Decarbonising Construction: **BUILDING A LOW-CARBON FUTURE**

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IN COLLABORATION WITH

Deloitte.

CONTENTS

FOREWORD

Carlos Maurer
Executive Vice President,
Shell Sectors and Decarbonisation

The construction industry is vast, providing jobs for over 255 million people globally and revenues for thousands of mainly small and medium-sized companies. It makes up around 13% of the world's economy, enables other sectors to function via the infrastructure it builds, and facilitates security, health and education through homes, hospitals and schools. Construction matters.

The construction sector accounts for 37% of global CO_2 emissions[1], of which 16% represent embodied carbon – CO_2 emissions coming from material sourcing and manufacturing, logistics, and construction activities. This makes it one of the biggest single sectors contributing to global warming. It is vital it decarbonises. The construction sector can also be an enabler of decarbonisation across other sectors through green buildings, renewable energy projects and production facilities for greener products, like electric vehicles.

Shell has set a target to become a net-zero emissions energy business by 2050, with shorter-term goals to ensure progress along the way. As part of this, we are working with customers, governments, and others to help address emissions in different sectors, such as construction. We aim to play a major role in helping the construction sector decarbonise and seek to understand where the opportunities lie and how we can contribute to accelerating progress.

"Decarbonising Construction: BUILDING A LOW-CARBON FUTURE" is the result of our work with Deloitte to shine a light on the challenge of decarbonising construction and offer the industry practical solutions.

I hope this report will serve as a useful tool and framework for construction companies, equipment manufacturers, policymakers, and other stakeholders to come together and accelerate progress on decarbonisation.

Let's build, then, for the future. Starting today.

Raman Ojha
Vice President,
Shell Construction and Road

This "Decarbonising Construction: BUILDING A LOW-CARBON FUTURE" report reflects the voice of the industry, by sharing the views and perspectives of nearly 100 European, North American and Asian construction executives and experts across the value chain.

The report highlights the challenge and opportunity of reducing embodied carbon, as most carbon reduction efforts in construction have been focused on operational carbon. Creating better visibility for embodied carbon and developing dedicated solutions will be critical to decarbonising the sector successfully.

When I read what the industry has to say in this report, I see that there is a great willingness and desire to decarbonise and three things resonate strongly. Firstly, regulations and standards for embodied carbon need to be established to incentivise faster action. Secondly, with emissions coming from construction materials representing the vast majority of embodied carbon in construction, developing low-carbon technologies and alternative materials will be key to reducing the sector's emissions. Lastly, the assets-owners must play a more active role and demand more low-carbon construction solutions in tenders.

The participants to the report made it clear that although the scale and challenge of decarbonising construction is significant, it can be achieved. I am confident that with a combination of innovative solutions, supportive regulation, and more collaboration across the value chain, we can and will accelerate progress to net zero.

Shell aims to be the partner of choice for decarbonising construction. We look forward to working with the industry to drive faster action. Together, we can meet the ambitions of both today and tomorrow.

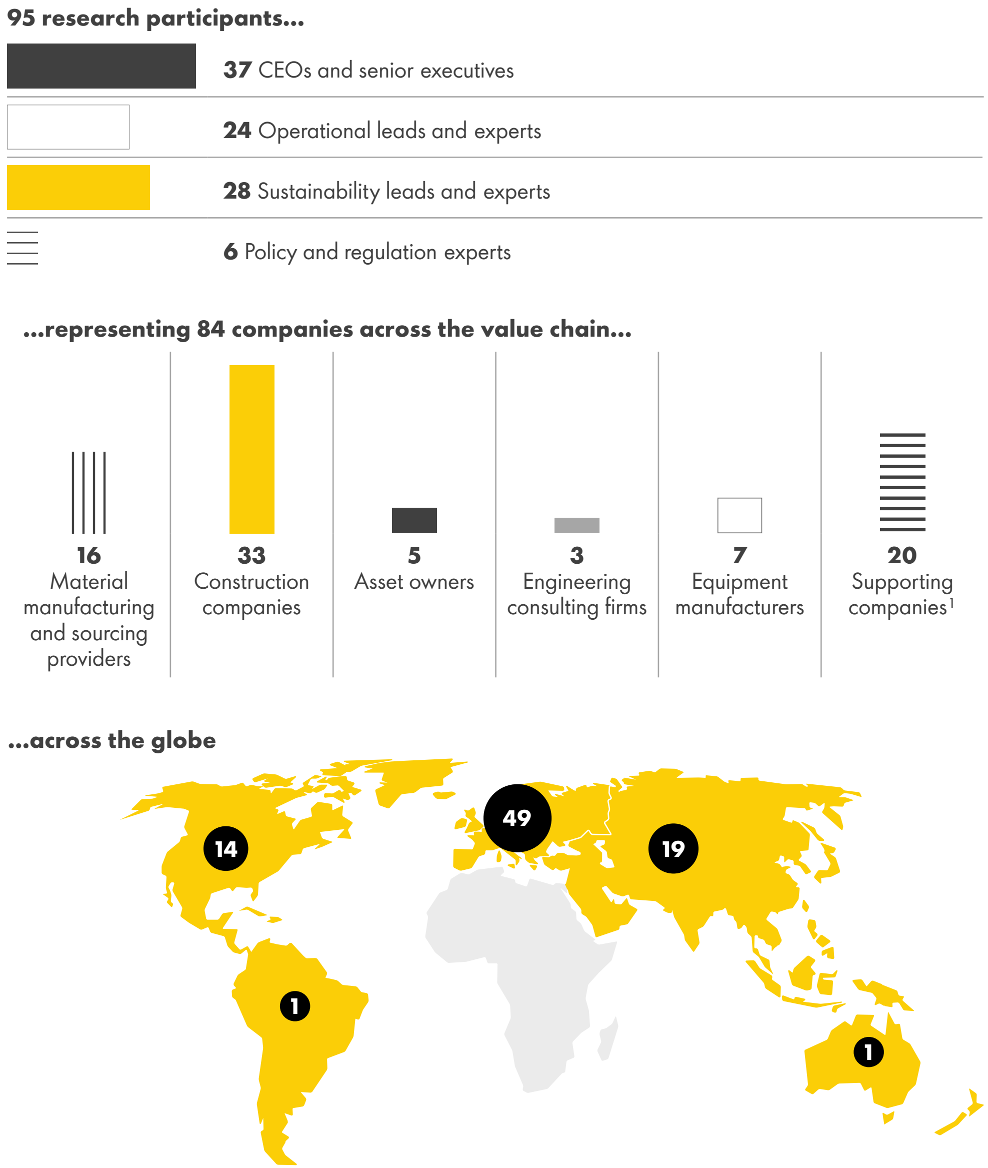
REPORT OBJECTIVES

This report reflects the perspectives of nearly 100 executives and experts, representing 84 organisations across almost all segments of the construction ecosystem and three focus regions (see exhibit 1). It aims to:

- **Take a comprehensive view over the construction value chain, with a dedicated focus on embodied carbon.** Many decarbonisation studies focus on specific challenges or stakeholder groups in isolation. Given the interdependency of factors, the sector needs a more comprehensive view, which includes economic, regulatory and organisational factors.
- **Reflect the voice of the sector.** No one stakeholder group can do this alone, and everyone will have a role to play. It is essential to understand the unique motivations and challenges of different groups and geographies, to develop solutions that will make an impact.
- **Clarify a practical way forward.** Construction leaders who participated in this research are at a point where they need to make decisions around decarbonisation. Working with them to converge on a set of solutions and a blueprint can help the sector act now and clarify the path forward.

This report reflects the insights industry executives and experts shared with us through interviews and working sessions, not the views of Shell or Deloitte. All engagements with participants were conducted in a manner that respects competition law.

Exhibit 1. Research participants



Note: 1) includes e.g. industry associations, financiers

Executive Summary

As a notable contributor to the global economy but also to global carbon dioxide (CO_2) emissions, the construction sector must decarbonise. Historically, the construction sector has been focusing primarily on cost and operational efficiency. If we add to that the complexity of its ecosystem, we will understand better why developing, implementing and scaling low-carbon solutions in construction is so challenging. Deloitte spoke with executives representing companies from the entire value chain of construction. The report "Decarbonising Construction: BUILDING A LOW-CARBON FUTURE" summarises their views on where we are today and what are the biggest barriers to decarbonisation. It also outlines what solutions the industry thinks are needed to help drive decarbonisation and proposes a clear roadmap for reaching net zero.

The consensus among those interviewed for this report – while challenging – the decarbonisation of the sector can be achieved. By scaling up the use of existing low-carbon solutions, developing more alternative materials and technologies, adopting supportive policies and extensively collaborating, the sector can achieve net zero.

Exhibit 2. Research highlights

1	The construction sector accounts for **37% of global carbon emissions**, of which **16% represents embodied carbon** mainly from material manufacturing. Significant carbon reduction needs decisive action now.
2	Applying a segment view, the **infrastructure end market** will likely decarbonise first; across the value chain, **construction equipment** will likely be the first to decarbonise.
3	Several barriers to decarbonisation exist: **ineffective procurement** practices; a **lack of regulation**; **production challenges** for low-carbon concrete and steel; and **no established standards** for data, methodologies and tools.
4	Most of the existing carbon reduction efforts have been focused on operational carbon. Creating **better visibility for embodied carbon** and **developing solutions to reduce it** will be critical.
5	**Asset owners have a leading role to play** to generate demand, kickstart collaboration, and increase investors' confidence to take the **leap of faith** necessary to invest in emerging technology.
6	**Synchronised regulations and standards** for embodied carbon will create the conditions required for action, including consistency on how embodied carbon can be measured.
7	**Low-carbon cement and concrete are within the sector's direct influence**; the focus should be on investment in alternative raw material inputs as carbon capture matures.
8	Demand from other sectors, especially automotive, will **increase the availability of low-carbon steel** and lower the production costs of low-carbon fuels and carbon capture.
9	**Improving workforce capabilities** around sustainable and digital solutions is needed to drive efficiencies.
10	A **system-level approach** is needed to optimise trade-off decisions between costs and carbon emissions.
11	Decarbonisation will be a **catalyst for embedding efficiency** and minimising unnecessary emissions throughout the sector.
12	**Sharing learnings** will help each region accelerate progress towards net zero.

Where we are today

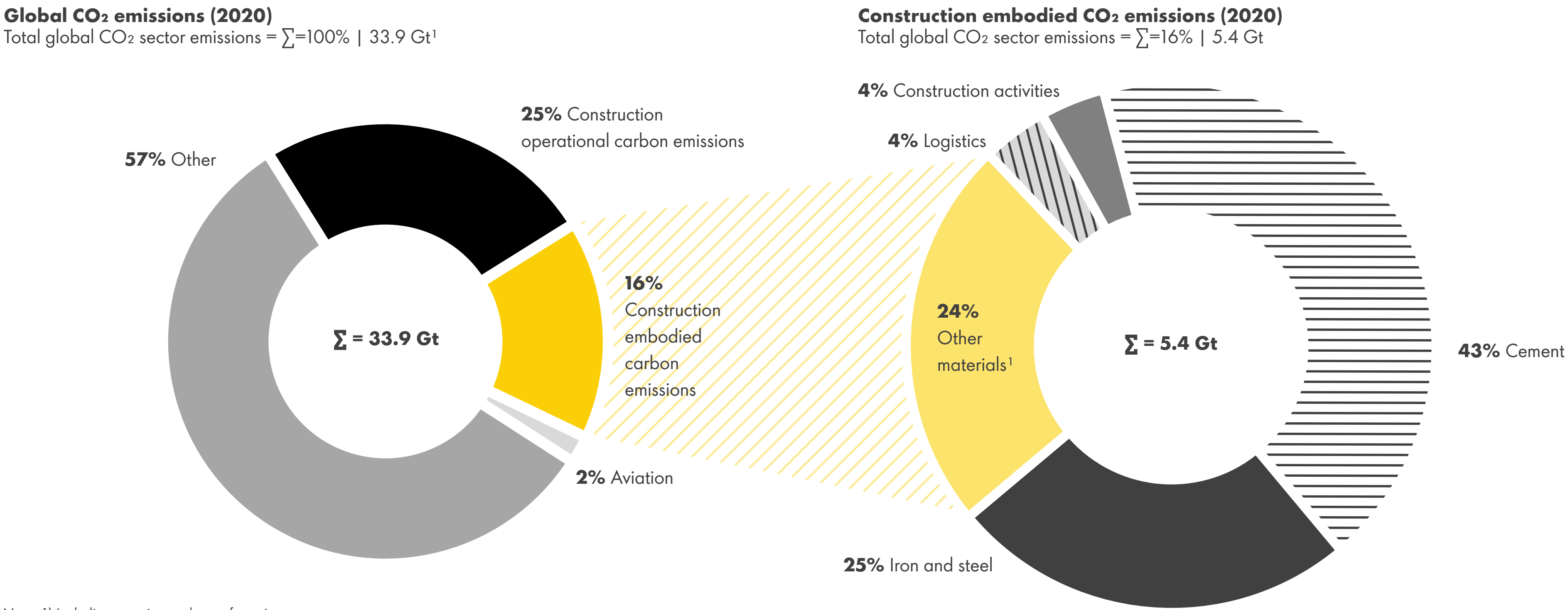
Construction is one of the largest single-sector contributors to carbon emissions. Emissions from the production of construction materials, construction activities and logistics – called embodied carbon – accounted for 5.4 gigatonnes of carbon dioxide (Gt CO_2) in 2020, or 16% of all global CO_2 emissions. If business continues as usual, these emissions are forecast to remain significant beyond 2050. The sector needs rapid action to decarbonise at scale.

Across the construction value chain, the sourcing and manufacturing of materials represents 92% of embodied carbon emissions, with 43% of these attributable to cement, 25% to steel and 24% to remaining materials, such as glass, aluminium, timber and asphalt. While decarbonisation of cement and steel is a priority, it is made harder by relatively high energy intensity, limited renewable energy supply globally, process emissions (for cement) and long asset lifetimes. Construction activities and logistics together account for 8% of emissions – which mostly come from the use of site equipment (e.g. generators or heavy machinery), road freight and shipping.

The focus has been and is on operational carbon because the solutions are available. Now is the time to shift focus to embodied carbon, which is bigger than entire sectors like aviation, and will likely be more complex to solve.

Executive, engineering firm

Exhibit 3.



Note: 1) Including sourcing and manufacturing
Source: IEA and Deloitte analysis

The construction sector can be broken down into three end markets – buildings, infrastructure and industrial projects – all likely to decarbonise at different speeds.

