In collaboration with
Boston Consulting Group

Scaling Low-Carbon Design and Construction with Concrete: Enabling the Path to Net-Zero for Buildings and Infrastructure

WHITE PAPER

MARCH 2023

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Foreword

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Mitigating climate change by decarbonizing construction, and more specifically materials used in construction such as concrete and steel, is a crucial and complex priority. This report focuses on addressing the challenges in reducing emissions from cement and concrete by deploying low-carbon design techniques and using low-carbon materials at scale.

Over the past several years, our organizations and others have done much work to create demand for low-carbon concrete and construction from public and private buyers, in order to catalyse investment in concrete decarbonization. Examples of this work include our previous publications such as *Green Public Procurement: Catalysing the Net-Zero Economy* and *Low-Carbon Concrete and Construction: A Review of Green Public Procurement Programmes*, which provide frameworks for green public procurement; as well as initiatives such as the First Movers Coalition, which at COP27 in November 2022 launched a private-sector commitment framework for purchasing near-zero cement and concrete.

To build on our previous work, and to support the design and construction of lower-carbon projects at scale, it became clear that we must also engage the design and construction players that operate between project procurement and material production and make critical decisions about concrete use, which influence projects' carbon footprint. Architecture, engineering and construction (AEC) firms must scale the use of low-carbon materials and design techniques in order to reduce the carbon footprint of buildings and infrastructure.

To produce this report, we undertook a series of discussions across the AEC and cement and concrete production communities. During these discussions, company leaders shared their objectives, strategies, reservations and challenges related to scaling low-carbon design and reducing concrete emissions. We encountered a range of complex concerns and in some cases frustrations, but also examples of promising progress and innovations, which have helped to mould this report.

The purpose of this report is to provide a framework for scaling low-carbon design with concrete that players across the value chain can adopt. While our primary focus is on the solutions that the AEC and cement and concrete manufacturing industries can act upon, we also recognize the critical influence of project buyers and governments and have included the actions they can take to support low-carbon design. Additionally, while the focus of this report is on cement and concrete, many of the ideas described can be applied to reducing emissions from other building materials and from entire projects.

Implementing these solutions will not be easy but defining them is an important starting point and one that we hope will inspire action. Trends in corporate decarbonization commitments and green public procurement programmes – as well as the growing pressure on companies to live up to their sustainability goals – indicate that low-carbon design and production of low-carbon materials will increasingly become capabilities that AEC firms and materials producers will need to adopt to remain competitive in the future. We believe that firms that begin the journey of scaling low-carbon design now are making smart investments, not only in the sustainability of our planet, but in the sustainability of their businesses.

Executive summary

The world is in the midst of an infrastructure and buildings boom. In every part of the globe, and especially so in the developing world, urban commercial centres and residential housing are expanding as economies grow. At the same time, new roads and bridges are being paved and designed to provide logistics channels for moving parts, supplies, manufactured goods as well as commuters, while old infrastructure is being modernized. This is all potentially good news for the global economy, except one glaring downside: buildings and infrastructure are responsible for approximately 40% of global carbon emissions each year, around 15 gigatonnes (Gt).[1]

Unabated, this number could grow dramatically, effectively undercutting decarbonization efforts in other sectors.

A substantial share of these emissions is released before an asset is ever used. The production of materials accounts for 15-20% of buildings emissions and 50-60% of infrastructure emissions (see Figure 1). Among building materials, concrete accounts for around 30% of building materials emissions (see Figure 2) and 7% of global carbon emissions.[2]

Yet, concrete possesses qualities that make it ubiquitous and important in construction – durability, resilience, thermal capacity, local availability, relative affordability and the ability to meet highly variable functional requirements. Therefore, in order to reduce the carbon footprint of buildings and infrastructure, it is critical to examine the manufacture and use of concrete. In 2021, the cement and concrete industry published its roadmap to net-zero concrete by 2050 through the Global Cement and Concrete Association, in which it identified the actions and policy enablers necessary to decarbonize the entire value chain of the sector. The roadmap identified the valuable role of low-carbon design and construction.

This paper examines how to scale this lever.

The potential

The decisions made by AEC firms about how to use concrete have an impact on – and if decided with intentionality, can reduce – a structure's lifetime emissions in several ways. Most immediately, decarbonizing the cement manufacturing process using near-term (available by 2030) technologies, specifying lower-carbon concrete formulations, and optimizing the volume of material used, can reduce project-level carbon emissions from concrete by up to 40% (see Figure 4). Furthermore, the way concrete is used in a structure's design can be optimized to improve its thermal efficiency, longevity and circularity, further reducing its carbon footprint.

The obstacles

Although reducing carbon emissions in buildings and infrastructure is an important opportunity requiring swift action, a series of obstacles prevents low-carbon design and construction with concrete from being deployed at scale today.

To begin with, measurement of carbon emissions across the entire life cycle of a project, and use of data to improve design decisions and track progress, is not the industry norm. This is, in part, because of the complexity of lifetime carbon assessment calculations and a lack of available data inputs. It can also be attributed to a lack of mandates for carbon measurement from governments, clients and firms.

Fragmentation in the design and building process also stands in the way of achieving lower-carbon outcomes. Different phases of design and construction are handled by different teams and firms, often with minimal coordination, limiting visibility into supply chains and impeding exchanges of information and ideas.

Adding to these challenges, low-carbon design techniques and products are not always aligned with industry norms and documented codes and standards, making it risky for firms to deploy them.

Perhaps most importantly, many clients, public and private, are not prioritizing carbon reduction (which can sometimes increase material and project costs) in their procurement decisions. This not only makes it difficult for AEC firms to prioritize low-carbon design, but creates uncertainty among cement manufacturers about the demand for low-carbon products, discouraging them from investing in decarbonizing their production processes. This adversely affects the economics and supply of low-emissions cement and concrete products, creating circular challenges and making designers hesitant to specify them.

The solution

This report offers a seven-part framework for overcoming the challenges and concerns that have stymied low-carbon design of buildings and infrastructure projects with concrete. Enacting this framework requires action and support from AEC firms, cement and concrete manufacturers, project buyers and investors, and governments.

1. **Adopt consistent life-cycle emissions measurement**

   AEC firms must conduct project-level, life-cycle carbon assessments, and do so consistently, in order to inform responsible design decisions and create accountability. The cement and concrete industry, on its part, must more frequently provide detailed environmental product declarations (EPDs).

2. **Increase collaboration across the value chain**

   Enhanced communication during the project design process between AEC firms and concrete manufacturers can improve supply chain visibility and facilitate lower-carbon project outcomes.

3. **Reduce risk through piloting, data and engagement**

   When standards, codes and industry norms work against reducing carbon emissions on buildings and infrastructure projects, AEC firms and cement and concrete producers must be willing to push for change by participating in dialogues with clients, academia and industry bodies to run pilots, invest in research, gather durability data and update standards.

4. **Evolve operating models with extensive leadership support**

   AEC firms must have clear mandates from the highest levels of leadership to prioritize low-carbon design, so that they can effectively upskill and enable teams to achieve lower-carbon outcomes.

5. **Signal demand and scale supply**

   By committing to specify and design for an increased volume of low-carbon materials and projects, AEC firms can help make the business case for cement and concrete manufacturers to invest in the plant upgrades needed to produce these materials at scale, improving their economics and availability.

6. **Prioritize carbon reduction in procurement**

   Project buyers, both public and private, can have meaningful influence in driving the AEC and cement manufacturing industries to act, by requiring disclosure of project and materials emissions and prioritizing carbon reduction in the partner selection and design process. Alongside demand signals from AEC firms, this can also help drive the necessary investments in technology and manufacturing.

7. **Establish supportive public policy**

   Governments can support the above steps and accelerate progress through a range of policy actions including regulation, incentives and funding, and by providing leadership to address key industry challenges.

