield ROI, the returns are significant. Factories in the Global Lighthouse Network typically achieve an ROI multiple of 2-3 within 3 years and 4-5 within 5 years.[16]

Keep people at the centre

While the adage 'robots are going to take our jobs' is familiar, manufacturing inherently involves human elements that cannot be replaced, even as digitalisation accelerates automation and machine intelligence. Producers aiming to integrate digitalisation into their companies must ensure their strategy includes a talent roadmap, prioritising reskilling incentives and opportunities.

An effective change management programme is the most critical component for successful digital transformation.

Additionally, adopting a centralised approach to digitalisation enables effective change, positioning companies for success. Notably, 70% of all Lighthouses recognise that an effective change management programme is the most critical component for successful digital transformation.[17]

Don't be left behind

The well-worn tale of competition between Blockbuster and Netflix epitomises the clash between traditional brick-and-mortar models and disruptive digital innovation. The story tells us that Blockbuster, once a dominant force in the video rental market, failed to anticipate the shift towards online streaming and subscription-based models, while Netflix recognised the potential of digital distribution early on and pivoted its business model to focus on streaming content over the internet. While Netflix's strategic investments in technology, data analytics, and original content production enabled it to thrive and reshape the landscape of the entertainment industry, Blockbuster's belated attempts to embrace online streaming and launch its own digital platform, ultimately left the company succumbing to bankruptcy in 2010.

Unsurprisingly, the reasons why some companies thrive and scale, while others flail and die (including in the of case Blockbuster and Netflix[18]) are more complex. However, the central message, echoed by Henry Bristol *et al*. in their article *Adopting AI at speed and scale: The 4IR push to stay competitive*[19] is that: "The more companies progress, the faster they progress. This also provides them with added agility and ability to respond to disruption—a major factor in the expanding performance gap between leaders and laggards."

15 *How digital and analytics can unlock full potential in steel*. McKinsey & Company (2021). https://www.mckinsey.com/industries/metals-and-mining/our-insights/how-digital-and-analytics-can-unlock-full-potential-in-steel

16 *Global Lighthouse Network: Adopting AI at Speed and Scale.* World Economic Forum (2023). https://www3.weforum.org/docs/WEF_Global_Lighthouse_Network_Adopting_AI_at_Speed_and_Scale_2023.pdf

17 *Global Lighthouse Network: Adopting AI at Speed and Scale*. World Economic Forum (2023). https://www3.weforum.org/docs/WEF_Global_Lighthouse_Network_Adopting_AI_at_Speed_and_Scale_2023.pdf

18 *A Look Back At Why Blockbuster Really Failed And Why It Didn't Have To*. Forbes (2014). https://www.forbes.com/sites/gregsatell/2014/09/05/a-look-back-at-why-blockbuster-really-failed-and-why-it-didnt-have-to

19 *Adopting AI at speed and scale: The 4IR push to stay competitive.* McKinsey & Company (2024). https://www.mckinsey.com/capabilities/operations/our-insights/adopting-ai-at-speed-and-scale-the-4ir-push-to-stay-competitive

The role of policy, standards and industry bodies in driving digitalisation

Considering the substantial untapped potential of digitalisation to aid cement companies in decarbonisation efforts, the implementation of a sector-wide digitalisation strategy, overseen by cement industry bodies – such as the World Cement Association (WCA), Global Cement and Concrete Association (GCCA) or other regional bodies – could significantly accelerate decarbonisation and the success of digitalisation programs across the industry.

A similar approach has been successfully tested over the last five years in the UK energy industry, where OFGEM, the UK regulator for gas and electricity markets, has been leading a digital transformation of the sector. The aim of this strategy is to establish a sector-wide objective of creating a robust digital energy system that expedites and facilitates the decarbonisation of the power grid.

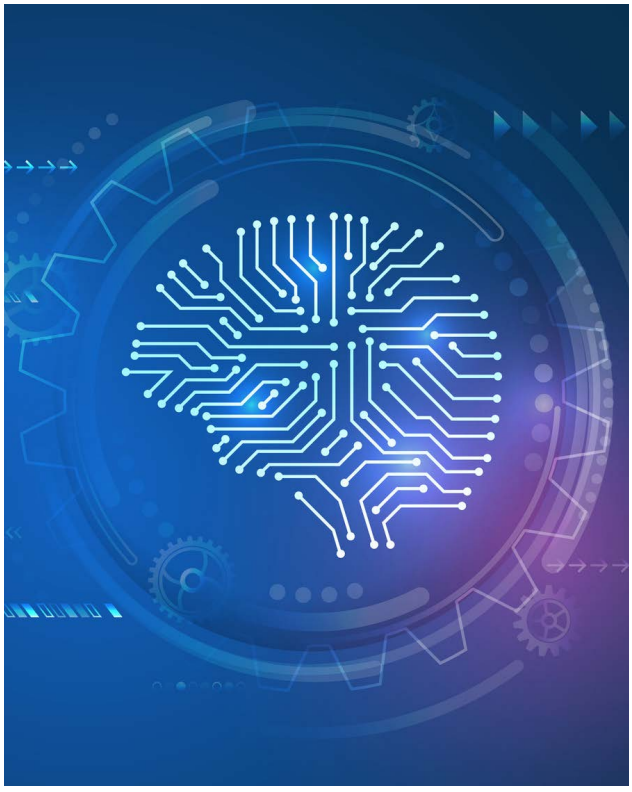
Drawing insights from OFGEM's work, we have identified key initiatives that are particularly relevant and potentially transformational for the cement industry:

Publish a digitalisation strategy

As part of a strategy to accelerate the digitalisation of the energy sector, the (formerly named) Department for Business, Energy, and Industrial Strategy (BEIS) launched the Energy Data Taskforce[20] to develop guidelines to improve data availability and transparency in the energy sector. This led to the publication of a groundbreaking report proposing a strategy and list of recommendations, 'A strategy for a Modern Digitalised Energy System'.