Infrastructure construction projects are likely to decarbonise soonest as they are generally publicly owned and have centralised budgets. The large scale of these projects also makes it easier for them to absorb the higher cost of low-carbon solutions. The **buildings** end market is likely to follow. The drive to decarbonise here is expected to come from large corporations with net-zero emissions strategies and demand from public and residential buyers, who are increasingly aware of the need to decarbonise. The **industrial** end market is expected to be the slowest to change. Large carbon emission footprints from this market's own operations, push embodied carbon lower on its priorities list. Still, some industrial end markets, like big technology firms, are showing signs of being first movers.

Geographically, construction emissions are highest in countries such as **China** and **India**, where economies are rapidly developing and therefore construction volumes are higher. Regulation around embodied carbon in these markets is nascent. More developed economies, such as **the Western and Northern European countries** and the **USA**, have smaller construction volumes on a per capita basis and here regulators are starting to act to restrict embodied carbon. Measures like the Emissions Trading System (ETS) in Europe and new subsidies introduced through the Inflation Reduction Act in the USA show clear signs of progress. There is also a growing sense of optimism in major markets like China, as noted by one interviewee: "China may not have significant regulation around construction today, but like they have shown in other sectors, when they choose to move, they can do so much faster than most western markets."

Barriers to decarbonisation

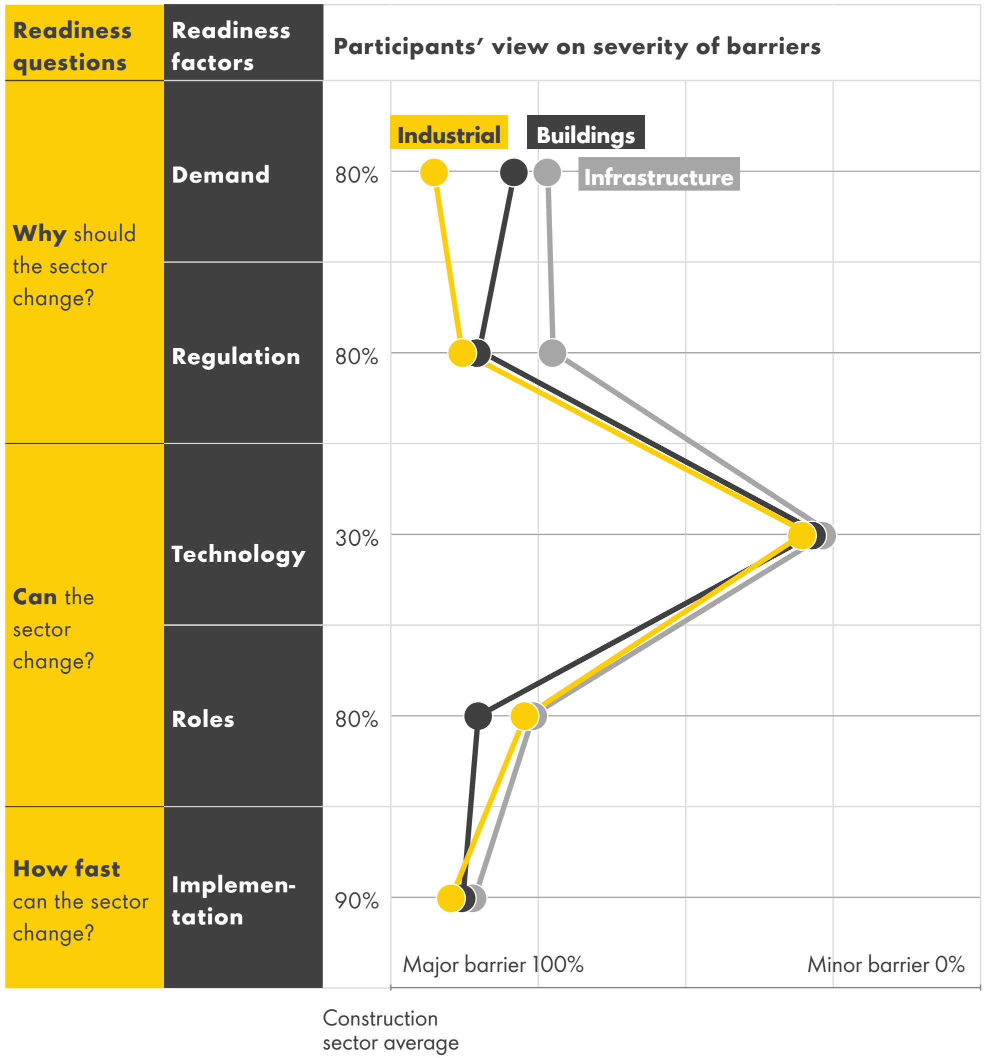
Research participants identified a range of barriers currently inhibiting the sector from decarbonising more quickly (see exhibit 4) with four highlighted as priorities to tackle:

- **Limited market and customer demand**: procurement practices operate in a fragmented market which typically prioritises cost and speed over reducing embodied carbon.
- **Insufficient regulatory incentives**: regulations for construction sub-sectors (e.g. cement and steel manufacturing) and end markets (i.e. buildings, infrastructure and industry) are neither aligned, nor adequate to incentivise action across the value chain.
- **Significant breadth and scale of technology implementation required**: steel and cement are the largest drivers of emissions. Technologies to decarbonise them are available, but require significant capital investment to mature and scale.
- **Lack of harmonised standards:** the lack of consistent definitions, data, methodologies and tools to account for carbon, as well as of a single regulatory body, results in varying interpretations, limiting the ability of market participants to claim outcomes consistently.

Barriers vary according to end market and their intensity is determined by differences in geology, climate, customer preferences, project size and technologies used.

These and other barriers are explored in greater detail in this report.

Exhibit 4. Construction sector decarbonisation readiness



Source: Interviews; Deloitte analysis

Potential Solutions for Decarbonising Construction

The interviews conducted showed that despite multiple barriers, thanks to early adopters, innovators and sustainability-driven asset owners, the global construction sector is already showing early signs of the change needed for decarbonisation.

Governments and financiers are pushing the need to reduce emissions higher up the agenda. Customers are starting to demand more low-emissions projects and construction companies are responding by making commitments and exploring new technologies. More than 80% of interviewees identified decarbonisation as a top three business priority and large construction businesses have committed to reducing emissions. These positive signs are gradually coalescing to accelerate the pace of decarbonisation, but more decisive action is needed to reach net zero.

Construction executives need to define and implement clear decarbonisation strategies, but the road ahead is unclear. What solutions are available already and what is their decarbonisation impact? Which are the easiest to implement? How can companies who have been focusing on operational efficiency turn their attention to instilling a decarbonisation mindset?

> We are seeing new initiatives all over the place, but it feels like there is too much to do, and we don't really know what matters most and where to start.
>
> CEO, building contractor

This research aims to guide the sector's progress on decarbonisation and has resulted in 15 solution themes. While no single solution will be enough, in combination they reinforce each other and create the conditions required for change.

Demand

Activating and aggregating demand for low-carbon products through joint sourcing and coalitions can encourage investment. Increasing awareness around embodied carbon and defining a common language will be foundational to create the momentum for more decisive action. Financiers can also incentivise low-carbon construction by recognising embodied carbon and extending financing schemes that currently certify only operational carbon. Creating scale in customer demand through coalitions and partnerships will give financiers and construction companies the confidence to make investments. Coalitions of financiers would also help these institutions better manage risk and unlock earlier investments.

Regulation

Policies will be key to accelerating low-carbon construction and must address demand and supply simultaneously. On the demand side, policies must incentivise the adoption of low-carbon assets while on the supply side they have to support the investment in more low-carbon construction solutions and technologies. Interviewees agreed that incentives and coercive policies will both be necessary to reduce embodied carbon emissions.

Technology

Technology innovations including renewable energy solutions, energy efficiency solutions and alternative materials are already being deployed in the construction sector.

For example, the vast emissions coming from cement and concrete production can be reduced by investing in low-carbon cement and concrete pathways, such as using more sustainable energy solutions to power the cement and concrete production processes, developing cleaner technologies to produce clinker or reducing the amount of clinker used in cement. To further this effort, carbon capture utilisation and storage (CCUS) is a technology that will need to be developed, and at scale, to further support the industry to achieve net zero.

Solutions to cut emissions coming from alternative materials are also emerging, such as low-carbon asphalt. In the asphalt production phase, the key technologies used to reduce emissions are low-carbon energy to power the asphalt plant and heat the asphalt mixture, replacing the hot-mix asphalt with warm-mix asphalt, or incorporating bio-based binders that have a lower carbon footprint.

Emerging technologies such as more energy efficient methods of creating iron, have proven that low-carbon steel production can be scaled. Scaling up production for low-carbon steel will need financiers, governments and asset owners to invest in processes and infrastructure.

The sector should also develop and adopt more alternative and circular materials, like advanced timber and recycled asphalt. This can be done through investments in R&D, both within the sector, and with adjacent sectors looking to improve circularity.

The roll-out of low-emission equipment is already happening, albeit with a shortage of low-carbon energy supply. Careful planning is needed to create high capacity grid connections and enable construction companies to connect to energy infrastructure onsite.

Roles

New skills, such as carbon data analysis and the development of low-carbon materials, will be needed to advance the technologies required to support decarbonisation. The sector needs to expand and develop new mechanisms to develop talent and increase knowledge and best practice sharing around carbon emissions.

More collaborative decision making across the construction value chain will also improve the adoption of new technologies. Collaboration and public-private partnerships will enable the sharing of both knowledge and risk.

Implementation

Making design and execution more efficient will minimise waste, reducing costs, and lower construction emissions at the same time. Modular design can reduce waste by more than 80% through standardised and repeatable construction methods. By monitoring the execution of projects, construction companies can ensure that planned carbon reductions are being realised in practice.

An update to existing standards for design and materials would release the industry from traditional working practices and allow low-carbon practices to be implemented. This would also enable companies to become agile enough to quickly adopt new innovations as they arise.

The sector also needs to secure an adequate supply of renewable energy. This can be achieved through power purchase agreements with producers or co-investment in new renewable projects. Energy transportation, supply and storage infrastructure needs to be built. Those manufacturing materials or involved in construction processes should consider their location according to the availability of low-carbon energy.

The sector needs to increasingly encourage more systems thinking: a way to consider the trade-offs between emissions, cost, operations, maintenance, and demolition. These systems should include the second-life of assets, components and materials and focus on the re-use and re-purposing of materials, limiting demand for virgin materials.

The Roadmap: Accelerating Decarbonisation in Construction

The 15 solutions identified through this research will all contribute to decarbonising the construction industry and require a phased, incremental approach (see exhibit 5).

- **The short term (2023 – 2030)** is about rapidly adopting and expanding the ready-now solutions and creating the conditions required for investment in longer-term low-carbon alternatives.
- **The medium term (2030 – 2040)** is about taking maturing low- and zero-carbon alternatives like low-carbon cement and steel and beginning to use them in commercial applications across the sector to make meaningful change.
- **The long term (2040+)** is about rapidly increasing adoption and scale of all solutions being deployed by the sector to accelerate towards net zero.

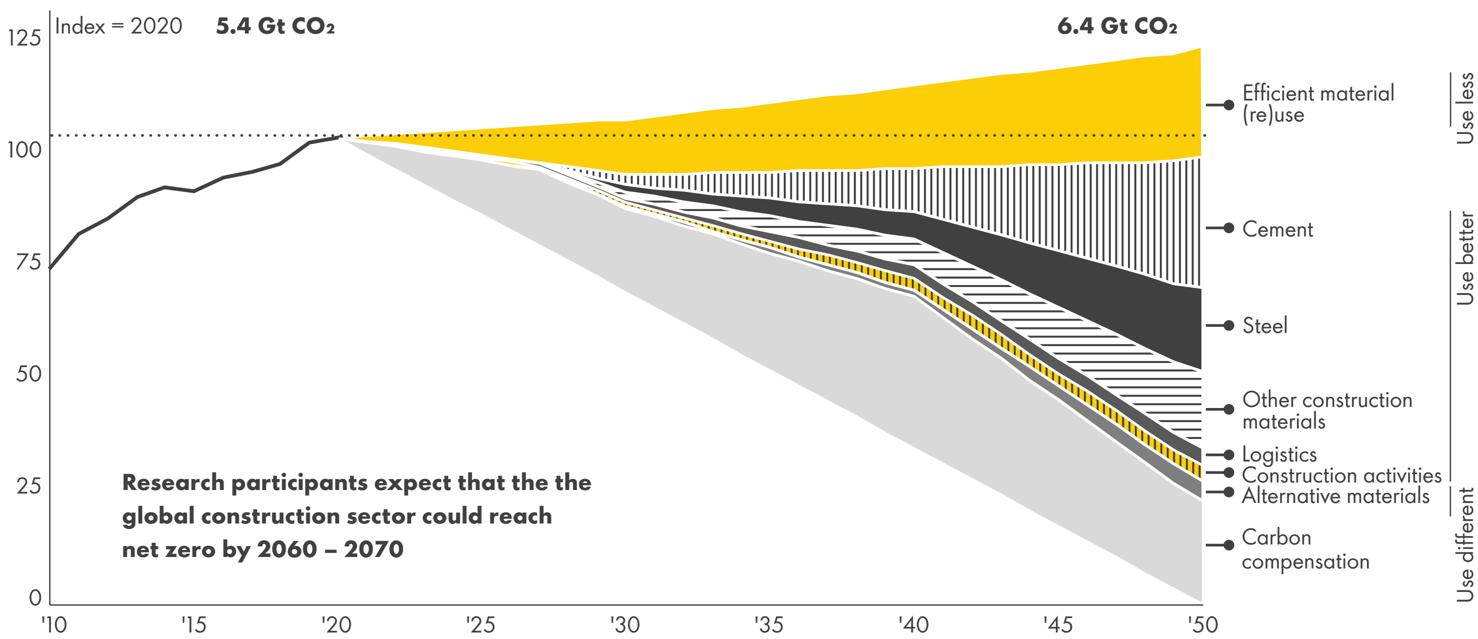
The value chain as a whole must move forward together but different parts of the chain can lead on different solutions. For instance, construction companies can drive efficiency gains, skills and contract models, while manufacturers can make low-carbon materials and equipment available.

The solutions outlined in this report can create the conditions required to start reducing the sector's emissions immediately and gradually accelerate the decarbonisation pace. While progress against this blueprint is likely to move at a different pace across geographies, with Western Europe already putting more strict regulation in place and beginning to invest in low-carbon materials, the industry should capture learnings from these efforts and use them to accelerate progress in slower moving regions.