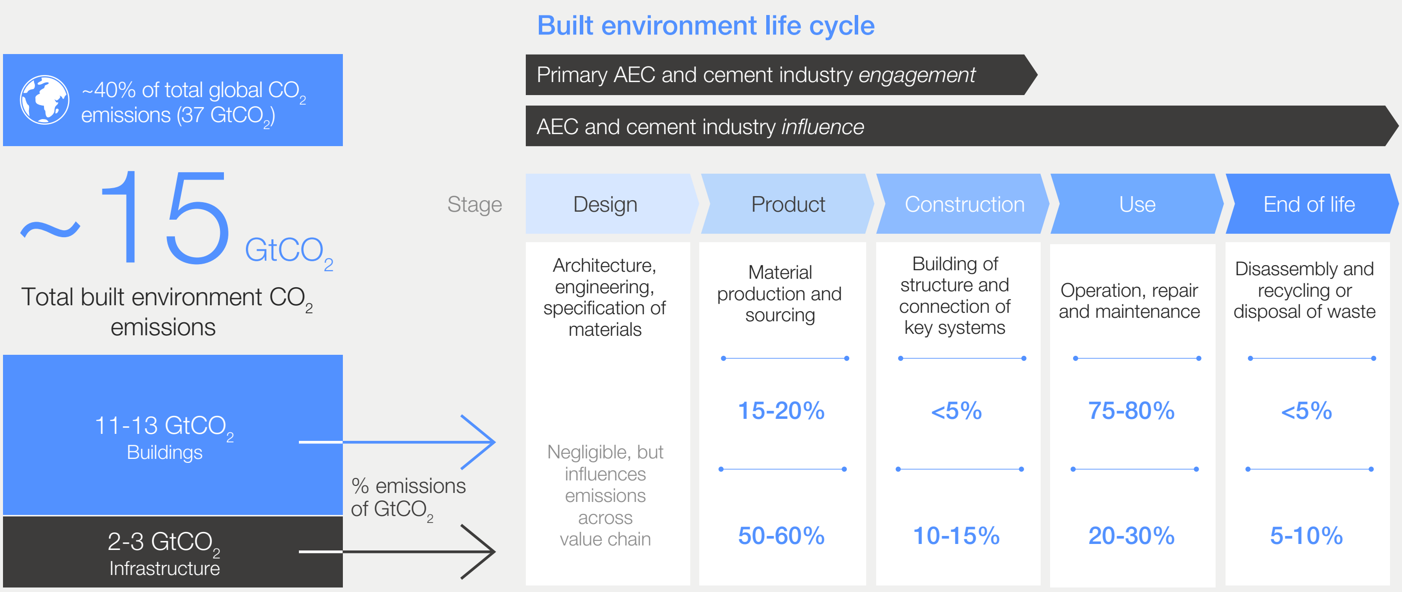
Given the urgency of reducing emissions from buildings and infrastructure, and the potential of low-carbon design and construction using concrete, all stakeholders – AEC firms, cement and concrete manufacturers, public and private buyers of construction projects and governments – must take these actions earnestly and speedily.

1 Introduction

Scaling low-carbon design with concrete: A path to net-zero construction.

Buildings and infrastructure are responsible for approximately 40% of the world's carbon emissions each year. A meaningful share of these emissions is released before an asset is ever used – through the production of building materials (an estimated 15-20% for buildings and 50-60% for infrastructure, although it can vary widely by project and geography) and construction activities. The remainder are emitted during the use of an asset through energy consumption, repairs, maintenance and at the end of its life, from demolition and waste. The design decisions made by project buyers and investors, architects and engineers before construction begins, and the choices that contractors make throughout the building process about which materials to use and how to use them, have a meaningful impact on the total life-cycle emissions of an asset.

FIGURE 1 **The built environment is responsible for around 40% of global emissions across the full project life-cycle**



Sources: IEA, "2020 Energy Technology Perspectives"; IEA, "Tracking Report - Buildings"; BCG analysis.

Note: Life-cycle analysis based on European Standards EN-15978 – includes materials, construction, operation and end-of-life emissions; excludes credit of material reuse and recycling.

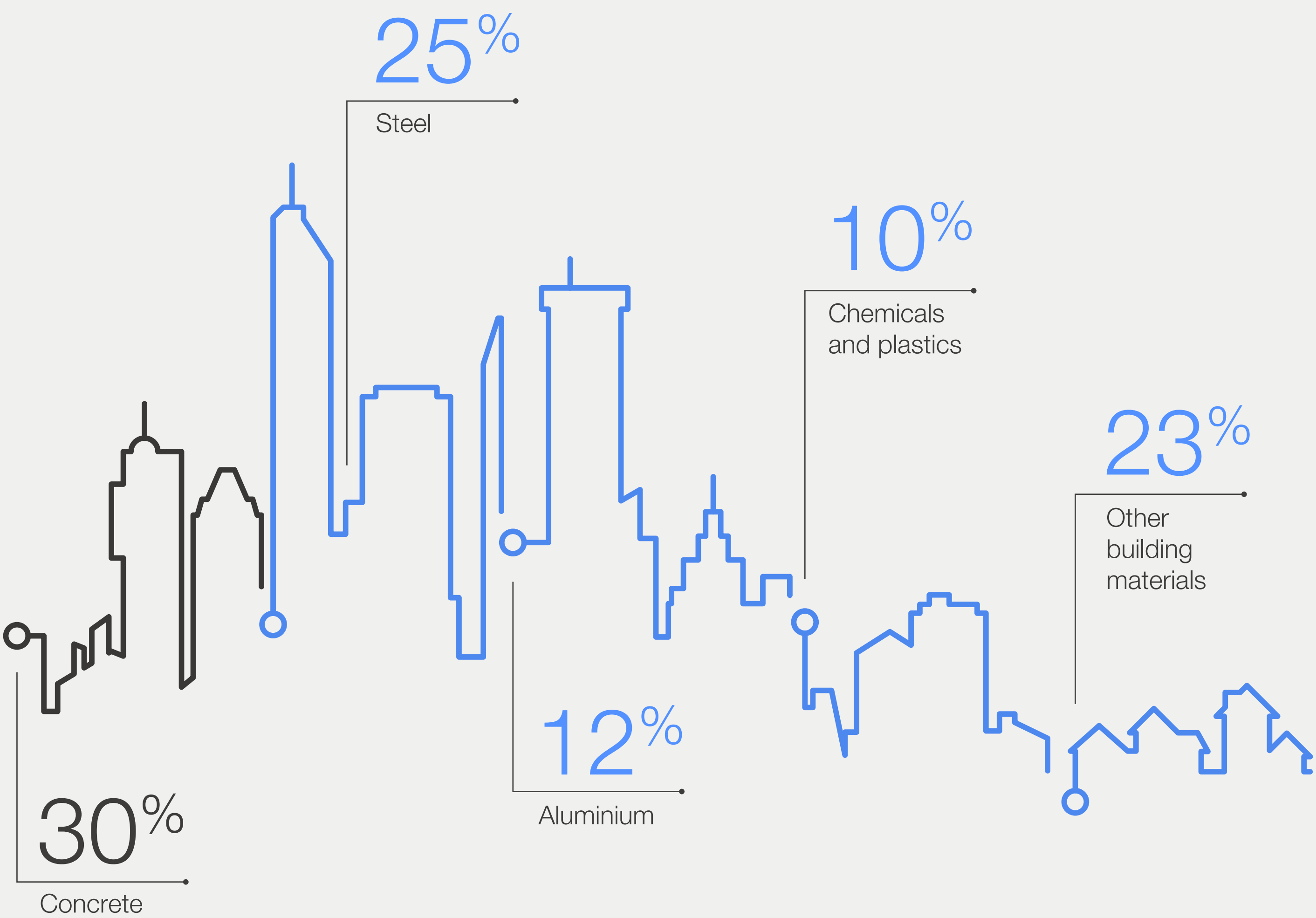
The role of cement and concrete

Concrete and cement (an essential material in concrete) are the most consumed human-made resources on Earth, responsible for approximately 7% of global carbon emissions and 30% of material emissions for buildings. The centrality of concrete and cement affects the carbon footprint of buildings and infrastructure in two crucial ways: directly through their own carbon emissions generated during manufacturing and construction, and indirectly through their positive contribution to the built project's energy efficiency, durability and longevity.

Global demand for cement is increasing, and in the absence of any action to respond to calls for net zero emissions, it is forecast to grow by 20% from 2020 to 2030.[3] Many of concrete's properties including its strength, durability, fire resistance, circularity, availability, resilience, thermal properties and affordability make it indispensable for critical infrastructure and buildings, which ultimately impact the health, safety and quality of life of billions of people. Therefore, in order to reduce the emissions of buildings and infrastructure while meeting societal needs, it is imperative to examine the use of concrete, and ways to reduce the carbon emissions related to it.