A key recommendation was the mandate for energy companies, particularly network operators, to publish a digitalisation strategy outlining steps to modernise data collection and infrastructure for data sharing.

This has resulted in energy companies submitting strategies enabling benchmarking and comparison of digitalisation progress. Importantly, this approach facilitates the sharing of best practices and open dialogue, streamlining problem-solving processes. This collaborative approach is especially beneficial in an industry with limited experience in digital technology and unique challenges as operators of critical infrastructure.



20 *Energy Data Taskforce.* UK Government (accessed April 2024).https://www.gov.uk/government/groups/energy-data-taskforce

Numerous major cement producers and associations have published decarbonisation strategies, demonstrating an industry-wide commitment to mitigate emissions in a sector responsible for 8% of global carbon emissions. Embracing a similar approach to digitalisation would be transformative.

The ideal mechanism to drive the publication of digitalisation strategies would be for major cement associations such as the WCA, GCCA or Cembureau to require their members to publish one.

Establish a common industrial information model

In a 2015 World Economic Forum survey[21] 47% of respondents indicated that establishing and promoting common standards are among the most important actions that governments can take to speed up the adoption of the industrial IoT.

This is an area where OFGEM has challenged energy companies to improve, using a common information model (CIM). This is an ontology that maps data in a principled and consistent manner, showing the properties of data and relations between variables. The FAIR data principles outlined earlier in this paper are a component of a CIM. A CIM is used for exchanging data models of electricity networks, data, and other information across transmission operators in Europe (OFGEM, 2022).

Currently, the cement industry lacks a standardised approach to data capture and storage, which hampers advancements in digitalisation technology. However, addressing this issue presents numerous opportunities, including:

- Facilitating cross-plant learning and technical advancement within the sector by leveraging emergent digital technologies such as advanced analytics, ML, and AI in cement production.
- Promoting cross-sector learning through transparent reporting and common information models across foundation industries. This approach could unveil previously unexplored insights into pyroprocessing and materials transformation.
- Meeting consumer demand for change by enabling informed decisions about purchasing low-carbon cement.

Update the best available techniques

Best available techniques' (BAT) refers to the available techniques which are the best for preventing or minimising emissions and impacts on the environment. Compliance with BAT is typically a legal requirement for industrial facilities, meaning that industries can improve their environmental performance while remaining competitive in the global market.

However, this best practice is highly focused on hardware technology. BATs require updating to explicitly recognise the opportunities afforded by digital technology and ensure compliance, globally.

Upskilling and educating the future workforce

In today's era of technological disruption, a pressing global concern is the widening gap between the rapid evolution of technology and the skilled workforce needed to sustain it.[22] Despite the growing integration of AI and automation, the training of engineers equipped to comprehend these advancements and supervise the cement industry of tomorrow should already be underway.

Government policies and substantial investments in upskilling and education are imperative, yet initiatives to cultivate a competent workforce for the future are lagging and more needs to be done.

21 *Standards and the digitalisation of EU industry.* European Parliament(2019). https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/635608/EPRS_BRI(2019)635608_EN.pdf

22 *Technology and the Skills Shortage.* Financial Times (2023) https://www.ft.com/content/b1b710a1-6d12-43e5-8508-ae4584a7289a

Conclusion

The cement industry needs to embrace digitalisation to ensure a resilient, profitable and, crucially, sustainable future.

Digitalisation offers a myriad of opportunities within cement production to bolster productivity, cut costs and decarbonise operations. We hope that the case studies outlined in this paper serve as tangible examples of what is achievable today.

In order to leverage the advantages of digitalisation, producers should adopt the blueprint for success as a starting point. Ensuring structured, accessible, and interoperable data is paramount. Urgency is key; following the playbook established by digitalisation leaders not only unlocks significant value but also minimises the cost associated with the learning curve. Failure to act swiftly risks creating a fatal gap between industry leaders and laggards.

Industry bodies also have a crucial role to play in accelerating the uptake of digital technologies. We recommend that the cement industry draw from the example set by the UK's energy sector and implement a sector-wide digitalisation strategy, overseen by cement industry bodies such as the WCA, GCCA and others. This oversight will provide leadership and a clear roadmap, laying a solid foundation for scaling digitalisation projects in the future.

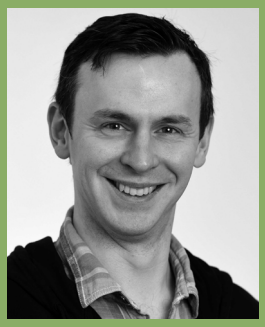
As a technical sector, the cement industry is familiar with embracing new technologies. As a sector with significant potential for reducing carbon emissions, now is the opportune moment to leverage the decades of research and investment poured into digitalisation and apply it to cement production.

Contact us

To discuss this paper, its findings and implications, please get in touch.

Josh Vernon, CEO

An experienced entrepreneur and CEO with expertise in scaling software solutions, sales and creating high-functioning teams.



Dr Daniel Summerbell, Co-founder & CSO

Pioneering research in cement sustainability. 10 years industrial process improvement expertise. Ex Institute of Manufacturing at Cambridge University. PhD and Postdoc from the University of Cambridge.

Aidan O'Sullivan, Co-founder & CTO

Pioneer in application of AI to energy systems; Professor, AI & Energy at UCL; Fellow, Alan Turing Institute; PhD Imperial College; Postdoc MIT

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