Based on the views shared by the participants in this research, decarbonising a sector of such scale and complexity will not be easy. However, those we spoke to were optimistic that a net-zero future is possible, with low-carbon solutions increasingly available. Construction leaders recognise the urgency, the opportunities for those who take the lead and the need for more collaboration across the value chain.

This report provides a blueprint to help guide progress and **build a low-carbon future**.

Exhibit 5. Decarbonisation pathway – sector sentiment



Source: Interviews, Deloitte analysis

Exhibit 6. The roadmap for decarbonising construction

Short term (2023 – 2030)

Adopt ready-now solutions and lay the foundation for zero-carbon alternatives

1. Increase awareness around embodied carbon
2. Activate and aggregate demand
4. Adopt policies to stimulate demand for low- and zero-carbon assets
5. Stimulate development of low-carbon solutions through policies
8. Develop and adopt alternative materials
9. Roll-out low-emissions equipment
10. Develop talent and increase knowledge sharing
12. Make design and execution more efficient
13. Update design and material standards

The sector should look for opportunities to adopt medium-term solutions as early as possible while keeping the focus on adopting all ready-now solutions.

Medium term (2030 – 2040)

Expand adoption of lower-carbon alternatives

3. Generate green financing standards and expand investment
6. Invest in low-carbon cement and concrete pathways
7. Scale low-carbon steel production
11. Adopt more holistic contract models and public-private partnerships
14. Secure supply of renewable energy and build distribution infrastructure
15. Increase circularity and systems thinking

As the adoption of lower-carbon alternatives begins to expand, short-term solutions should continue to be strengthened and adopted in markets where decarbonisation is just beginning.

Long term (2040+)

Scale all solutions across regions and end markets

Commitments and incentives should continue to evolve, and technology solutions and required infrastructure should be rolled out at larger scale as demand increases and new use cases become viable.

Where We Are Today

THE DRIVE TO DECARBONISE

The 2015 Paris Agreement set a bold ambition to limit global warming to well below 2 degrees Celsius and strive to limit it to 1.5 degrees Celsius. A key element in pursuing that goal is to achieve net-zero emissions by 2050. To respond to the challenge, countries and companies are setting carbon emission targets and developing plans to reach them. While targets have been set, the challenge is significant and each sector has a key role to play.

Action is needed – and fast. All sectors of the global economy must play a role, however the challenge will be most difficult in the hard-to-abate sectors. These are sectors with long-lived assets that are difficult to electrify, either because of high heat requirements, or the need for dense energy carriers.

Where we are: The construction sector is harder-to-abate, and plays a critical role in modern society.

The construction sector is essential for modern society. It delivers the buildings we live and work in, the roads and bridges that connect us, and the industrial facilities that produce and distribute our energy and goods. In 2020, construction output accounted for around 13% of the global gross domestic product (GDP)[2] and is responsible for the direct employment of more than 255 million people – about 8% of the global workforce[3].

The construction sector can also be an enabler of decarbonisation across other sectors as it will build low-carbon buildings, renewable energy projects and factories for more sustainable products, like electric vehicles.

Decarbonising construction will be particularly difficult because of some unique factors:

- Construction is made up of multiple interconnected sectors. Construction touches many sectors within the global economy, including the majority of the harder-to-abate sectors (see exhibit 3). Zero-emission construction will not be possible until each of these sectors has decarbonised, and each requires a unique set of solutions.
- **It is difficult to create a common view of emissions** in the sector. The interconnectedness of sectors, numerous actors, and complexity of projects make it difficult to measure and attribute emissions. "The baseline is where it starts, but nobody knows it for sure. This tells something about the maturity of sustainability in the construction sector", confirmed one engineering firm's Executive General Manager.
- **Construction is locally organised and operates with low profit margins**. The top 30 global construction companies generate only 17% of their revenue internationally[4]. The sector is full of small local operators who are used as subcontractors for large projects. The local nature of the sector makes alignment of the various subsectors, and achieving the scale required to decarbonise, difficult. Further, the sector's hyper-competitiveness results in low margins (although this varies by project type and region). In 2021, a typical margin on a medium commercial project was 5% in Singapore, 2.5% in London, and 4% in Chicago and Amsterdam.[5] This restricts companies' abilities to invest in new technologies.

CARBON EMISSIONS IN CONSTRUCTION

Where we are: The construction sector's embodied carbon emissions account for more than 16% of global CO_2 emissions but remain relatively hidden.

Calculating the emissions from the construction sector requires an understanding of the overall construction value chain (see exhibit 7), that primarily comprises:

- **material sourcing** and manufacturing, including core construction materials like cement, steel, aluminium, glass and asphalt;
- **construction activities**, including installation, maintenance, repair, deconstruction, demolition and waste processing;
- **logistics**, including the transport of raw materials, finished construction products and waste; and
- **operations**, including maintenance, heating, cooling, lighting and powering of assets once constructed.

Arriving at a total emission number for the sector is complicated. Sources vary with respect to different components included or omitted, for example:

1. **value chain steps**, i.e. material sourcing and manufacturing, construction activities, logistics, and operations;
2. **end markets**, i.e. buildings, infrastructure and industrial assets;
3. **the sector's emission share** in each value chain step, especially when it comes to materials other than cement or steel, e.g. amount of emissions in chemicals manufacturing which can be attributed to construction;
4. **emission types**, i.e. energy and process emissions; and
5. **geographical boundaries**, i.e. which countries are included.

The most commonly referenced figure states the sector is responsible for 37% of global CO_2 emissions[6]. That figure, however, includes 8.6 Gt operational CO_2 emissions from buildings, but excludes 3.2 Gt embodied CO_2 from other end markets (i.e. infrastructure and industrial facilities).

Exhibit 7. Emissions in the construction value chain

This report will focus on the **embodied carbon** emissions of the construction sector. Embodied carbon consists of emissions coming from material sourcing and manufacturing, logistics, and construction activities, including those associated with demolition and waste processing. These emissions conservatively account for 5.4 Gt of CO_2, or 16% of global CO_2 emissions; five times a major sector like aviation.[7]

This report will not focus on operational emissions, which account for 21% of global CO_2, because the solutions are largely known and are being implemented through actions such as insulation improvements and sourcing renewable power for heating. Conversely, embodied carbon emissions are often unnoticed, and are considered by interviewees to be **harder-to-abate** given the value chain complexity and limited existing solutions.

1. **RESEARCH HIGHLIGHT**

The construction sector accounts for 37% of global carbon emissions, of which 16% represents embodied carbon mainly from material manufacturing. Significant carbon reduction needs decisive action now.

Historically, embodied carbon emissions have gone relatively unnoticed given the disconnect between the construction process and broader society and daily users.

> As a society, we focus on the emissions we can see like those from cars and airplanes. We are blissfully unaware of the emissions coming from buildings, infrastructure and industrial projects, let alone the embodied carbon associated with building them.

Head of Sustainability, building contractor

Greenhouse Gas Protocol emission scopes

The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard is a widely used accounting standard to look at a company's emissions. It considers three scopes:

- **Scope 1** – Direct emissions from owned or controlled sources e.g. fuel combustion in company trucks or exhaust gases from steel making;
- **Scope 2** – Indirect emissions from the generation of purchased energy e.g. the carbon emissions from a powerplant that generated the used electricity; and
- **Scope 3** – All other indirect emissions in the value chain, including procured materials, e.g. from upstream/downstream distribution, waste disposal and business travel.

These scopes cover emissions across the value chain of a product, from the perspective of a single producer. For example, in construction the embodied carbon of cement is a scope 3 emission for the construction company, but a scope 1 emission for the cement plant.

Where we are: Construction emissions are primarily driven by material sourcing and manufacturing

As mentioned, the construction sector is comprised of multiple subsectors which supply to a wide range of end markets (see exhibit 8).

The different assets within each end market require different construction methods, materials and equipment, and have different owners. For example, a large infrastructure project, such as a new railway, would require large consortia to provide planning, design and execution, with the government as a typical owner. On the other hand, a simple office building within a municipality would likely be built by a local construction firm, for a private commercial real estate investor.

The construction of buildings accounts for 60% of total global construction spend, infrastructure contributes around 35% and industrial 5%.[8]

Most sector emissions (92%) are driven by the manufacturing and sourcing of materials. This is due to emissions from the chemical processes required to produce materials, the energy intensity of these processes, and the sheer volume of materials required. From an emissions perspective, cement is the largest contributor, followed by iron and steel, and other building materials – such as glass, aluminium, plastics and asphalt. Logistics and construction activities account for 8% of construction emissions. All these materials will require different processes to decarbonise – these processes are further explored in Appendix A – Ways to reduce emissions in construction.

Exhibit 8. CO_2 emissions per end market across the construction value chain – INDICATIVE

● CO_2 emissions (Gt/yr, 2020)[1]

			Material manufacturing and sourcing[2]			Installation, maintenance, deconstruction, waste		
End market	**Segment**	**Asset**	**Cement**	**Iron and steel**	**Other materials[3]**	**Construction activities[4]**	**Logistics[5]**	**Σ**
				Σ 5.0 (92%)				
Buildings	Residential	Houses	1.4	0.7	0.9	0.1	0.1	3.2 (60%)
		Apartments						
	Commercial	Offices						
		Retail						
	Public							
Infra	Wet	Port	0.8	0.5	0.4	0.1	0.1	1.9 (35%)
		Dam						
		Dike						
	Dry	Road						
		Rail						
		Bridges/tunnels						
		Utilities						
		Airport						
Industrial	Heavy	Power	0.2	0.1	●	●	●	0.3 (5%)
	Light	Processing[6]						
			2.3 (43%)	1.3 (24%)	1.4 (25%)	0.2 (4%)	0.2 (4%)	5.4

Note: 1) Emissions allocated to end markets based on spend; 2) Cement, steel and construction activities based on IEA 2020 data; 3) Other materials based on Hertwich et al. Other materials such as aluminium, other metals, glass, other minerals, wood, plastic and rubber, and bitumen; 4) Emissions from equipment and deconstruction, waste and disposal; 5) Including small part logist ics for raw materials; 6) Incl. manufacturing and production, retail and logistics, chemicals, paper and mining, and steel and cement producers;
Source: IEA; Global Status report for Buildings and Construction; Hertwichet al (2019) "Increase carbon footprint of materials production driven by rise in investments"; Eurobitume (2019); Future of construction; Marketline

Where we are: Infrastructure and buildings likely to decarbonise faster than industrial assets

Due to the unique characteristics of each construction end market (ownership structures, materials required, number and complexity of projects, etc.), they differ in terms of their readiness to decarbonise. Readiness can be assessed using factors like demand, regulation, technology, roles, and implementation (exhibit 9). These factors are used again to assess the barriers to decarbonise the sector, and the solutions which will be required to address them.

Infrastructure projects are likely to decarbonise soonest. This is partly because many infrastructure projects are developed by governments who are able to take a wider set of factors into account than purely commercial enterprises, and whose procurement policies increasingly contain emissions reduction targets. Infrastructure projects also typically have bigger and more centralised budgets than building projects, which makes it easier to absorb the additional cost of carbon reduction measures. As noted by an Operations Lead at an engineering firm: "Pushed by the government, HS2*, which is one of the largest infrastructure projects in Europe, is planning to reduce embodied carbon emissions, by leveraging its purchasing power to drive development of lower-carbon concrete."

> We cannot imagine that we will be creating clean green energy from an offshore wind turbine that is made out of traditional high-carbon steel and cement if low-carbon versions are available.

Sectoral banker

Buildings projects are expected to decarbonise more slowly than infrastructure. Spending is less centralised than infrastructure with a wider range of smaller players. This means more players will need to change in order to make an impact. Building owners can be further broken down into residential commercial, and public buildings. These segments have different ownership structures which influence their ability to decarbonise.

Commercial and public segments are expected to decarbonise faster than residential, as large companies and governments behind these projects have higher drive to decarbonise, given their commitment to emission targets.

For the residential segment, interviewees believed that individual homeowners lack awareness around embodied carbon. As an executive of a residential building developer said, "Except for a very, very small segment, we see the home buyer as uninformed on embodied carbon." This does vary by segment within residential buildings. For example, interviewees also observed that investors and developers are placing increasing importance on environmental, social and corporate governance (ESG) ratings, as it is a prestige benefit for premium housing.

Industrial end markets have focused nearly all effort to date on constructing assets which are cheaper to run and maintain in order to lower operating costs which often represent the majority of the lifetime cost of the asset. Embodied carbon has not yet become an important factor for these asset owners, as an interviewee from a large engineering, procurement and construction (EPC) contractor noted: "For our industrial clients, operational emissions are more than 90% of the total lifecycle emissions of a plant, so that is their first and foremost priority." However, this perspective could change as more low-carbon industrial projects are commissioned. For example, renewable power facilities such as wind and solar farms increase awareness around the materials and processes used to construct them, simply through the principle of what they stand for.

2. **RESEARCH HIGHLIGHT**

Applying a segment view, the infrastructure end market will likely decarbonise first; across the value chain, construction equipment will likely be the first to decarbonise.

* HS2 is Britain's new high speed rail line being built from London to the North-West of the UK.

Exhibit 9. Construction end market characteristics

	1. Demand Asset owner focus on embodied carbon	**2. Regulation** Policies incentivising asset owners to lower carbon from materials and equipment	**3. Technology** Clarity on technology options to reduce embodied carbon	**4. Roles** Degree of concentration of owners	**5. Implementation** Common standards, data and methodologies for asset owners	**Decarbonisation readiness**[1] High level assessment
Buildings	**Emerging** demand in specific segments, e.g. commercial brand offices; increasing real estate investor focus on **ESG** criteria	**Emerging** embodied carbon regulations for asset owners in select geographies; main focus still on operational carbon	**Partially aligned** across end markets on main options to reduce embodied carbon, less so on how to implement and scale these	**Fragmented** across many owner segments, with some concentration in real estate portfolio owners and large corporate owners	**Limited** (global) alignment on standards, databases or methodologies to calculate embodied carbon in assets, and make better design and operational choices	●◐○○○
Infrastructure	**In place**; governments typically the owner, who apply country wide CO_2 commitments in procurement	**Emerging** embodied carbon regulations for asset owners in select geographies		**Somewhat concentrated**, with government as typical owner and larger scale projects enabling cost absorption		●●◐○○
Industrial	**Limited**; main focus on operational carbon, less so on embodied	**Limited**; embodied carbon regulations to be developed		**Somewhat concentrated**, since industrial companies often work internationally, and build on designated industrial areas		●○○○○

Impact on readiness

High | Neutral | Low

Note: 1) 5 full circles equals easy to decarbonise relative to other end markets, 0 stars equals hard to decarbonise relative to other end markets
Source: Interviews; Deloitte analysis

Where we are: Construction activities and logistics have a higher readiness to decarbonise than manufacturing of cement, steel and other building materials

Like the different end markets of construction, the subsectors which participate in the sector show different levels of readiness to decarbonise because of their unique characteristics (exhibit 10).