FIGURE 2 | **Concrete is responsible for approximately 30% of materials emissions for buildings**

Buildings and share of materials-related emissions



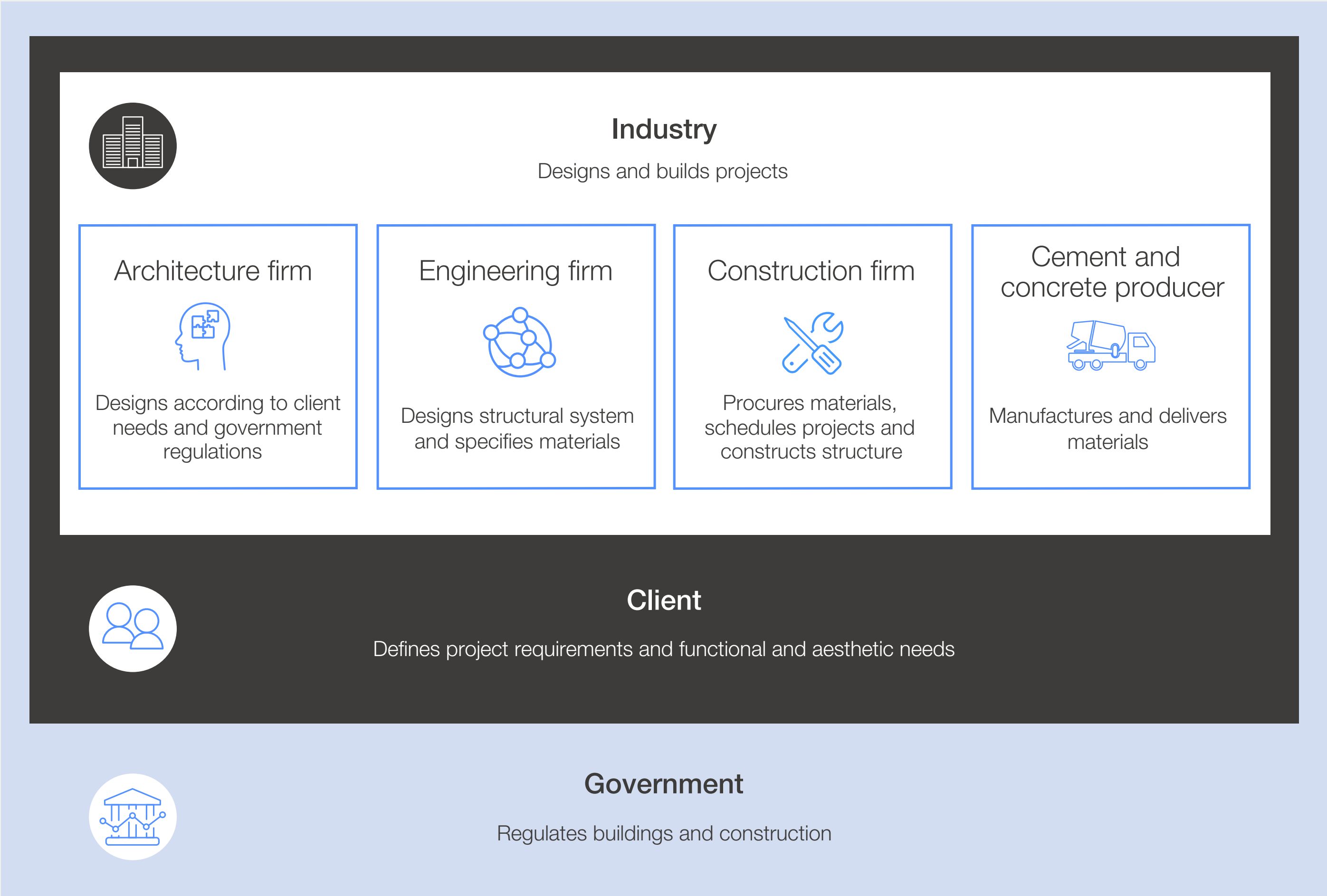
Source: BCG analysis.

The role of design

Along with materials producers that supply the cement, concrete and other materials used in construction, AEC firms can significantly influence a project's carbon emissions. The choices these firms make in the initial stages of a project determine the materials and construction techniques used, the energy consumption, repairs and maintenance during operation, and the resilience, longevity, circularity and recyclability at the end of life. These factors ultimately determine a project's total carbon emissions over many years. These design decisions are of course also influenced by project buyers (public and private), who set project priorities and budgets, and by governments that issue building and construction regulations.

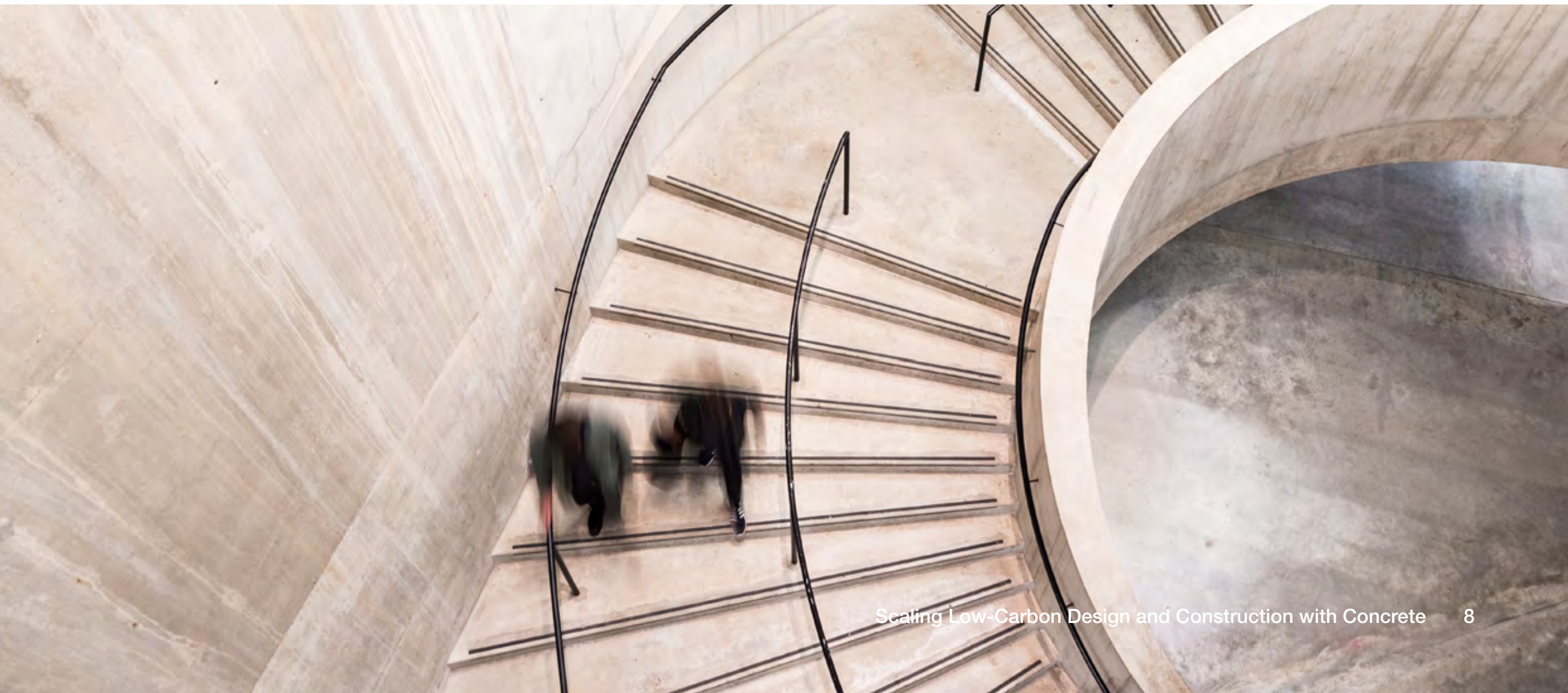
By setting and working towards a goal to minimize carbon emissions from the very beginning of a project, project buyers, AEC firms, and cement and concrete producers can collaborate to reduce carbon emissions across the building and infrastructure life cycle. There are obstacles to doing this and challenges to address, but this is a huge opportunity that could make a critical difference in reaching the goal of limiting the global average temperature increase to 1.5°C above pre-industrial levels.

FIGURE 3 | **An illustrative view of the buildings and infrastructure value chain**



Source: BCG analysis.

To scale low-carbon practices in the industry, low-carbon design and construction must be recognized as a critical enabler for reducing the carbon footprint of buildings, and must accordingly be prioritized by AEC firms, cement and concrete producers, project buyers, investors and governments.



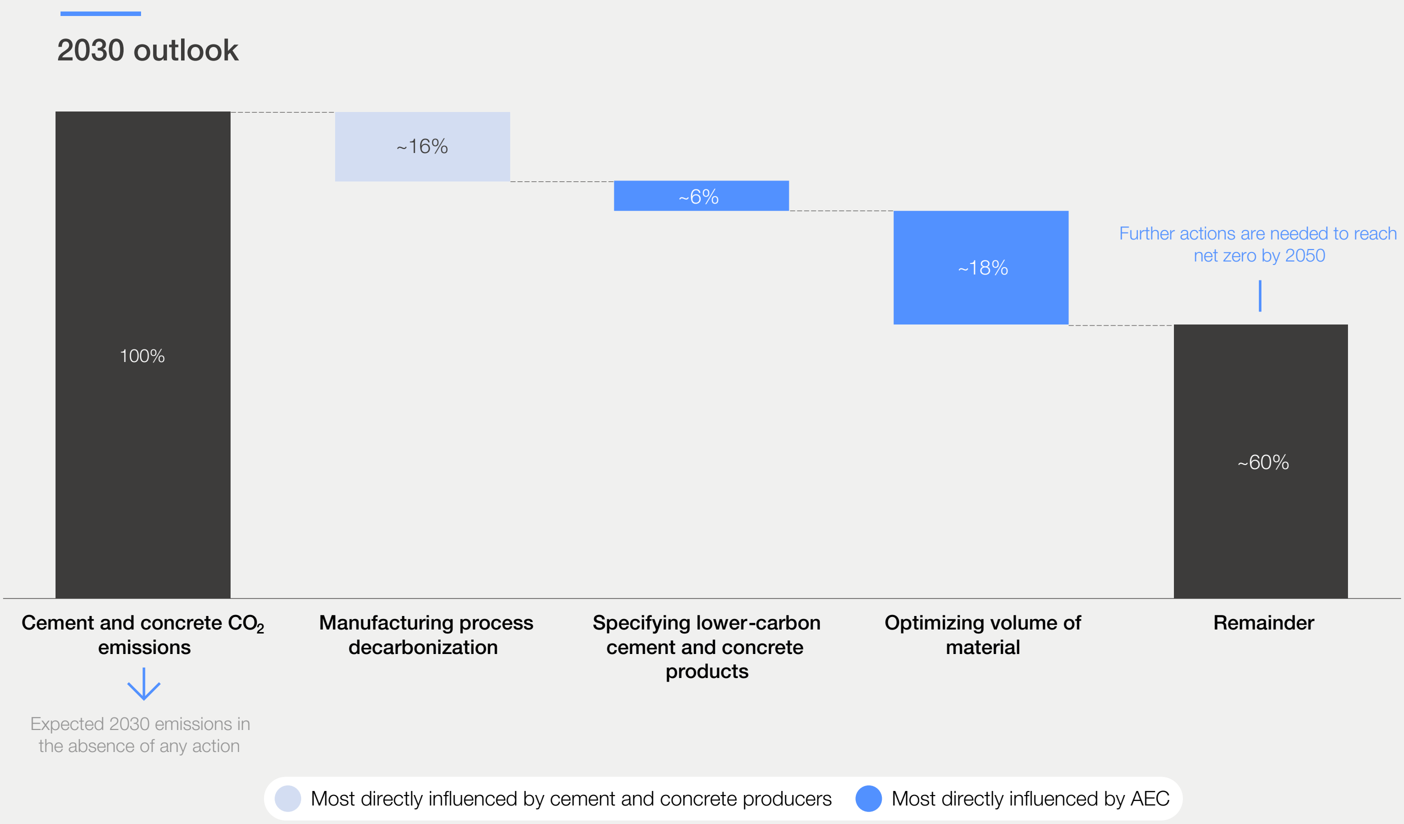
2

The potential of low-carbon design and construction

Large-scale deployment of low-carbon design tactics and the use of existing and upcoming manufacturing technologies can meaningfully reduce the carbon footprint of construction projects.

The total concrete emissions in a project can be reduced by up to 40% by 2030 (see Figure 4) by using existing or upcoming technology in the manufacturing process, specifying the use of low-carbon concrete products, and optimizing the volume of materials used. Additionally, other techniques related to the construction, use and end-of-life stages can further shrink a structure's carbon footprint over its life cycle.

FIGURE 4 **Low-carbon design can reduce the cement and concrete emissions of construction projects by up to 40% in the near term**



Sources: Global Cement and Concrete Association, *Concrete Future – The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete*, 2021; Institution of Civil Engineers, *Low Carbon Concrete Routemap*, 2021; *A Project-Based Comparison Between Reinforced and Post-Tensioned Structures from a Sustainability Perspective*, 2011; University of Wollongong, *Environmental impact assessment of post tensioned and reinforced concrete slab construction*, 2013; BCG analysis.

BOX 1 Holistic design decision-making

Designers must holistically assess the various levers they use, and over the whole project life cycle, in order to maximize emissions reductions while meeting project goals. For example, designs that maximize energy efficiency may require more carbon-intensive materials.

Clients and designers face choices while designing the service life of a project: do they want to design a long-lasting, resilient project with low maintenance, or a project with a shorter lifespan that will need higher maintenance and earlier replacement? These alternatives should not be compared only on initial carbon impacts, but over the entire lifetime.

Clients and AEC firms must also consider trade-offs between emissions reduction design tactics and other project criteria such as cost, project scheduling and aesthetics. They must also be thoughtful about how much new construction is undertaken while keeping in mind opportunities for refurbishing and repurposing existing structures.

Four significant low-carbon design levers include:

1. **Reducing the carbon footprint of materials**

   Manufacturing process decarbonization: A number of decarbonization levers can be deployed in the cement manufacturing process that do not affect the properties of the end products other than their global warming potential (GWP, the standard unit of measurement of carbon emissions). Examples include the use of alternative fuels and renewable energy and efficiency improvements. While largely being deployed as first of their kind projects, carbon capture and storage (CCS) technologies are also critical production-side decarbonization levers and are needed to fully decarbonize cement and concrete manufacturing. Although these decarbonization levers fall largely on manufacturers to implement, AEC players can make specifications and purchasing decisions based on the GWP of materials.

   Specification of lower-carbon concrete products: Architects and engineers typically specify the materials that should be used in the projects they design, sometimes with input from construction firms and materials producers. Specifying concrete products with lesser GWP (while meeting technical performance and safety requirements) can make a significant difference in a project's emissions. The most common product of this type is blended cement, made with supplementary cementitious materials (SCMs), reducing the volume of clinker used. However, use of SCMs at high percentages typically reduces the strength gain rate of concrete, which can impact construction schedules (and costs) – an element that engineers and construction firms must bear in mind.

   Optimization of material volume: The overall quantity of concrete in a project can be reduced through design choices, such as the spacing and width of slabs and columns, and the use of hollow spaces (most frequently applicable in buildings). Additionally, the carbon intensity and quantity of cement can be optimized for lower emissions. For example, the use of higher-strength concrete, which is often more carbon intensive, sometimes enables the use of lesser volume. These trade-offs have to be assessed on a case-by-case basis. Beyond the design phase, efficient use of cement and concrete during construction can also reduce the volume of material used and the associated carbon footprint.

2. **Enabling thermal efficiency**

   In many situations, designers can use concrete's high thermal capacity, that is, its ability to store heat, as part of a heating and/or cooling strategy to reduce operational energy. This is a complex and nuanced consideration as design tactics that incorporate thermal efficiency depend on geography, use, environmental design and other factors.

3. **Increasing structural resilience and longevity**

   Given the increase in extreme weather events due to climate change, concrete is an especially valuable material since it has inherent properties that enable designers to deliver longevity and resilience with little or no extra materials. Concrete's high density and rigidity make it extremely durable against rain, flooding, humidity, strong winds, freezing, chemicals and other threats. Therefore, concrete can be used to increase the overall lifespan of buildings and infrastructure and minimize repairs and maintenance, delaying or avoiding additional product- and construction-stage emissions.