A detailed summary of the drivers of emissions for each of these subsectors, and the decarbonisation options available for each can be found in Appendix A – Ways to reduce emissions in construction.

Cement is the key ingredient in concrete, the world's most-used building material[9]. As one academic explained: "Concrete offers strength and versatility that other materials cannot offer. Cement originated as the binder in concrete, because it's cheap, useable and available en masse." Cement typically represents ~90% of the carbon footprint from each cubic metre of concrete. The cement sector accounted for 2.3 Gt CO_2 emissions in 2020, or 43% of embodied construction emissions. The emissions from the traditional cement production process, combined with long asset lifetime of plants and the low cost and margins around traditional cement make it harder to decarbonise.

Steel is a key component for construction and is used, for example, in structural elements, reinforced concrete, pipelines and train tracks. More than half the steel produced globally (52%) is used by the construction sector[10]. Steel accounted for 1.3 Gt CO_2 emissions in 2020, or 24% of construction emissions. Overall, the difficulty for steel to decarbonise is moderate. Demand for low-carbon steel is emerging, but steel has long asset lifetimes and limited availability of the low-carbon energy required to fully decarbonise production. As mentioned by a steel executive: "Steel is considered harder to decarbonise, but if you think about it, there are only about 550 plants globally so it should be doable if we focus our efforts on this limited number of plants".

Other construction materials include glass, aluminium, plastic, rubber, wood, minerals and bitumen, amongst others. They accounted for 1.4 Gt CO_2 emissions in 2020, or 25% of construction emissions. For some of the subsectors like glass and aluminium, decarbonisation will be challenging because of their energy intensity (require more renewable energy, and higher costs) and lengthy plant lifetimes. Other subsectors like bitumen are dependent on fossil-based material sourcing, although they are developing bio-based alternatives. In contrast, subsectors like timber are less carbon intensive by nature. However, they are limited in availability. On average, these other construction materials' producers have more incentive to decarbonise compared to cement and steel. This is largely because many of these materials are also used in other markets, like fast-moving consumer goods, where the sectors producing them face greater social pressure to reduce emissions.

Construction activities generate emissions mainly through equipment running on internal combustion engines or generators. Construction activities accounted for 0.2 Gt CO_2 emissions in 2020, representing 4% of global construction emissions. They are likely to decarbonise faster than construction materials. Construction activities have a moderate clarity on roles and decision making, since the equipment manufacturers market is relatively concentrated globally. However, despite similar decarbonisation options as road freight, a key difference is that construction equipment charging or refuelling infrastructure must be onsite (often in remote locations), as opposed to being installed in a fixed location like a highway petrol station. Installing infrastructure to each site is more prohibitive than shared infrastructure. Overall, the readiness to decarbonise is relatively high for construction activities, given the understanding of the technology options and the relatively short lifespan of construction equipment.

In **logistics**, most emissions originate from road freight and shipping to transport materials and equipment to and from construction sites. Overall, logistics accounts for 0.2 Gt CO_2 emissions (2020), equivalent to around 4% of embodied construction emissions.

Road freight emissions occur from raw materials logistics, distribution of building materials, such as concrete, to the construction site, and disposal of waste. Overall, the readiness to decarbonise is relatively high for road freight due to emerging customer demand, regulatory incentives, alignment on decarbonisation options, and relatively short asset lifespan.

Shipping emissions come primarily from vessels doing raw material logistics and from the distribution of building products to construction sites. Steel trade, for example, often relies on shipping due to the weight associated. Due to the lack of alignment on future fuels and relatively long asset lifetime, the readiness to decarbonise is lower than for road freight.

Where we are: Growth of carbon emissions from construction expected to slow, driven by reduced demand from China

The International Energy Agency (IEA) forecasts that growth in cement and steel production will slow considerably towards 2050, which will also impact the growth rate of embodied carbon emissions in construction. This is a direct consequence of material demand from China, India and other Asia Pacific countries reducing as they further develop. While material consumption in the emerging economies of the Middle East, Africa and Latin America is expected to grow, this will be comparatively smaller.

Exhibit 10. Construction subsector characteristics

<table>
<tr><th colspan="2"></th><th>1. Demand
Ability to capture green premiums in end markets</th><th>2. Regulation
Regulations enforcing lower emission manufacturing</th><th>3. Technology
Clarity on technology options to reduce carbon</th><th>4. Roles
Degree of concentration of suppliers</th><th>5. Implementation
Asset lifetime and required infrastructure</th><th>Decarbonisation readiness[1]
High level assessment</th></tr>
<tr><td colspan="2">Cement</td><td>Limited; nearly all cement directed to the construction sector, with primary focus on costs</td><td rowspan="3">Emerging; carbon taxes applicable in select geographies, e.g. Emissions Trading System (ETS) in the EU and other selected regions</td><td>Partially aligned (alternative fuels, alternative materials CCUS)</td><td>Concentrated; top 10 covers 29% of global production; ~3,600 plants total</td><td rowspan="3">Limited; substantial asset lifetime decreases opportunities for change, and extensive supply of infrastructure for renewable energy needed</td><td>●●○○○</td></tr>
<tr><td colspan="2">Iron and steel</td><td>Emerging demand for low-carbon steel from automotive end market</td><td>Aligned (CCUS or DRI)</td><td>Concentrated; top 10 covers 27% of global production; ~550 steel plants total</td><td>●●●○○</td></tr>
<tr><td colspan="2">Other construction materials</td><td>Emerging demand for lower carbon aluminum, timber etc. from consumer-facing sectors</td><td>Aligned (electrification, alternative fuels)</td><td>Concentrated; industry characteristics assumed to be similar to steel</td><td>●●●○○</td></tr>
<tr><td colspan="2">Construction activities</td><td>Emerging demand from urban sites that require low emissions in general</td><td>Emerging; regulation is being developed in selected regions</td><td>Aligned (electrification and alternative fuels), largely following road freight</td><td>Somewhat concentrated; top 10 contractors cover <20% market; top 10 equipment manufacturers cover 70% of the market</td><td>Favourable; shorter asset lifetime, but charging infrastructure required</td><td>●●●◐○</td></tr>
<tr><td rowspan="2">Logistics</td><td>Road freight</td><td>Emerging demand from consumer-facing sectors, as road freight is close(r) to end customers</td><td>In place; regulations to increase vehicle efficiency in place and growing in many regions</td><td>Aligned and partially in place (electrification and alternative fuels)</td><td>Somewhat concentrated; top 6 truck manufacturers account for 50% MDTs[2]; ~3 million truck owners, ~63m vehicles</td><td>Favourable; shorter asset lifetime, infrastructure being built</td><td>●●●●○</td></tr>
<tr><td>Shipping</td><td>Limited</td><td>Emerging; the EU plans to include maritime in the new ETS</td><td>Not aligned (ammonia, methanol, liquid H_2)</td><td>Somewhat concentrated; top 10 ship owners cover <20% of the global capacity; top 10 ship builders cover 60% of the market</td><td>Somewhat favourable; substantial asset lifetime, but high concentration in port infrastructure</td><td>●◐○○○</td></tr>
</table>

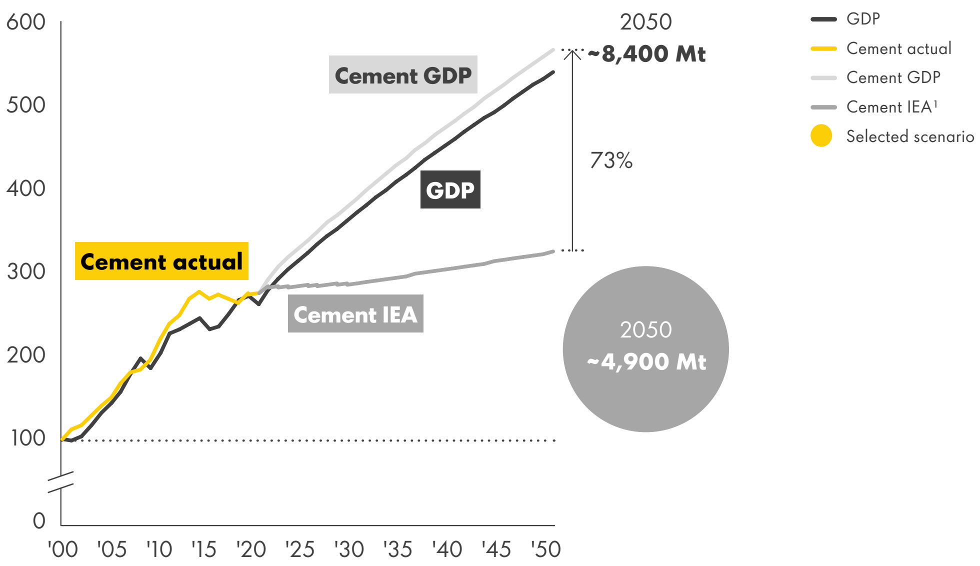
Impact on readiness

High (dark) | Neutral (light grey) | Low (white)

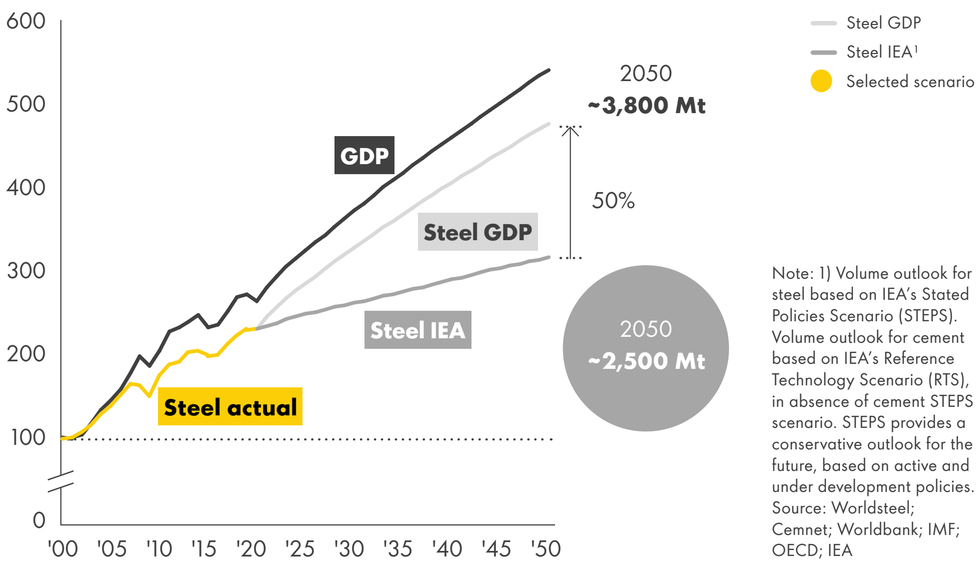
Note: 1) 5 full circles equals easy to decarbonise relative to other subsectors, 0 stars equals hard to decarbonise relative to other subsectors; 2) Medium-duty Truck
Source: Interviews; company websites; Deloitte analysis

Exhibit 11.

Cement demand development outlook (Mt, 2000 = 100)



Steel demand development outlook (Mt, 2000 = 100)



Note: 1) Volume outlook for steel based on IEA's Stated Policies Scenario (STEPS). Volume outlook for cement based on IEA's Reference Technology Scenario (RTS), in absence of cement STEPS scenario. STEPS provides a conservative outlook for the future, based on active and under development policies.
Source: Worldsteel; Cemnet; Worldbank; IMF; OECD; IEA

Where we are: Magnitude of construction emissions requires the sector to act urgently and at scale, to achieve net zero in 2050

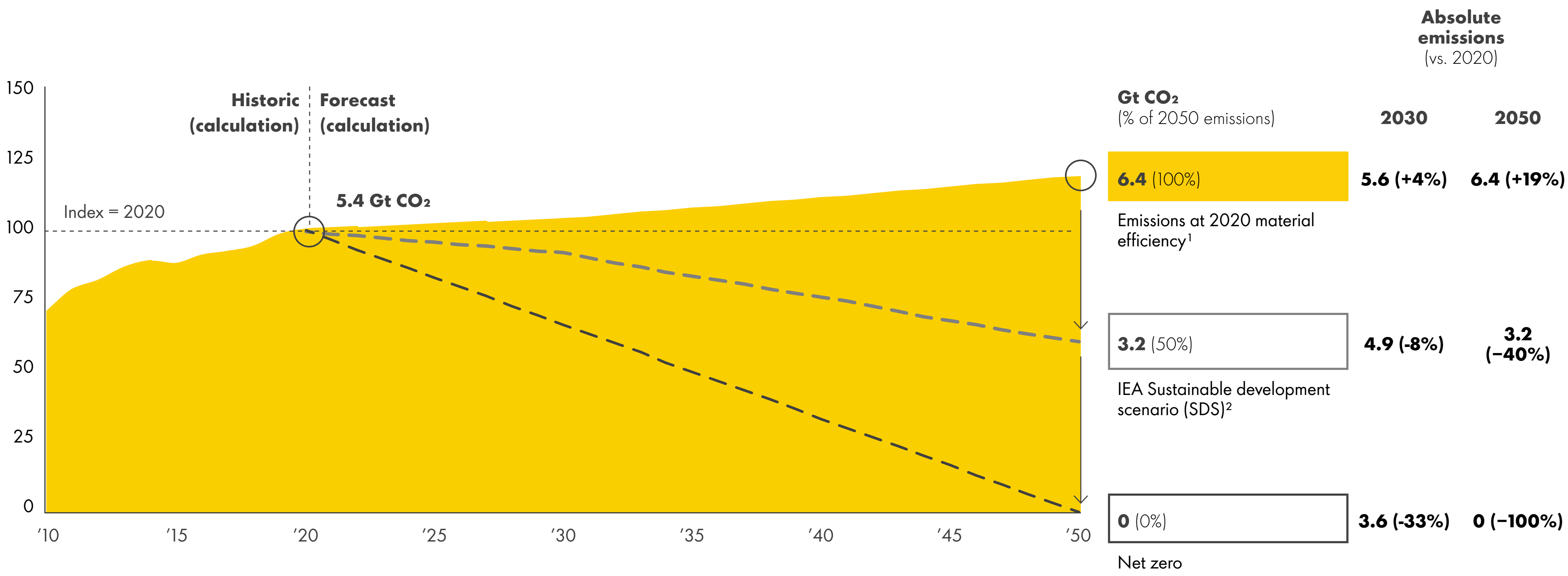
While the growth of construction volumes is expected to slow, the construction sector's emissions could rise to 6.4 Gt CO_2/year in 2050 if we continue business as usual (see exhibit 11), based on projections for material demand and assuming a broadly unchanged intensity of carbon emissions.

This growth rate leading up to 2050 is relatively low (19%) when compared with other high growth sectors like aviation (114%)[11]. Despite this, the absolute value of construction emissions will remain high between today and 2050. Additionally, interviewees noted the complexity to decarbonising the construction sector relative to other hard-to-abate sectors due to the lack of a single global regulatory body like those that exist in shipping (International Maritime Organization – IMO) and aviation (International Air Transport Association – IATA), in addition to the other characteristics explored in this chapter. Although this is a rather pessimistic view, it is also a stark reality check for the sector that more and faster action is needed. Summarised by an engineering firm's Chief Environment Officer: "Bending the curve of embodied emissions in this sector is monumental, as we still have to start on it."

Decarbonisation targets and pathways are already available for some subsectors. For instance, the Global Cement and Concrete Association sets out a roadmap for net-zero cement production by 2050 and the World Steel Association advocates[12] limiting global warming to below 2 degrees Celsius by 2050. However, reaching these targets is not a given. **Decarbonising construction requires coordinated action, at scale, today**.

> If the world is really going to decarbonise construction, everyone and every country needs to have a roadmap that they follow.
>
> Materials manufacturer

Exhibit 12. Global construction carbon emission development (Gt, 2020 = 100)



Note: 1) Steel emission forecast is calculated with emission intensity ('20) and IEA STEPS volume forecast. Construction's share of 54% global steel consumption (2020) kept constant. Cement emission forecast is calculated with emission intensity ('20) and IEA RTS volume forecast. Other materials and equipment are extrapolated based on current emission intensity and future cement production; 2) Total emissions for cement and steel for 2030 and 2050 reported in SDS. Other materials emissions scaled based on steel emission intensity development. Logistics and construction activities scaled based on road freight emission development.
Source: Worldsteel; Cemnet; Worldbank; IMF; OECD; IEA.

Barriers to Decarbonisation

DECARBONISATION READINESS FACTORS: SUMMARY

This research used a systematic approach to assess the readiness of the construction sector to decarbonise, using three core decarbonisation readiness questions and five readiness factors (see exhibit 13). It looks at decarbonisation through a comprehensive, sector-wide lens and examines barriers to break down the challenge into manageable components.

From an end market perspective, the severity of barriers can vary depending on differences in customer preferences, project size and technologies used.

In many respects, the barriers to decarbonisation are common across the world. Globally, material and design standards remain unaligned and technologies for low-carbon cement and steel are yet to be developed at scale. Yet, there are also geographical nuances. Demand and regulatory incentives for low-carbon construction are emerging in Europe but remain less developed in many other markets. While the measures in Europe are still considered insufficient by the interviewees, they show that some markets are shifting faster than others. More regional differences are highlighted in Appendix B – Regional Differences.

Exhibit 13. Sector decarbonisation readiness framework

Readiness questions	Readiness factors	Description
Why should the sector change?	**Demand**	Pressure and incentives from customers, investors, financiers etc. which creates motivation to decarbonise
	Regulation	Instruments applied by regulators and governments to accelerate change
Can the sector change?	**Technology**	Alignment on technical and commercial feasibility of alternative materials and lower emission technologies
	Roles	The ease in making decisions, clarity on roles and responsibilities, and alignment of priorities for key stakeholder groups
How fast can the sector change?	**Implementation**	What it takes to replace or upgrade the sector at scale, people, processes, equipment, energy, materials supply, etc.

Overall, construction's readiness to decarbonise is relatively low, with four main barriers identified by research participants:

- **Limited market and customer demand:** procurement practices operate in a fragmented market which typically prioritises cost and speed. This is particularly felt in the buildings and industrial end markets, but less so in infrastructure, where public sector decision-makers are able to take a wider set of factors into account.

- **Absence of regulatory incentives:** regulations for construction subsectors (e.g. cement and steel manufacturing) and end markets (i.e. buildings, infrastructure and industry) are not aligned, nor adequate to incentivise action across the (global) value chain.

- **Breadth and scale of technology implementation is significant:** the production of low-carbon construction materials, such as cement and steel, is constrained by multiple techno-economic factors, like major capital expenditure, availability of raw material substitutes, access to renewable energy and immature CCUS infrastructure.

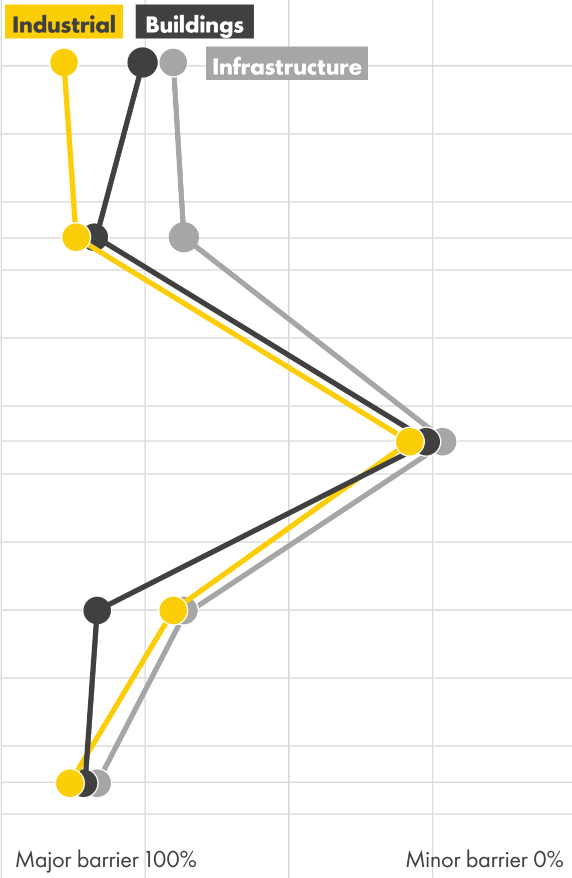
- **Lack of harmonised standards:** the lack of consistent definitions, data, methodologies and tools to account for carbon, as well as of a single regulatory body, results in varying interpretations, limiting the ability of market participants to claim outcomes consistently.

While these four barriers were most frequently mentioned, interviewees also identified a range of other barriers across the readiness factors (exhibit 14). These are explored in greater detail in the following section.

3. RESEARCH HIGHLIGHT

Several barriers to decarbonisation exist: ineffective procurement practices; lack of regulation on both supply and demand sides; production challenges for low-carbon concrete and steel; and no established standards for data, methodologies and tools.

Exhibit 14. Construction sector decarbonisation readiness



Readiness questions	Readiness factors	Participants' view on severity of barriers	Main barriers	End-market: Build	End-market: Infa	End-market: Ind.
Why should the sector change?	**Demand**	80%	Design and procurement decision criteria prioritise cost and speed.	Major	Moderate	Major
			Financiers are reluctant to invest in uncertain new technologies with unclear payback periods.	Moderate	Moderate	Major
	Regulation	80%	Regulations do not incentivise action across the value chain and are lagging in markets with the highest production emissions.	Major	Major	Major
			Regional variations in regulations and standards limit investment at scale.	Moderate	Minor	Moderate
			Outdated standards slow adoption of new technologies and practices.	Moderate	Moderate	Moderate
Can the sector change?	**Technology**	30%	Low-carbon cement challenged by process emissions, scarce material substitutes, limited access to alternative fuels, and immature CCUS.	Minor	Minor	Minor
			Low-carbon steel challenged by immature CCUS, raw material scarcity, and high costs of renewable energy.	Minor	Minor	Minor
			Limited adoption of alternative building materials.	Minor	Minor	Minor
	Roles	80%	Focus on individual projects limits scale and long term commitment.	Major	Moderate	Moderate
			Expertise around low-carbon practices is limited to a few large companies.	Moderate	Moderate	Moderate
How fast can the sector change?	**Implementation**	90%	Inconsistent definitions, data, frameworks and tools limits ability to compare and claim decarbonisation outcomes.	Major	Major	Major
			Construction is a conservative sector where there can be a reluctance to adopt new technologies and practices.	Moderate	Moderate	Moderate
			Enabling production and distribution assets for alternative fuels and carbon capture not at scale yet.	Major	Major	Major

Construction sector average

Revelance
- Major
- Moderate
- Minor

Source: Interviews; Deloitte analysis

DEMAND

One of the primary considerations for any decarbonisation initiative is who will pay for it. 80% of interviewees indicated neither owners nor financiers are currently willing to pay a low-carbon premium for lower-embodied carbon assets (exhibit 15). Asset owners are inclined to minimise construction costs and focus on lowering operating costs over time. The focus on lowest costs extends across the value chain, from engineers to contractors and materials providers. As a result, low-carbon construction activities and materials struggle to secure investment.

The infrastructure end market is slightly more advanced in this area than the buildings and industrial end markets. This is for two main reasons: first, the embodied emissions in infrastructural assets are proportionally larger than the operational emissions; second, the assets are often owned by the public sector – where design and procurement decision criteria are often broader than purely cost.

Industry perspective: Design and procurement decision criteria prioritise cost and speed

Current construction design and procurement practices tend to prioritise the project's cost and speed of implementation, and as a result decarbonisation criteria are not usually considered. Even when lower emissions are taken into account at the start of a project, for example in the design or material supply decision making, too often the full lifecycle emissions are disregarded.

Construction is a competitive, low-margin sector with relatively low barriers to entry and many players across a fragmented value chain. As such, cost and timeliness remain the two largest differentiators, and risk management is key.

Non-financial objectives such as a reduced carbon footprint are seldom prioritised. In the design stage, lifecycle carbon trade-offs are rarely measured. Emissions reductions at one point in the value chain can lead to higher emissions during other stages. In the absence of Lifecycle Assessments (LCAs), these decisions reportedly lack a detailed consideration and understanding of the implications. As noted by one building developer's Head of Sustainability: "At the end of the day, it comes down to cost. If I think the customer will pay for it, I will add it, otherwise it is not worth it for me".

> Contractors don't seem to be driven by whether a premium material needs to be replaced twice or ten times in a building's lifetime; they seem focused on initial price.
>
> Sustainability Director, engineering firm

For those projects in which carbon requirements are articulated at the start of the project, it is commonly observed that the focus is not consistently maintained between the design and the execution of the project. This is particularly the case when capital is constrained or timelines are not met. In the words of a building contractor executive: "We always start a project with good intentions to reduce the carbon footprint, but when reality hits, I have to choose based on costs."

Exhibit 15.

INTERVIEW INSIGHT

80%

Research participants believed that the subsectors and financiers are unwilling to pay a 'low-carbon premium' to lower embodied carbon.

Interviewees noted increasing examples of carbon-related criteria in procurement. However, these tend to be limited and are often seen as a formal box-ticking exercise only. As a result, contractors bidding for projects rarely push the boundaries of what is possible as investments in more sustainable propositions are not seen as a genuine differentiator. As noted by one industrial EPC executive: "There are sustainability criteria, but there is no benefit to us surpassing them. The client wants what they have asked for and are not going to reward us for being more sustainable if it impacts costs".

Industry perspective: Financiers are reluctant to invest in uncertain new technologies with unclear payback periods

Financiers, investors, and insurers have been reluctant to finance the early investments required to develop new technologies at scale. This is because many of the technologies remain unproven, or the future returns are uncertain. While venture capital and government R&D grants have a role to play, traditional financiers are needed to provide the scale of capital required to enable the decarbonisation of the sector.

Technologies like carbon capture, utilisation and storage (CCUS), new cement processes and steel plants will require significant capital investment before they are available at scale. For example, switching just one average European steel plant to green hydrogen would require €3.3-7 billion[13]. These technologies remain either immature or more expensive than the solutions used today. As long as technology risk remains high, or there is uncertainty around customer willingness to pay for low-carbon construction, financiers will likely remain reluctant to provide significant capital. As noted by one banking executive "We cannot finance an asset that I am not sure will be able to pay off its debt. We take risks, but we are investing with people's savings and pensions so that risk needs to be well understood, and we do not feel that many of these solutions are well understood today."

This uncertainty is more pronounced for low-carbon steel than low-carbon cement. To lower emissions, cement producers can start by applying incremental improvements in fuels and raw materials used that are relatively well known to the industry. On the other hand, low-carbon steel has larger uncertainty around the high capital investment needed to overhaul existing assets, the viability of technology pathways and the ability to secure a supply of hydrogen. This makes financiers reluctant to take on such a complex, high-risk investment.

Investors and financiers are beginning to offer low-carbon incentives to their customers, such as discounted mortgages for energy-efficient homes, but they have yet to do this for embodied carbon. Like with customer demand, awareness around embodied carbon needs to be elevated with financiers to ensure it gets the focus it needs to better understand the associated risks and unlock capital.

REGULATION

Exhibit 16.

INTERVIEW INSIGHT

80%

Research participants believed that a lack of regulatory incentives for end-markets and subsectors is a key barrier to decarbonisation.

Construction is a complex sector to regulate due to the wide range of asset types, multiple subsectors, and unique local geographical characteristics. 80% of interviewees said the absence of adequate regulatory incentives was a major barrier to decarbonisation (see exhibit 16). They called for more consistent, updated and aligned regulations for supply and demand, with more clarity around how policy would evolve over time.

The infrastructure end market is challenged less by regulatory incentives than buildings and industrial assets are. This is because infrastructure like roads and railways are more homogenous across regions and use similar materials. For example, although the USA varies in topography and climate, 94% of its roads are paved with asphalt.[14]

Industry perspective: Regulations do not incentivise action across the value chain and are lagging in markets with the highest production emissions

The industry's subsectors and end markets lack regulations that incentivise decarbonisation of both supply and demand in parallel. This makes suppliers hesitant to invest large sums because there is no clarity on sufficient demand and therefore a return on investment. Furthermore, uncertainty about how long policies will last adds to hesitancy to invest. These challenges are exacerbated by the fact that construction emissions are currently concentrated in areas where the regulatory landscape is more nascent.

In the absence of sufficient regulation, a value gap arises between the cost of producing low-carbon materials and energy and the market price for which they can be sold. By way of illustration, producers of low-carbon steel will have higher costs per tonne of steel versus conventional producers. This is a result of investments required to overhaul assets and increased operating costs in order to adopt low-carbon energy carriers. A low-carbon steel bridge would therefore be more expensive for infrastructure owners than a traditional one.