4. **Designing for disassembly**

   "Design for disassembly" (DfD) is an approach that uses modular building techniques to allow for reusing materials after building deconstruction. The DfD planning process makes material reuse and return plans clear early in the design phase in order to maximize the reuse of elements and avoid waste at the end of life.

The framework described in this report focuses primarily on the first lever: reducing the carbon footprint of materials. This lever has the greatest impact on product stage emissions, which also represent a meaningful share of overall project emissions (See Figure 1). Moreover, it can make a significant difference in the short term, compared to design tactics targeting buildings or infrastructure usage or end-of-life emissions. In addition, this lever was the highest priority of many of the firms interviewed for this report. Nevertheless, many of the obstacles and solutions presented here are also applicable to other design decarbonization levers.

3 Obstacles to scaling

AEC firms and producers of cement and concrete face a series of challenges in delivering low-carbon materials and projects at scale.

Although swift action is needed to address carbon emissions from buildings and infrastructure – and proven techniques can have a meaningful impact – low-carbon design strategies are not being used at scale today. AEC firms are raising a variety of interrelated concerns about the feasibility of implementing low-carbon design and construction approaches – many of which they feel are beyond their control. The obstacles that remain significant barriers to scaling low-carbon design include:

– **Difficulty in measurement.** Assessing the entire carbon footprint of a project accurately and consistently is hard for many AEC firms, because of major capabilities gaps related to technology, data, process and expertise.

  While software exists to estimate whole life-cycle emissions for entire projects, collecting and refining the data to make these assessments accurate is difficult. Despite concrete having more environmental product declarations (EPDs, which document the emissions of materials) published than any other material, EPDs with sufficient specificity are not always available. In addition, EPD formats and product category rules (PCRs), which define how EPD measures are calculated, can vary by region and materials, making interpretation and comparability of data troublesome.

  In practice, project-level carbon assessments are typically conducted only when a client or a government demands it, or an AEC firm mandates it. For example, the French government requires carbon assessments for select types of buildings through its RE2020 regulation. However, this is far from a global norm today. Given this lack of consistency in assessing projects and the lack of infrastructure for utilizing emissions data, teams are not consistently trained, structured and resourced to measure project emissions – or to use emissions data to inform design decisions.

– **Fragmentation of the design and build process.** AEC firms typically make design and construction decisions in separate stages of projects, with limited coordination between them. Design and construction firms as well as concrete producers have expressed interest in more upfront collaboration to drive low-carbon outcomes, but many are unsure how to achieve this, especially when it is not part of a client's project requirements. Without a more collaborative approach, decisions made in the initial stages of the project may obviate the low-carbon solutions that can be used in later stages. And they are frequently made without sufficient visibility into local supply chains to understand options for low-carbon materials for the construction phase of the project.

– **Established norms and potential risks' potential to hinder innovation.** AEC firms are often reluctant to choose certain techniques and products that would reduce project emissions because they run counter to the industry norm or, in some cases, are not compliant with industry standards and codes. Furthermore, it can be the case that some clients have in-house specifications and these may not be updated to newer standards that permit certain blended cements and SCMs, as well as lower clinker factors. In other cases, standards and codes themselves do not include newer innovations and less conventional products, such as recycled materials from construction and demolition waste (CDW), in their definitions and frameworks. In addition, testing of these techniques and products to prove their safety and durability can be an expensive and lengthy process, which further slows their adoption.

– **Supply and demand imbalances and uncertainties.** Cement and concrete producers must make capital investments to manufacture lower-carbon materials at scale. Generally, new equipment is needed, older plants must be retrofitted or newer ones built in order to begin using new fuels or raw materials or to deploy new and innovative technologies. It is a chicken and egg situation: if AEC firms and their clients as well as policy-makers don't prioritize the use of low-carbon concrete in buildings and infrastructure projects, many manufacturers will be loath to allocate capital expenditures for materials production. And until low-carbon cement and concrete products are produced at greater scale, their availability and cost will be a concern for the industry.

- **Clients' failure to prioritize low-carbon design.** Arguably the most significant obstacle impeding AEC firms from adopting low-carbon design is a lack of demand from clients such as real-estate developers, governments and corporations. Achieving low-carbon outcomes requires additional effort, adds complexity and sometimes increases costs. Although this is not always the case, lower carbon materials can be more expensive, and labour costs may rise as more hours are needed to build more complex designs and allow for longer concrete strength-gain rates (see Figure 5 for examples of how product and labour costs could impact project budgets). In the absence of client demand or willingness to pay more for a project, AEC firms often find it prohibitively burdensome to prioritize low-carbon design and construction.

BOX 2

The green premium for low-carbon concrete and construction

The cost premium associated with low-carbon concrete and construction projects is difficult to generalize and can vary widely. However, given that the cost of concrete as a material in a typical building (see figure 5) is around 5%, a green premium on concrete alone will not be a significant percentage of the overall final cost of a new building.

The green premium of concrete is challenging to generalize for several reasons:

- **Lack of definition.** No standard definition for "low-carbon" or "green" cement and concrete exists – either in terms of how decarbonization is achieved or embodied carbon levels.

- **Broad set of decarbonization levers.** Tactics for reducing the carbon intensity of concrete range from levers that can in *some* cases reduce costs, such as use of SCMs and renewable energy, to technologies such as CCS, currently estimated to increase the cost of cement production by up to 70%.[4]

- **Geographic variation.** The carbon intensity of concrete varies by location and is influenced by a range of factors. Factors include the availability of lower carbon raw materials, such as SCMs; the price and proximity of alternative fuels for plant operations and supply chain shipments; the state of the local electricity grid and electricity sources; and the technology and machinery used in individual factories.

Quantifying the broad cost implications of low-carbon concrete on projects is complicated by other variables and design decisions. These include:

- **Other materials.** Designers and clients seeking to reduce embodied carbon emissions of their projects will often also consider using low-carbon steel and other low-carbon materials, incurring green premiums beyond just concrete. Furthermore, the interplay of different materials in a structure means that choices made about the carbon footprint and cost of one material may affect the usage and cost of another.

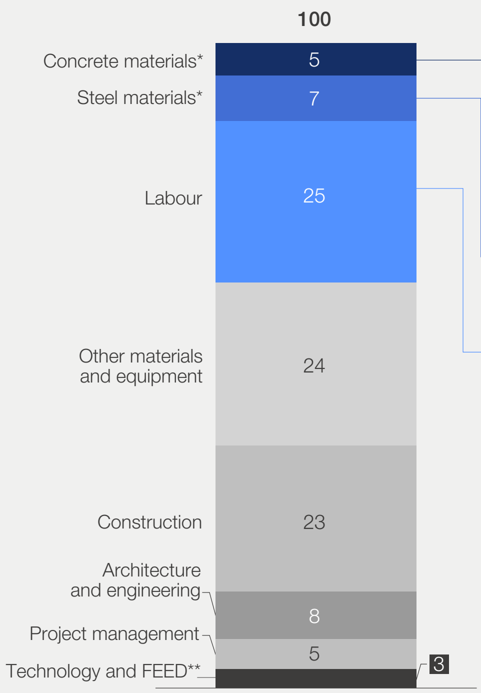
- **Design optimization.** Some increased material costs can be offset through other design choices, such as optimizing the volume of materials and leveraging the use of special concretes.

- **Project variability.** Broadly speaking, construction projects encompass a wide range of possibilities and structures. Therefore, a low-carbon concrete premium will impact each project differently.

Given this complexity, it is important that initiatives and projects be clear about the level of their decarbonization ambitions, so that economic implications can be assessed. It is also vital that quantifications of the green premium be used with consideration for the context in which they are calculated.

FIGURE 5 | Example implications of low-carbon design on project costs

Example of building cost structure



Example of building project cost implications of low-carbon design

Cost component	No increase scenario	Low estimate scenario +10% material cost +2% labour cost	Medium estimate scenario +25% material cost +5% labour cost	High estimate scenario +50% material cost +10% labour cost
Concrete cost implication	+0%	+0.5%	+1%	+2-3%
Steel cost implication	+0%	+1%	+2%	+3-4%
Labour cost implication	+0%	+0.5%	+1%	+2-3%
Overall cost implication	**+0%**	**+2%**	**+4%**	**+9%**

Concrete and steel are the two materials with the largest carbon footprints in most structures and the focus of many embodied carbon efforts. **Labour costs** can increase due to the rate of strength gain and the complexity implications of low-carbon design.