Updated policies for both end markets and subsectors are needed to bridge the value gap.

Policies for end markets are needed to stimulate demand for lower-embodied carbon assets and materials. However, interviewees noted that these policies, such as subsidies, tax incentives and directives, do not currently go far enough, and are mainly focused on operational carbon (e.g. energy labels for buildings).

Policies for construction subsectors are also needed to stimulate the supply of new materials, lower-carbon equipment and logistics. However, commonly deployed instruments such as the Emissions Trading System (ETS) and carbon taxes are not yet stringent enough to cover the value gap between traditional materials and more expensive low-carbon options. For example, the EU ETS in the construction sector predominantly comes down to cement and steel manufacturing, which have extensive free allowances and relatively low prices relative to the abatement costs.

While some markets are showing signs of change, regulation is currently mostly nascent in geographies where construction volumes – and thus emissions – are largest (see exhibit 17). EU nations were seen by interviewees as having the most mature regulations around embodied carbon. This is due to examples like mandatory Lifecycle Carbon Assessments (LCAs) in markets like France, the Netherlands, Denmark and the UK, the EU's ETS, and regulations around construction equipment in Norway.

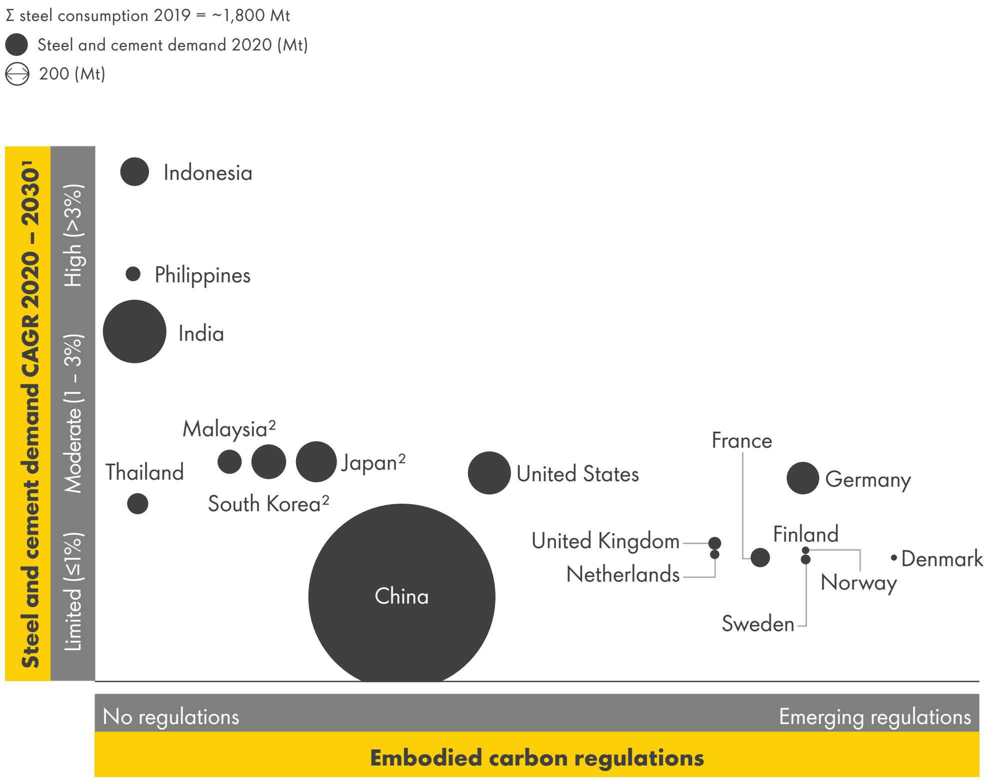
> We need a stick or a carrot; we don't have either of these.
>
> CEO, material supplier

Interviewees noted that regulation around embodied carbon was still nascent in China and India. While both countries have set net-zero targets (2060 and 2070 respectively), there is limited regulation in place today. To realise a meaningful emission reduction in the construction sector, regulation will be needed across all geographies. The role and timing of different geographies is further explored in Appendix B – Regional differences.

Finally, interviewees expressed concerns about the timing of regulatory incentives across the value chain. Because the construction value chain is so broad, each subsector will require similar pace and equitable magnitude of investment in decarbonisation. To illustrate, investment in a new materials manufacturing facility is obsolete if it does not have the clean energy to power it, or an end market willing to pay for it. Synchronising the pace and magnitude of investments is difficult as other sectors are also attempting to secure limited supplies of low-carbon energy to support their own decarbonisation efforts. In order to decarbonise the construction sector, governments will need to introduce equitable incentives and regulation on the end markets, subsectors, and their supply chains.

> I don't want to invest in zero carbon concrete when only a few of my customers are asking for it, and my customers won't ask for it if what I offer is too expensive. Governments need to help both of us out, and at the same time.
>
> Chief Innovation Officer, cement manufacturer

Exhibit 17. Steel and cement demand vs. embodied carbon regulations



Selected regulations

- Max. 12 kg CO_2e/m^2 per year for new buildings >1000 m² (Sustainable Construction Strategy)
- ETS sets gradually reducing emissions cap on selected industries (Directive 2003/87/EC)
- Life cycle assessment mandatory for residential buildings and offices (RE2020)
- Inflation Reduction Act of 2022 provides incentives for low-carbon materials by stimulating carbon capture and green hydrogen

Notes: 1) Average of steel and cement CAGR per geography 2) Steel production CAGR 2010 2019 is used due to lack of recent data available
Source: CemNet ; Worldsteel ; IEA; European Commission; World Green Building Council; Buy Clean California Act; Danish Ministry of the Interior and Housi

Deep dive: Construction regulations across the world

The construction sector is subject to a large number of varied regulations across the globe. Exploring them warrants a separate report but here we provide an overview of key insights on the regulatory status for selected countries, in the context of decarbonising the construction industry.

Exhibit 18. Overview of selected construction regulations

	Selected regulatory insight	Interviewee commentary around challenges and opportunities
EU	• Most regulated globally e.g. EU ETS. Regulators pushing hard in the EU • Taking lead in standards for construction sector	• The level of translation of EU guidelines and directives into national regulations varies vastly between member states
UK	• Well developed regulations with particular focus on waste management • Focus on net-zero buildings, electrical equipment and construction waste	• Many key regulations relevant to construction are still missing clear rules of enforcement
Nether-lands	• Regulatory landscape developing rapidly in building renovations and circularity • Life cycle assessment mandatory for buildings >100 m²	• Construction regulation (bouwbesluit) and Circular economy implementation are the only regulations legally binding for the construction sector
France	• Well-developed landscape with focus on energy performance of buildings • Focus on regional level regulations based on regional needs	• Most regulations at national level only serve as guidelines for the regions, resulting in fragmented implementation at local level
Germany	• Most developed regulatory landscape in Europe and national and regional level • Focus on building energy savings and sustainability action	• Regions have autonomy on implementing regulations resulting in fragmented and varied targets and level of enforcement
United States	• Inflation Reduction Act 2022 is anticipated to result in significant new investments in renewable infrastructure with direct impact to the construction sector	• Focus on incentives more than regulations • Fragmented state legislation while Federal legislation serves as guidelines
China	• Key national level announcement and plans in place, not always fully executed yet • Historically, changes have been implemented at speed	• No clear regulation is currently developed outside of the national plans • Incentives and subsidies relevant to construction sector are still being put into place
Indonesia	• Landscape expected to mature slower than others in region	• Government nudges, but no real regulation • Lack of specific incentives for sustainability in construction
India	• Majority initiatives not legally binding in the construction sector • Enforced decarbonisation regulations focus on circular waste management	• Many key initiatives relevant to construction are still missing clear rules of enforcement • Majority of grants and incentives are focused on mature products
Malaysia	• Majority initiatives not legally binding in the construction sector • Focus on waste management and environmental quality	• Many key initiatives relevant to construction are still missing clear rules of enforcement
Philip-pines	• Focus primarily on energy efficiency and sustainable utilisation	• Government nudges, but limited regulation • Lack of specific incentives for sustainability in construction
Thailand	• Focus primarily on eco friendly chemicals and sustainable utilisation	• Government nudges, but limited regulation • Lack of specific incentives for sustainability in construction

Source: Interviews; Deloitte analysis

Industry perspective: Regional variations in regulations and standards limit investment at scale

Multiple authorities within the construction sector has resulted in a wide variation between regulations and standards in different regions. This causes complications for material and equipment suppliers to secure approval for emerging technologies, making it difficult to scale these solutions in a timely and cost-effective manner.

Standards in the construction sector typically describe technical requirements to ensure the safety of structures. Such standards are applied to both materials and designs. Material standards, for example the European cement standard, prescribe the composition and specifications of cement types. Design standards, like the Eurocodes, prescribe safety norms and calculation methods for structures.

Standards exist at various levels. In Europe, the common design standard are Eurocodes, which are supplemented by national variations like Building Decree in the Netherlands, which includes its own safety norms. Regional bodies, such as a municipality, can apply additional regulation, such as the City of London's LCA requirements, which must be met in order to get a building permit. These stacked standards and regulations create complexity in design and execution when organisations operate across borders. As one regulator's policy officer mentioned: "European norms are aiming for standardisation, but instead they make everything more expensive and complex".

Industry perspective: Outdated standards slow adoption of new technologies and practices

Standards within the industry are often many decades old and this deters contractors from adopting new technologies and practices. Innovative technologies and practices to lower embodied carbon are often unable to be used because standards prescribe specific, traditional technologies and not generic performance metrics. Interviewees perceived the adaptation of standards to be high-risk and costly, requiring extensive testing, approvals and agreements from various stakeholders.

Interviewees noted that the standards landscape moves more slowly than innovation does, meaning more efficient technologies are at times available, but are not able to be adopted. For example, interviewees indicated that the amount of cement in concrete can, in theory, be reduced but outdated standards prohibit this in practice. "We tried to adjust our national concrete standard with a wide committee, but eventually didn't succeed, because various groups didn't dare to challenge the standard; for example, a building cannot be insured without complying to the (old) standard", mentioned a regulator's executive. These outdated standards deter contractors from exploring ways to improve production, such as piloting new technologies. This slow evolutionary pace exacerbates sector's risk-aversion and fear around new materials and activities. The Head of Sustainability for a large road manufacturer and operator said: "We could make our roads out of over 80% recycled material, significantly reducing emissions. We are not able to today because the existing standards limit the amount of recycled material we can add."

This also applies to more mature regions. The Netherlands, despite its more advanced regulation, provides an example of how standards can impede uptake of new materials. The country's mandatory LCA assessment methodology has yet to account for new technologies, such as CO_2 reduction from bio-based materials. As a result, adoption of low-carbon materials such as cross-laminated timber has been limited.

TECHNOLOGY

Compared to market and regulatory factors, alignment around feasible technology options is seen as less of a challenge in the construction sector. Most interviewees believed that low-carbon steel and cement will be required, as well as electrified or alternative fuels for construction activities and logistics. That said, some of the required technologies are not yet commercially available and require considerable infrastructure, particularly low-carbon cement and steel.

Cement

Industry perspective: Low-carbon cement challenged by process emissions, scarce material substitutes, limited access to alternative fuels, and immature CCUS technology

The cement sector is close to the heart of the construction sector, and the decarbonisation options are mostly known throughout. From interviews and existing cement and concrete roadmaps[15,16], four decarbonisation options emerge that all face their own challenges. The options are:

1. **Fuel substitution** is limited by alternative fuel availability – such as biomass and hydrogen – making it less cost-competitive, and often requiring supporting infrastructure to be in place. Cement plants are often in remote areas close to raw material sources, which makes fuel sourcing more challenging. This option would address combustion emissions, solving 40% of total emissions at a maximum, without affecting the remaining 60% process emissions.

2. **Clinker substitution** materials such as coal fly-ash and furnace slag have limited – and in some cases declining – supply. Availability is often geographically concentrated. This is due to declining coal consumption and decommissioned blast furnaces that are the source of these substitutes. Newer types of substitutes are still in the development phase, or in operation on a small scale only.

3. **Alternate chemical processes for clinker production.** New technologies are being developed which focus on replacing limestone calcination as the primary process for clinker production – the largest driver of cement emissions. Examples of this include breakthroughs like those of Cambridge University and UCLA which use recycled concrete and electricity or limestone alternatives, electricity and a unique stoichiometric process to create zero-carbon alternatives to clinker[17,18].

4. **Carbon capture** and the required infrastructure are still immature. A range of technologies are being piloted across the globe, with varying degrees of readiness. According to the IEA, technologies with full capture rates will not be commercially available until 2024 at the earliest[19], and scaling is only expected after 2030. This was also acknowledged by an executive at an engineering firm: "A key hurdle we need to overcome is where to put the CO_2 and building the required infrastructure".

All options are further challenged by the wide availability and cost-competitiveness of the OPC used today. This is expected to change in time as more stringent carbon taxes, technological developments and economies of scale materialise. For instance, a tonne of low-carbon cement following the CCUS option is anticipated to be 40% cheaper than OPC in 2050, and clinker substitution – specifically with calcined clay – could already be 40% cheaper today (see exhibit 20).

Exhibit 19.

INTERVIEW INSIGHT

30%

Research participants believed that a lack of consensus on technology options is a major barrier to decarbonisation.

> Ordinary Portland Cement is incredibly cheap and abundantly available, so the same will have to be true for any viable alternative.

Head of Sustainability, cement manufacturer

Exhibit 20. Total cost of ownership – Cement

	Coal (OPC – Ordinary Portland Cement[1])			Gas (OPC – Ordinary Portland Cement[1])			Coal + Clinker substitution (Calcined clay[2])			Coal + CCUS3 (OPC[1]) (Coals + Carbon Capture Utilisation and Storage (Ordinary Portland Cement[3]))	
	2020	2030	2050	2020	2030	2050	2020	2030	2050	2030	2050
Feedstock and energy cost[4, 5] ($/t)	29	31	36	47	53	65	23	25	29	71	89
Production cost[6] ($/t)							4	4	4	80	70
Carbon cost[7] ($/t)	33	117	277	26	92	216	20	71	168	12	28
Cost of end product ($/t)	62	149	313	72	144	281	47	100	201	162	187
Carbon emission reduction vs coal (OPC1)				0.2 t CO_2 / t cement (22% reduction)			0.3 t CO_2 / t cement (39% reduction)			0.8 t CO_2 / t cement (90% reduction)	
Cost delta vs. Coal				120%	100%	90%	80%[2]	70%	60%	110%	60%

Note: European view, excluding free ETS allowances; 1) Original Portland Cement, assumed to be a mixture of 95% clinker and 5% gypsum; 2) Calcined clay not currently available in sufficient quantities for global application; cement mixture assumed to be 50% clinker, 30% calcined clay, 15% limestone, 5% gypsum; 3) CCS limited commercial availability in 2020, not modelled. Assuming post combustion technology, 90% capture rate assumed. CCUS cost of \$93/t CO_2 in 2030 and \$82/t CO_2 in 2050 (excl. energy). Plant assumed relatively close to shore; 4) Energy prices from world energy outlook 2020; 5) Including raw material cost. Clay assumed to be available within 10km; 6) Only production cost on top of regular cement planned included. For calcined clay CAPEX for flesh calciner, with production capacity of 300kt/yr, depreciated over 15 years and additional OPEX associated with calcined clay manufacturing; 7) Carbon cost ranging from \$38/ton in 2020, to \$324/ton CO_2 in 2050;
Source: IEA, LC3 financial attractiveness report, Manning et al. (2019) – Evaluation of raw material extraction, Plaza et al. (2020) – CO_2 Capture, Use and storage in the Cement industry; Monteiro et al. (2022) – SSUC scenarios for the cement industry

Meanwhile, contractor purchasing habits for cement would also need to change. One Industrial EPC contractor's strategy director said, "Contractors buy cement in small quantities as they source project by project. That is not enough to nudge cement producers into investing in more capital-intensive solutions, like CCUS infrastructure."

Steel

Industry perspective: Low-carbon steel challenged by immature CCUS, raw material scarcity, and high costs of renewable energy

While industry stakeholders are more aligned on the possibilities to decarbonise steel than cement, a number of technological challenges remain which could limit progress. These include: immature CCUS technology, a scarcity of raw materials, and the high costs of renewable energy.

From interviews and extensive industry research available, multiple decarbonisation options emerge. The main ones are conventional plants with carbon capture, or new types of plants with direct reduced iron (DRI) – electric arc furnace (EAF) technology that are potentially powered by hydrogen. Overall, these options face challenges.

The processes that are reliant on carbon capture (conventional process with carbon capture, DRI using natural gas) are challenged by nascent technologies, in the same manner as described in the previous barrier (cement).

DRI plants require scarce high-grade iron ore. Only ~30% of global iron ore is suitable for these processes. This hinders DRI-EAF's ability to scale, even if steelmakers are able to absorb high costs of asset replacement. Also, hydrogen DRI plants do not exist at scale yet. Though some pilots do exist, there is currently no full-scale hydrogen-based DRI plant functioning in the world.

Finally, processes using renewable energy (EAF plants and DRI plants using hydrogen) face high costs of energy supply as well as the absence of supporting distribution infrastructure. "Don't focus on the steelmaking, but on getting the H_2.", said one steel producer's Director of Partnerships. Neither CCUS nor green hydrogen production is at a sufficient scale globally to facilitate the transition to low-carbon steel.

Because of this, low-carbon steel is not yet affordable at scale (see exhibit 21). Low-carbon steel produced following the DRI-EAF option, either with natural gas or hydrogen, is 50% and 240% more expensive, respectively. The cost premium associated with the production of low-carbon steel is expected to decline over time, driven by more stringent carbon taxes, technological developments and economies of scale. To illustrate, the cost per tonne of low-carbon steel using the DRI-EAF with hydrogen might be 30% cheaper than the conventional option by 2050.

The report "Decarbonising Steel: Forging new paths together" offers additional and nuanced barriers to be overcome.

Exhibit 21. Total cost of ownership – Steel

- Yellow: Scenario when H_2 cost remains at $3.3/kg in 2030 and $2/kg 2050
- Grey: Scenario when H_2 cost remains at $4.7/kg in 2030 and $4/kg 2050
- Hatched: Scenario when H_2 cost remains at $5.5/kg in 2030 and 2050s

	BF-BOF Blast Furnace – Blast Oxygen Furnace			BF-BOF + CCUS Blast Furnace – Blast Oxygen Furnace + Carbon Capture Utilisation and Storage[1]			NG DRI-EAF Natural Gas Direct Reduced Iron – Electric Arc Furnace[2]			H_2 DRI-EAF Hydrogen based Direct Reduced Iron – Electric Arc Furnace[2,6]		
	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
Feedstock and energy cost[4, 5] ($/t)	108	115	126		139	158	133	149	180	552	357 / 483 / 357	558 / 427 / 252
Production cost[4] ($/t)	49	49	49		143	131	170	170	170	191	191	191
Carbon cost[5] ($/t)	60	215	506		103	262	27	95	225	6	20	48
Cost of end product ($/t)	218	378	722		385	552	329	414	574	749	568	491
Carbon emission reduction vs BF-BOF				0.9 t CO_2 / t steel (52% reduction)			0.9 t CO_2 / t steel (56% reduction)			1.5 t CO_2 / t steel (91% reduction)		
Cost delta vs. BF-BOF					100%	80%	150%	110%	80%	340%	140%	70%

Notes: European view, European steel plants are typically more CO_2 efficient than the global average; 1) CCS rate assumed 52%, based on 70% capture rate for BF and 23% for coke oven. 20% CCS cost reduction towards 2050, starting at $120/t CO_2 captured; forecast in real values; 2) Calculations assume DRI-EAF co-located; 3) Excluding raw materials, H_2 costs: $5.5/kg in 2020; 4) Assuming asset upgrade cost for BF-BOF and asset upgrade costs BF-BOF to DRI-EAF, written off over 20 year lifetime. Including maintenance cost; 5) Carbon price ranging from $38/ton in 2020, to $300/ton CO_2 in 2050, excludes EU ETS free allowances; 6) Increase in cost explained by increasing energy price;
Source: IEA, BMWI, PBL, Tata Steel Nederland/Ijmuiden RB report, ICF & Fraunhofer, EIB, ECB, Deloitte

Alternative materials

Industry perspective: Limited adoption of alternative building materials

The industry is unwilling to adopt alternative building materials and this is largely due to the perceived operational and financial risks.

Research into alternative materials has been limited because most construction suppliers operate on thin margins and often do not have the capital to invest in early-stage and high-risk material innovation. As a result, availability is limited and variable across markets: "We have to invest massively in materials that don't exist today; this is a bottomless R&D pit. We need Albert Einstein and scientists deployed en masse", said the CEO of a large infrastructure owner.

Application of alternatives like bio-based materials (e.g. timber) or reused materials (e.g. secondary asphalt) is further constrained by:

- increased operational complexity associated with adopting alternative materials – for example, using alternative types of cement alongside Ordinary Portland Cement implies parallel supply chains and duplicate onsite processes;
- higher costs associated with producing some of these alternative materials – for example, cross-laminated timber; and
- physical limitations in availability, e.g. limited global supply of harvestable wood, and limited waste management infrastructure for reusing building materials and components.

Another consideration is that the appetite from financiers, insurers and construction companies is low until these alternatives are recognised by regulatory standards, and by owners and users of the asset. On top of that, there are high costs associated with the certification process, since new materials are traditionally difficult to obtain regulatory approval due to the perceived risks of switching from a proven product.

ROLES

The construction sector is a long and complex value chain, with many participants having influence over decisions. It can be unclear how priorities are aligned and how knowledge is shared to drive quality decisions on decarbonisation. Participants to the research identify limited alignment, the prevalence of small-scale initiatives, and limited expertise around decarbonisation options as key challenges to address.

The buildings end market struggles slightly more than the infrastructure and industrial end markets. This is due to the extent of the fragmentation and one-off projects that occur to create unique buildings. In contrast, most infrastructure or industrial projects are more concentrated.

Industry perspective: A focus on individual projects limits scale and long-term commitment

Traditionally, the construction sector focuses on individual projects without adequate cross-project visibility and alignment of priorities. This is because of the number and composition of different stakeholders involved each time, which makes it difficult for the sector to collaborate effectively across the value chain. In addition to this, stakeholders within individual projects have differing motivations which are often not aligned and focused on the short term only. As a result, sufficient scale and long term commitment for new decarbonisation solutions is lacking.

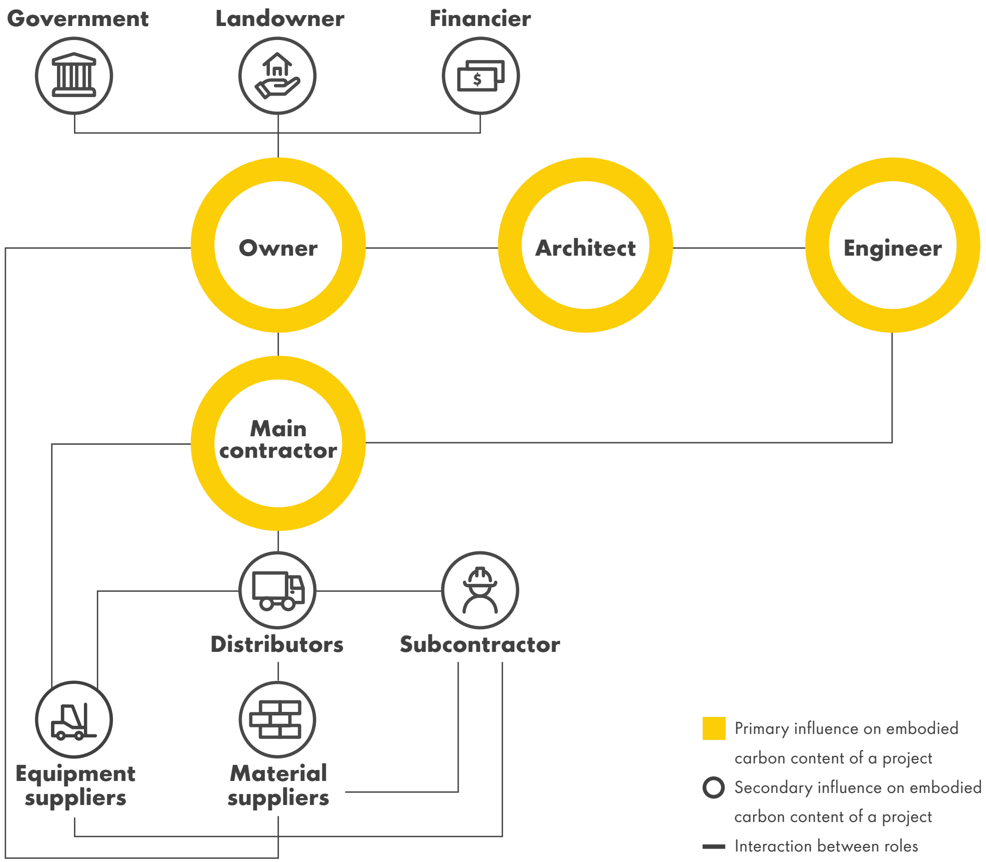
Exhibit 22.

INTERVIEW INSIGHT

80%

Research participants **believed** that **challenges** to **make decisions across the value chain** is a barrier to decarbonisation.

Exhibit 23. Roles involved in typical construction project



A construction project involves many different actors coming together (see exhibit 23) for short periods of time with individualised contractual arrangements. Collaboration is often focused on short-term objectives, as opposed to long-term alignment on strategic priorities. Contracting models within projects are often complex with multiple subcontractors. For example, a single-family residential building project typically employs 20 or more subcontractors[20], from plumbing and electrical wiring to flooring and painting. For large landmark projects, like the London Olympic Park, the number of subcontractors can be thousands[21]. "You work with very local subcontractors – often not more than six guys with a van, rarely with decarbonisation as a priority, and with different incentives to the major players", said an engineering firm's Head of Sustainability.

The lack of priority alignment is particularly evident between the subsectors and end markets. For instance, interviewed contractors assumed that the short-term availability of cost-competitive, low-carbon cement was a given. However, cement suppliers indicated this might take a decade, driven by the large-scale investments that are needed. A similar phenomenon occurs between contractors and equipment manufacturers. Contractors were confident that low-emission equipment can be rolled out by the end of the 2020s, while interviewed equipment manufacturers were sceptical that the necessary infrastructure will be available in time.

Industry perspective: Expertise around low-carbon practices is limited to a few large companies

A few large companies have the expertise for low-carbon practices but there is no clear mechanism to disseminate knowledge across the value chain. Companies are not incentivised to share their innovations and this prevents the accumulation of knowledge, limiting progress and perpetuating a lack of awareness about decarbonisation challenges and potential solutions.

> The local small players don't have money or time to invest in trainings – they just want to put food on the table.

Director of Operations, major building contractor

The innovation which has happened to-date has been concentrated within large companies who can spread the cost and risk across a broader operation. Even within these companies, expertise tends to be concentrated in pockets.

IMPLEMENTATION

The time and effort needed to enable and scale emerging decarbonisation options is perceived as the largest barrier to accelerating change. A significant challenge is a lack of consistency in the definitions of low-carbon materials, in the data available and across calculation methodologies used to account for carbon. Also cited as key challenges were a conservative culture, and the lack of distribution and storage infrastructure for low-carbon fuels and captured carbon.

Exhibit 24.

INTERVIEW INSIGHT

90%

Research participants **believed** that the **time** and **effort** needed to **scale solutions** is a major barrier to decarbonisation.

Industry perspective: Inconsistent definitions, data, frameworks and tools limits ability to compare and claim decarbonisation outcomes

Inconsistent definitions about what constitutes low-carbon materials, inconsistent data sets, and no agreed framework to measure and benchmark carbon performance limit stakeholders' ability to compare emissions performance. While there are many tools available to measure performance, they have varying material performance data and carbon accounting methodologies, which makes it confusing to facilitate uniform lifecycle decision making over multiple value chain players. This limits the ability to claim favourable emissions performance.

Solutions are still a work in progress: "It's not there yet, but the UK's Royal Institution of Chartered Surveyors is developing a built-environment carbon database, which follows their reporting advice and guidelines", said a Chief of Sustainability at an engineering firm.

Using low-carbon steel as an example, there is currently no unified standard to compare suppliers. Standards are based on emissions or production processes, and qualifying thresholds for emissions intensities are set at anything from 2.5 tonnes CO_2 per tonne of crude steel, to near zero.

Although initiatives are emerging to make data sets consistent – such as the ISO Environmental Product Declaration, and material passports for selected products – companies today have no choice but to use data that might not be fully applicable based on their geography or precise manufacturing methods.

The absence of an agreed framework to measure and benchmark carbon performance forces multiple companies to do the same work in parallel – for example, to define baselines and attribute emissions to certain value chain participants. This is particularly evident around an organisation's indirect emissions across its value chain (Scope 3 emissions).