Source: BCG analysis.
*Includes concrete and steel material costs only. Other labour and material costs typically bundled with concrete and steel (concrete framing, etc.) are included in other categories.
**Front-end engineering design.

Notes: Additional low-carbon opportunities within other categories could have corresponding green premia. Project cost structures vary across projects and geographies.

4 Seven steps to scale low-carbon design and construction with concrete

Achieving broad use of low-carbon design principles will require action from across the AEC and cement and concrete manufacturing industries, clients and governments.

Given the obstacles to scaling low-carbon design and construction, a collaborative and concerted effort by key players across the AEC and cement and concrete industries – as well as independent actions within these firms – is needed. To incentivize and enable these activities, the rest of the buildings and infrastructure ecosystem – clients, developers, investors and governments – will also have to support and demand prioritization of low-carbon projects. In turn, that will accelerate progress and provide AEC firms with the backing they need to make low-carbon design a priority.

Seven actions from AEC firms, cement and concrete producers and other public and private buildings and infrastructure stakeholders can propel low-carbon design and construction.

FIGURE 6 **A framework for scaling low-carbon design and construction with concrete**

Industry

Architecture, engineering, construction, cement and concrete

1. **Adopt consistent life-cycle emissions measurement**
Conduct whole-life-cycle emissions assessments consistently using detailed product-level data (EPDs) to inform responsible design decisions.

2. **Increase collaboration across the value chain**
Engage other players early (e.g. an AEC with cement and concrete producers) to improve supply-chain visibility and understand partner capabilities and constraints.

3. **Reduce risk through piloting, data and engagement**
Increase testing, piloting and tracking of low-carbon solution performance and engage with clients and relevant organizations to update codes and standards.

4. **Evolve the operating model with extensive leadership support**
Prioritize low-carbon solutions, set company targets, measure carbon reduction progress, upskill the organization, and evolve processes and team composition.

5. **Signal demand and scale supply**
Signal demand by committing to specify and procure low-carbon materials and scale supply of low-carbon materials by investing in plants.

Clients

Public and private entities that commission projects and investors

6. **Prioritize carbon reduction in procurement**
Shift selection criteria so that carbon is a key consideration, require emissions assessments and establish project carbon reduction targets.

Governments

National, regional, local

7. **Establish supportive public policy**
Enact policies that accelerate progress and address economic gaps where needed, and update government codes and standards to support use of low-carbon solutions.

Source: BCG and World Economic Forum analysis

1 Adopt consistent life-cycle emissions measurement.

Conduct whole life-cycle emissions assessments for all projects. Project-level, whole life-cycle carbon assessments, using state-of-the-art software, must be conducted and shared with clients to inform responsible design decisions, establish baselines, compare options, create accountability, and in an ongoing fashion track progress towards emissions reduction targets. Arup, a global engineering firm is one example of a firm that has done this, committing to whole life-cycle measurement of all projects (new and retrofit), beginning in 2022.[5]

Make more specific and widely available EPDs. For project carbon assessments to be most accurate and useful, EPDs (or environmental product declarations) made by materials manufacturers must become more widely available. Generic EPDs that are not manufacturer- or plant-specific, can be useful early in the design and engineering process for initial estimates of project-level emissions. But for more accurate and detailed measurements, plant-level EPDs are necessary, particularly given the possible emissions level variations for the same product, depending on the plant at which it was made, among other factors.

According to a survey by the National Institute for Environmental Studies, the cost of producing a single EPD can range from $12,500 to over $40,000.[6] Over half comes from preparation efforts and the rest goes towards verification and other fees. At this cost, producing specific EPDs for each product made, not to mention each order, can be prohibitively costly.

To achieve the level of granularity in EPDs at scale that AEC firms are seeking, manufacturers should adopt new digital tools to automate and capture data inputs for EPDs, such as energy sources and raw material components, since manual data collection and preparation is simply not scalable. This requires cement and concrete manufacturers to make capital investments. Consequently, demand signals from AEC firms (discussed in part 5 of the framework) and/or requirements from clients or governments, are essential to justify EPD expansion.

Harmonize standards. Considering how important EPDs are to carbon measurement – and how much they can vary by region – efforts are under way to harmonize public category rules (PCRs) and EPD formats in order to make them more user-friendly. For example, the ECO Platform is a non-profit association that promotes the harmonization and networking of all existing EPD programmes in Europe. It establishes standards for verification and regular audits to ensure its EPDs are consistent and user-friendly.[7] Continued support of harmonization work by the AEC and cement industries can help achieve more accurate and consistent project emissions measurement.

2 Increase collaboration across the value chain.

Engage partners early. More communication in the project design process between architectural, engineering and construction firms and cement and concrete manufacturers can improve supply chain visibility and make certain that design decisions, specifications and final material selections are made with a clear understanding of the lower-carbon materials available locally. Architecture firm Gensler says that it frequently works to identify engineering and construction partners (and their suppliers) as early as possible in the design process, so that they can begin a dialogue around the project's carbon footprint. Greater collaboration also enables firms to become familiar with each other's capabilities and constraints relevant to a given project, enabling more coordinated decision-making and improving potential outcomes. This collaboration can be further enhanced by technology such as building information modeling BIM (building information modeling) software to improve efficiency and facilitate data exchange.

Build capabilities. To facilitate this level of communication, cement and concrete producers likely need to increase the level of support they provide to architecture and engineering (A&E) firms. Architects and engineers need to understand the detailed characteristics of available low-carbon cement and concrete products (especially newer innovations) and how they can be used in projects. This can be done through a range of measures such as upskilling of existing commercial teams, creation of new specialized support roles, and development of content such as fact sheets and videos on low-carbon materials and applications.

Use performance-based specifications. To avoid placing excessive limitations in the design stage on what type of concrete construction firms can use in the building phase, one approach is for A&E firms to craft performance-based specifications for materials. This gives construction partners the freedom to pick from available options that meet the performance criteria, rather than be locked into specific blends of cement. Additionally, A&E firms can also include requirements for EPDs and set GWP (global warming potential) limits in specifications to ensure that the carbon footprint is considered in the material procurement process. For this approach to be successful, construction firms must prioritize low-carbon material selection and be closely connected to the supply chain.

3 Reduce risk through piloting, data and engagement.

When industry or regional standards and codes work against reducing carbon emissions in buildings and infrastructure projects, AEC firms can be proactive in helping to change them. Standards and codes tend to follow the market, rather than the reverse – and if companies can demonstrate that other approaches are more beneficial to the environment while achieving the necessary safety and performance requirements, standards bodies and policy-makers are likely to update their standards and codes.

Pilot low-carbon solutions. A way to approach changing standards that have not kept up with current conditions is risk-appropriate piloting. AEC firms can identify opportunities to use carbon reduction products and techniques that are not aligned with the prevailing standards in low-risk environments, such as non-structural applications, assuming that there is sufficient evidence of their safety (either through lab testing or because other firms have piloted them).

Establish performance data. It is important, though, that AEC firms monitor the performance of the pilot programme closely, which is not the norm for most projects – frequently, AEC firms only follow up on project efficacy and results if a problem arises. Further, firms should share the results of their pilots through industry channels and with materials manufacturers to showcase successes of viable low-carbon solutions, thereby helping to inform future decisions. In part, this can be accomplished through the publication of case studies or inclusion of application examples on product fact-sheets.

Support updates to codes and standards. When there is sufficient data to support it, AEC firms and cement producers should argue for and encourage updating standards and codes by presenting pilot data to relevant committees in organizations such as the International Organization for Standardization, the European Committee for Standardization, and ASTM International. Often this is a lengthy process, which can be challenging to prioritize since it does not directly generate revenue. However, this engagement is critical for making progress in reducing carbon in buildings and construction. Additionally, in cases where clients maintain their own standards, firms can sometimes directly persuade clients to update such standards or allow exceptions through dialogue about an individual project. Firms can also similarly work with national standardization entities that are dedicated to developing national building codes.

BOX 3

Updating standards to enable use of lower-carbon products: The PLC example

Portland Limestone Cement (PLC) is a cement that contains between 5% and 15% finely ground limestone to replace clinker. This reduces the carbon emissions in manufacturing cement by 8-12%, making PLC a low-carbon alternative to Ordinary Portland Cement (OPC).[8]

Although PLC has been used in Europe since the 1960s, it was not adopted for use by any US state departments of transportation until 2008. Following the successful use of PLC by the city of Denver in its 40th Avenue project in 2007, the Colorado Department of Transportation became the first such agency to approve the use of 10% limestone PLC under the ASTM International C1157 concrete performance standard. Over the next 10 years, PLC was seen to have maintained a level of quality and performance equal to OPC.

Since departments of transportation tend to rely heavily on the American Association of State Highway and Transportation Officials' (AASHTO) standards, and AASHTO had no equivalent performance standard to ASTM C1157, the use of PLC by departments of transport was limited, even after Colorado's actions. However, after the Utah and Oklahoma departments began to use PLC in projects and further research and piloting confirmed its efficacy, PLC's blended specification gained acceptance from AASHTO in standard M240 in 2012.[9]

This has led to the acceptance of PLC by more than 90% of US state-level departments of transportation. As a result, the demand for PLC in the US has grown and producers are making PLC readily available through existing supply chains.

Government must play a role. Most often, standards and codes are maintained by industry associations and government codes reference those. In such cases, governments should ensure that these codes point to the best-suited industry standards that meet safety and performance needs to allow the use of low-carbon solutions. Moreover, when government agencies do maintain their own standards and codes (such as the US states' departments of transportation), it is important that they play a more active role in working with industry to ensure that those codes don't unnecessarily impede low-carbon solutions.

4 Evolve the operating model with extensive leadership support.

Many AEC firms need to make changes to current operating models, which are typically not designed for the type of collaboration, consistent measurement and project requirements needed to deliver low-carbon projects. These changes will need clear mandates from the highest levels of leadership, championing low-carbon design as a priority.

Set targets and commitments. Once AEC firms have processes in place to assess project emissions, they can set targets and make commitments towards emissions reduction. Commitments from leadership to prioritize low-carbon design provide organizations with meaningful directives. For example, as part of its Architecture 2030 pledge, global architecture firm Gensler says all design teams will analyse their life-cycle and embodied energy, discuss options with clients, and encourage the selection of materials that have less embodied energy.[10]

Evolve processes and teams. Targets and commitments are only valuable if project teams have the resources and skills to reach them. Organizational change led by top managers to upskill, recruit relevant talent, improve information sharing channels and enhance team collaboration is vital. See Box 4 for an example framework for mobilizing firms to meet embodied carbon targets.

BOX 4

Embodied carbon action plans: A framework for organizational change

To encourage firms to take on the types of organizational change needed to scale low-carbon design and create accountability, the SE2050 initiative (described in Box 5), requires signatories to submit embodied carbon action plans (ECAPs), which are published on the SE2050 website. Each ECAP must include:

– An internal announcement notifying employees of the firm's SE2050 commitment.

– An education plan to teach employees about embodied carbon.

– A knowledge sharing narrative to communicate the firm's carbon reduction work externally.

– A reduction strategy with specific and measurable goals.

– A reporting plan to track progress.

– An annual summary of lessons learned to inform the next year's strategy.

For example, an ECAP by Magnusson Klemencic Associates (MKA), a Seattle-based civil and structural engineering firm, includes:[11]

– A sustainability technical specialist team, managed by a designated "engineering champion", to share innovations and carbon reduction strategies across the organization and to ensure that the firm is on track to meet its goals.

– Ongoing internal workshops for technical development focused on material quality control and embodied carbon tracking.

– Sponsored webinars, open to all, to highlight low-carbon advancements within the industry and encourage collaboration to reduce carbon footprints.

– Guides that detail the firm's learnings about measuring carbon emissions at the design and product procurement stage, at the construction phase, and in the whole-building life cycle.

5 Signal demand and scale supply.

Commit to specifying and procuring low-carbon products: Demonstrating increasing market demand for low-carbon concrete and EPDs is imperative to encourage producers to invest in the plant upgrades required to produce these materials and the processes needed to document their emissions levels through EPDs. Construction firms must make commitments to procure low-carbon products, and while architecture and engineering firms don't buy materials directly, they can send demand signals through commitment to low-carbon material specification. Demand signals can also come in the form of low-carbon procurement policies established by project buyers, covered in part 6 of the framework.

Ensure credibility and impact: Importantly, to be taken seriously and make a tangible difference, low-carbon demand signal initiatives must balance ambition and practicality. That is, they need to be aggressive enough to incentivize manufacturers to change their production processes and meaningfully reduce emissions, while also staying within reach technologically, logistically and economically, so that companies can realistically agree to make low-carbon commitments. Equally essential is that demand evidence be sensitive to regional variability. Materials availability, economic conditions and regulations diverge widely globally, impacting local baseline cement and concrete emissions levels as well as regional activities to reduce carbon.

Invest in scaling supply: Demand signals are of course intended to spur action from cement and concrete producers to invest in scaling supply of low-carbon products. Producers must take action to increase production of low-carbon materials (and EPDs to verify material emissions), which often requires capital investments in plants. In some cases, this will increase material costs (which are expected to come down in the long-run with technology advancements and scale). However, in other instances – for example, when using alternative fuels, renewable energy and SCMs – the unit costs of production will be neutral or even provide savings.

FIGURE 7 Actions can be taken across the AEC and cement and concrete production industries

<table>
<tr><th></th><th>Architecture and engineering firms</th><th>Construction firms</th><th>Cement and concrete producers</th></tr>
<tr><td>1 Adopt consistent life-cycle emissions measurement</td><td colspan="2">– Assess whole life-cycle emissions consistently, adopt measurement software and processes, and set baselines for project-level emissions</td><td>– Invest in EPD automation</td></tr>
<tr><td>2 Increase collaboration across the value chain</td><td>– Identify and engage downstream partners early
– Switch to performance-based specifications</td><td>– Align with upstream and downstream partners on emissions goals
– Select materials optimized for carbon reduction</td><td>– Engage upstream to communicate low-carbon solutions</td></tr>
<tr><td rowspan="2">3 Reduce risk through piloting, data and engagement</td><td colspan="3">– Increase participation in industry committees and to update codes and standards</td></tr>
<tr><td colspan="3">– Increase testing, piloting and tracking of new low-carbon solutions in risk-appropriate applications</td></tr>
<tr><td rowspan="2">4 Evolve the operating model with extensive leadership support</td><td colspan="2">– Set company targets and measure carbon reduction progress</td><td rowspan="2">– Build capabilities to inform and consult with AEC firms about low-carbon products and solutions</td></tr>
<tr><td>– Upskill organizations and evolve processes and team composition to support low-carbon design and measurement</td><td>– Train teams and update processes to evaluate carbon emissions in product selection</td></tr>
<tr><td>5 Signal demand and scale supply</td><td colspan="2">– Send demand signals by setting commitments to specify and procure low-carbon materials</td><td>– Invest in plant upgrades to scale production of lower-carbon materials</td></tr>
</table>

BOX 5 | Demand signals and procurement coalitions

A number of coalitions are focusing on collecting and promoting demand signals and compelling project buyers to update their procurement policies.

- **SE2050:** This initiative consists of signatory members from A&E firms who commit to reach net-zero embodied carbon by 2050 and create Embodied Carbon Action Plans (ECAPs). Top global A&E firms are among its 100 members.
- **Architecture 2030:** The Architecture 2030 challenge for embodied carbon asks the global architecture and building community to immediately meet a maximum GWP of 40% below the current industry average, scaling to zero by 2040. Over 2,600 organizations have signed onto this initiative worldwide.
- **ConcreteZero:** Businesses that join ConcreteZero commit to using 100% net-zero concrete by 2050, meeting interim targets of 30% low-emission concrete by 2025 and 50% by 2030. As of late 2022, 17 founding members had made this commitment, including members from the AEC industry and developers.
- **First Movers Coalition:** This is a global initiative harnessing corporate purchasing power to decarbonize "hard to abate" industrial sectors. It has launched sectoral purchasing commitments to accelerate breakthrough technologies, including one for cement and concrete, launched at COP27.[12]
- **Industrial Deep Decarbonization Initiative:** This is a global coalition, run by the United Nations Industrial Development Organization (UNIDO), of public and private organizations working to stimulate demand for low-carbon industrial materials. The initiative released a global Green Public Procurement Pledge in 2022 for governments to sign, committing to using low-emission cement, concrete and steel in all public projects by 2030.[13]

6 Prioritize carbon reduction in procurement.

AEC firms frequently argue that if clients – from both public and private sector – would demand, prioritize and be willing to pay for low-carbon design and construction in their project requirements, they would quickly follow their lead and deliver lower-carbon projects. AEC firms note that passing on incremental costs and charging more for low-carbon projects, at least at this early stage, could result in losing jobs to other bidders. And even if AEC firms keep cost increases down, they would expend time and resources altering their operating model – a substantial undertaking that is difficult to gain support for if not explicitly valued by customers.

Adopt green public procurement programmes. Governments account for approximately 25% of construction revenues.[14] Given their potential clout, some governments are moving towards minimizing the carbon footprint in projects they procure. To support governments considering such actions, *Low-Carbon Concrete & Construction: A Review of Green Public Procurement Programmes* published in 2022 outlines a framework for green public procurement policies. The first step is for governments to require disclosure of emissions, establish baselines and set targets for concrete purchases and construction activities. Next, they can implement procurement policies, including requirements, scoring systems and incentives to ensure that those targets are reached.[15]

Evolve private procurement practices. Private developers and corporations commissioning projects can also make a difference in reducing the large contribution of buildings and infrastructure to global carbon emissions by prioritizing low-carbon design in projects. Indeed, private developers will be increasingly pressured to minimize emissions in concrete and construction by the broad decarbonization pledges that they are making and by the growing number of investors who are attempting to hold these companies to their commitments. As decarbonization goals expand and edge closer to their deadlines over the next decades, corporations will need to pull more abatement levers to meet these targets.

Some companies are beginning to set specific targets for building projects that they are responsible for. For instance, Salesforce has set a goal of 80% reduction in embodied carbon in its construction efforts by 2030 and net zero by 2050. Real-estate investors such as IPUT and British Land have also set targets of a 40% embodied carbon reduction and 50% whole-life carbon reduction by 2030, respectively.

Another reason for the private sector to consider moving towards low-carbon design is its potential impact on asset values and revenues. Some analyses have shown that buildings that achieve certification in the US achieve 11% higher rents and 21% higher sale values per square foot compared to non-green buildings.[16] Furthermore, many investors speculate that in the future, less-green assets will be hit with "brown discounts". However, it is important to keep in mind that certifications like LEED and analyses of green building asset values tend to consider a broad range of factors such as water usage and energy efficiency, with embodied carbon playing a relatively small role in the overall assessment. A direct link between low-embodied carbon and impact on asset values has not been established.

7 Establish supportive public policy.

Beyond public procurement policies, standards and codes, governments can take action on national, regional and municipal levels to support the solutions outlined, accelerate progress and reduce economic barriers to low-carbon design as it relates to cement and concrete. These actions can range from wide-reaching, highly impactful measures such as implementing a carbon price, to directed and more politically neutral measures such as updating codes. Examples of supportive policy include:

- **Regulation:** Regulation can be used to require disclosure of carbon emissions or set maximum limits for the embodied and operational carbon footprint of building materials or entire projects.
  - Example: France's RE2020 policy sets maximum embodied carbon GWP limits per square metre for new residential buildings, offices and schools.[17]

- **Incentives:** Providing tax credits and direct financial payment can reduce the economic burden of adopting low-carbon design and construction practices.
  - Example: The US and Canada provide tax credits for carbon capture and storage through the Inflation Reduction Act (2022) and the Investment Tax Credit for Carbon Capture, Utilization and Storage, respectively.

- **Funding:** Allocating funds to innovative projects that require large capital expenditures can spur breakthrough low-carbon innovations.
  - Example: Between 2020 and 2030, the European Commission's Innovation Fund will award €38 billion to low carbon innovation projects, such as carbon capture and storage or industrial process technologies that reduce emissions.[18]

- **Leadership and guidance:** Spearheading collaboration in areas such as testing and measurement standardization can help accelerate progress by providing the industry with common definitions and frameworks.
  - Example: The US National Institute of Standards and Technology (NIST) created the Low Carbon Cements and Concretes Consortium to evaluate and develop methods to characterize and quantify carbon in low-carbon cements and concretes.[19]

Conclusion

Architects and engineers have a massive opportunity to reduce the carbon footprint of the buildings and infrastructure they design. But they can only do so with the support and collaboration of the clients who commission these structures, the construction firms that build them, the manufacturers that produce the required building materials, and the governments that choose whether and how to regulate and engage in these matters.

Some crucial steps that can be taken to scale low carbon design are outlined below.

AEC firms:

– Conduct whole life-cycle emissions assessments, pilot new low-carbon solutions, and prioritize low-carbon design and construction within their own firms, altering the operating model and culture to fit.

– Collaborate with each other and cement and concrete producers to further low-carbon goals.

Cement and concrete producers:

– Increase the support and education provided to AEC firms.

– Invest in EPD production and scaling up of the supply of low-carbon materials.

Project buyers (both public and private):

– Prioritize low-carbon designs in their requirements, bid selection and design process.

Governments:

– Provide leadership to accelerate progress and incentivize the adoption and innovation of low-carbon solutions.

Much can be achieved if participants across the value chain are willing to step up, contributing their part and working collaboratively. Now is the time to act.

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The authors would also like to thank Bouygues, CEMEX, Global Cement and Concrete Association and its members and affiliates, Mission Possible Partnership and Mott MacDonald for their contribution.

Endnotes

1. IEA, “2020 Energy Technology Perspectives”, 2020, https://www.iea.org/reports/energy-technology-perspectives-2020.
2. Ibid.
3. Global Cement and Concrete Association, 2022.
4. Adam Baylin-Stern and Neils Berghout, “Is carbon capture too expensive?”, IEA, 2021, https://www.iea.org/commentaries/is-carbon-capture-too-expensive.
5. Kate Adlington, “Arup commits to whole lifecycle carbon assessments for all buildings work and withdrawal from fossil fuels from next year”, ARUP, 2021, https://www.arup.com/news-and-events/arup-commits-to-whole-lifecycle-carbon-assessments-for-buildings-and-withdrawal-from-fossil-fuels.
6. Tomohiro Tasaki, Koichi Shobatake, Kenichi Nakajima and Carl Dalhammar, “International Survey of the Costs of Assessment for Environmental Product Declaration”, Procedia CIRP, 2017.
7. Eco Platform, https://www.eco-platform.org/home.html.
8. CEMEX USA, “Portland Limestone Cement: Frequently Asked Questions”, 2022, https://www.cemexusa.com/documents/27329108/59104358/cemex-plc-faq.pdf/18ac7b81-87a3-e815-6d68-4ca2f56e73fe?t=1656362428799.
9. Innis, Al, “Portland-Limestone Cement after 10 years in the field,” CP Road Map, 2018.
10. Gensler, “A Path Toward Net Zero Energy Buildings”, 2019, https://www.gensler.com/gri/genslers-path-to-net-zero.
11. Magnusson Klemenic Associates, “Embodied Carbon Action Plan”, 2022, https://www.mka.com/cms_docs/SE2050_MKA_Embodied%20Carbon%20Action%20Plan%20(ECAP)_2022-05.pdf.
12. First Movers Coalition Cement and Concrete Commitment”, https://www3.weforum.org/docs/WEF_FMC_Cement_Concrete_Commitment.pdf.
13. Industrial Energy Accelerator, “Green Public Procurement, A Campaign of the Clean Energy Ministerial”, https://www.industrialenergyaccelerator.org/the-gpp-pledge/.
14. US census monthly construction spending, 2020.
15. Mission Possible Partnership, “Low-Carbon Concrete and Construction: A Review of Green Public Procurement Programmes”, 2022, https://missionpossiblepartnership.org/wp-content/uploads/2022/06/LowCarbonConcreteandConstruction.pdf.
16. Cushman & Wakefield, “Green Is Good: Sustainable Office Outperforms in Class A Urban Markets”, 2021.
17. Ministere de la Transition Ecologique, “Code of Construction and Housing”, Appendix to Article R172-4, Chapter 2, http://rt-re-batiment.developpement-durable.gouv.fr/.
18. European Commission, “What is the innovation fund?”, 2020, https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund/what-innovation-fund_en.
19. Federal Register, “Low Carbon Cements and Concretes Consortium”, 2022, https://www.federalregister.gov/documents/2022/06/14/2022-12744/low-carbon-cements-and-concretes-consortium.

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