> We need to distinguish between counting and accounting carbon. Accounting has rules to it, and it is unclear who is going to develop a rule-based accounting methodology for carbon.
>
> Researcher

Industry perspective: Construction is a conservative sector where there can be a reluctance to adopt new technologies and practices

According to many interviewees, the construction sector is hesitant to adopt new practices and technologies in production and on construction sites. This is in part because mistakes in the low-margin construction sector can be costly, because there is a lack of incentives to innovate, and because the risks of new technologies are difficult to manage.

Interviewees cited the slow rate of change from legacy practices to new ones such as digitalisation as a key example. "It is not uncommon to sign off on processes manually, on paper; particularly among the team on the ground", said a building contractor executive.

> We're still pushing for a digital transformation, let alone a green transformation.

Business Unit Director, building contractor

Risk aversion further inhibits the adoption of new technologies and practices, attributable to the fact that mistakes are costly and "can easily put you out of business", an infrastructure contractor executive commented.

The net result of legacy practices is for instance evidenced by the amount of onsite material losses. An estimated 30% of the total weight of new virgin building materials delivered to a building site ends up as waste. These commonly known, but large-scale solutions are not often implemented.[22]

This slow rate of adoption could be accelerated through incentives – particularly for operational personnel: "We have been doing this for ages – why all of a sudden this change; what is in it for us?", commented an infrastructure contractor's Head of Innovation.

Industry perspective: Enabling production and distribution assets for alternative fuels and carbon capture not at scale yet

The construction sector is competing with other sectors for the limited supply of low-carbon fuels, such as renewable electricity, biofuels and hydrogen. "We are not the only sector which needs to decarbonise; there are limited supplies of these new fuels, and I am now competing with shipping, power and other sectors for access to them" said one large steel producer. Supply of this low-carbon energy varies across geographies, depending on investments made, and the number of sun hours or availability of wind or hydro power.

Investment is needed to construct the enabling production and distribution assets for alternative fuels and carbon capture. "The challenge is how fast we can scale in supplying renewables to enable this transition", noted a regulatory body's team lead. To scale production, new assets need to be in place. To illustrate, producing green hydrogen requires, among other things, solar or wind farms and electrolysers. Undertaking such a project would require obtaining permits, which can take years to achieve, driven by politically sensitive and often slow bureaucratic processes to get development plans approved and financed. The construction phase that follows to build this infrastructure is further complicated by scarcity in materials but also workforce capacity and expertise. As a result, this is a challenge which requires multiple layers to be solved.

Next to alternative fuels, a key enabler for decarbonising cement and steel is CCUS. Today, the infrastructure to distribute low-carbon fuels, and transport and store captured CO_2 is missing. This is predominantly because "it requires hundreds of billions in spend across multiple sectors, and the development of completely new industries that do not exist today", said a researcher working for another regulatory body.

Potential Solutions for Decarbonising Construction

SIGNALS OF CHANGE

Increasing numbers of political leaders are making commitments to reduce carbon emissions. EU and USA administrations have plans to realise net-zero by 2050, with China and India making net-zero commitments of before 2060 and 2070, respectively. The plans are translating into action through policy and regulation. For example, the recent USA Inflation Reduction Act focuses over $5 billion in investment towards low-carbon procurement.[23]

Business leaders are also making net-zero commitments, as illustrated below (exhibit 26). These commitments are particularly high among European businesses. Asset owners seem to lag behind compared to the other participants, with decarbonisation not a top priority for half of them. As we will see later in the report, asset owners play a key role in stimulating the demand for low-carbon solutions, so they need to include more carbon emissions requirements in their construction projects. While the prioritisation of decarbonisation varies by segment, it remains a key factor for all direct participants across the sector. The urgency to decarbonise is succinctly captured in the following interviewee quote:

Exhibit 25.

INTERVIEW INSIGHT

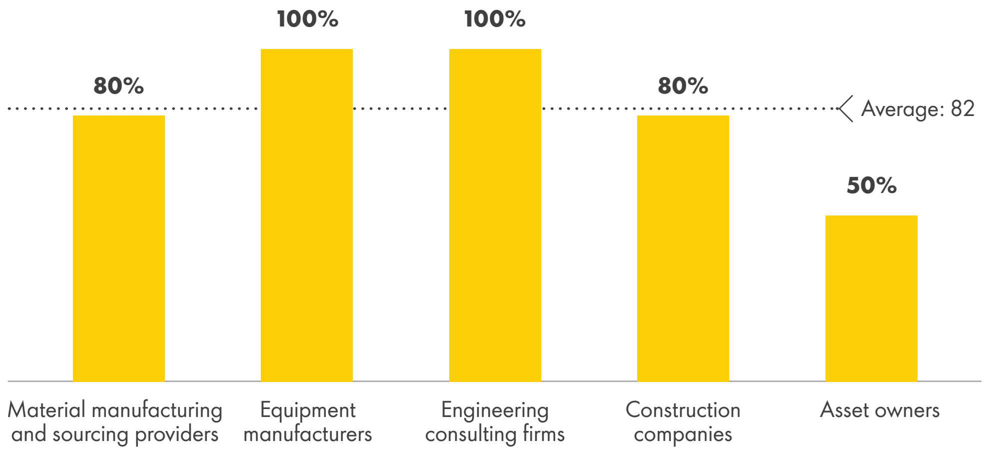
80%

Over 80% of interviewees highlighted decarbonisation as a top-three business priority (exhibit 26), and the majority of large companies across all construction subsectors have made emission reduction commitments

> Regulation is getting more intense, our customers and financiers are asking us more questions, and even our employees are demanding action. The change is coming, and will only intensify. We can either use it as an opportunity today, or be out of business tomorrow

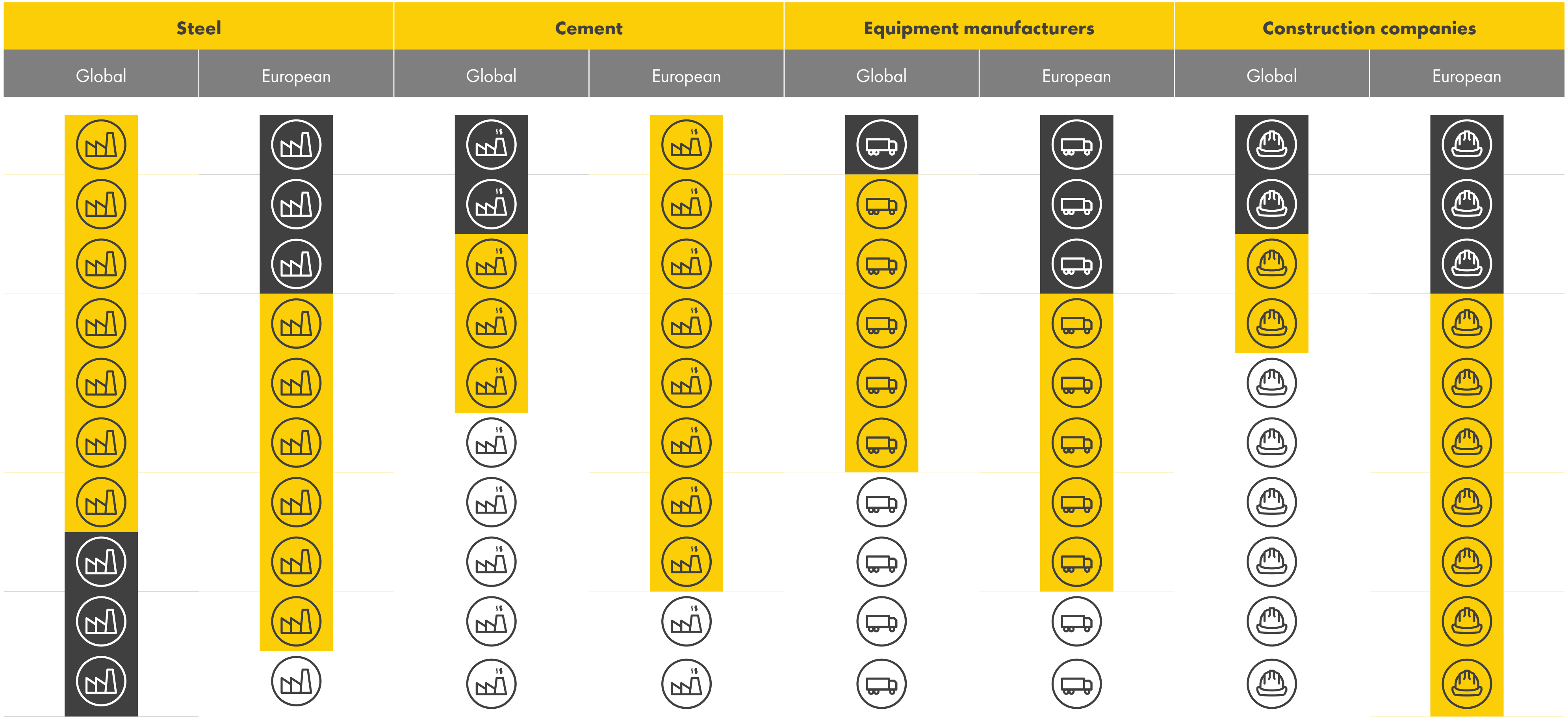
Executive, large building contractor

Exhibit 26. Participants that consider decarbonisation as top three priority



Source: 84 research participants; Deloitte analysis

Exhibit 27. Companies with decarbonisation commitments (top 10 players per subsector)



- 2050 commitments [1,2,3]
- 2030 commitments only
- No commitment

Sources: Corporate websites and Deloitte analysis
Notes: 1) Count includes explicit commitments to near-zero or net-zero Scope 1 & 2 emissions; inclusion of Scope 3 commitments is varied 2) Top10s used from World Steel Association, 2021 (steel); Statista, 2021 (cement); International Construction, 2021 and Statista, 2021 (equipment); Deloitte, 2020 (construction). 3) Top10s based on production capacity (steel, cement) and revenue (equipment, construction); European Top10s defined by headquarters (steel) and regional data (cement, equipment manufacturers,construction)

THE INSPIRING BEGINNING

We are seeing new initiatives all over the place, but it feels like there is too much to do, and we don't really know what matters most and where to start.

CEO, building contractor

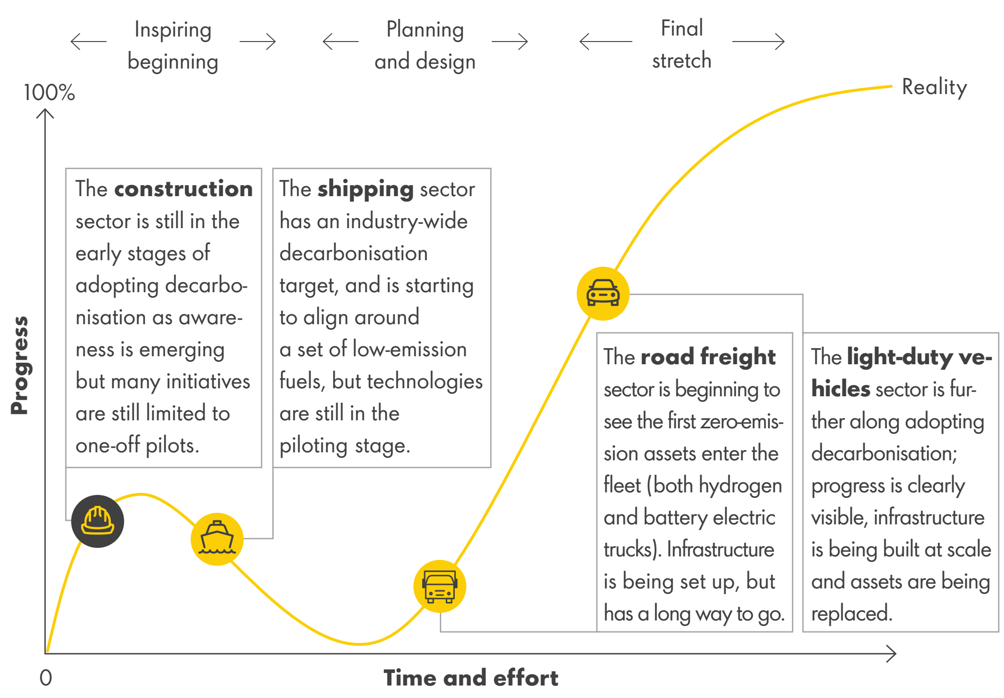
Construction's journey ahead can be put into perspective by looking at the phases through which a sector adopts change. The early stages are often characterised by a sense of unbounded urgency and optimism. This is known as the "Inspiring Beginning" where sector participants recognise the need to change, and the possibilities feel limitless, and every action is a sign of progress. This is where the construction sector currently sits: the participants interviewed in this study support the urgent need for change, but the route to net zero remains unclear.

In the subsequent "Planning and Design" phase, progress can be slow as the scale of the challenge becomes more apparent and unforeseen challenges arise. For example, as technology solutions are tested in pilot programmes, high costs and technological limitations may become more evident.

Finally, as those challenges are addressed and the pathways become more clear, optimism begins to grow. The "Final Stretch" becomes less about tackling uncertainty and more about execution. Momentum builds and each day brings progress towards that end goal.

An understanding of the path forward should be used to shorten the time from the beginning to making things a reality. The following section outlines a set of potential solutions to help the sector accelerate progress.

Exhibit 28. Typical decarbonisation change-adoption phases – ILLUSTRATIVE



Source: Kanter (2006) "Confidence: How Winning Streaks and Losing Streaks Begin and End"; Raffaelli (2018) "Leading and Managing Change"; Deloitte analysis

SOLUTION THEMES

The construction executives surveyed for this report identified a wide range of initiatives to overcome the barriers to decarbonisation. A series of industry workshops and review sessions refined these into a catalogue of 15 solution themes. This section details these potential solutions and aims to go beyond a focus purely on the technologies required, outlining a set of actions to increase their adoption and scale within the sector.

The industry is not starting from scratch, and some progress can already be seen around the solutions. Engaging with the stakeholders through our research helped establish what was working and what was not. This nuance was used to create solutions that build on initiatives in place today or close gaps around specific barriers.

Although each solution is important, the integration of solutions will be critical to accelerate change across the entire value chain. The applicability of solutions may vary also by geography and end market. For example, some markets may already have regulation in place, while others may place more emphasis on conducting pilot trials of new technology.

The full list of solution themes is summarised in exhibit 29. In the following chapter, an integrated roadmap provides a clear view across these solutions themes, and who needs to do what, when.

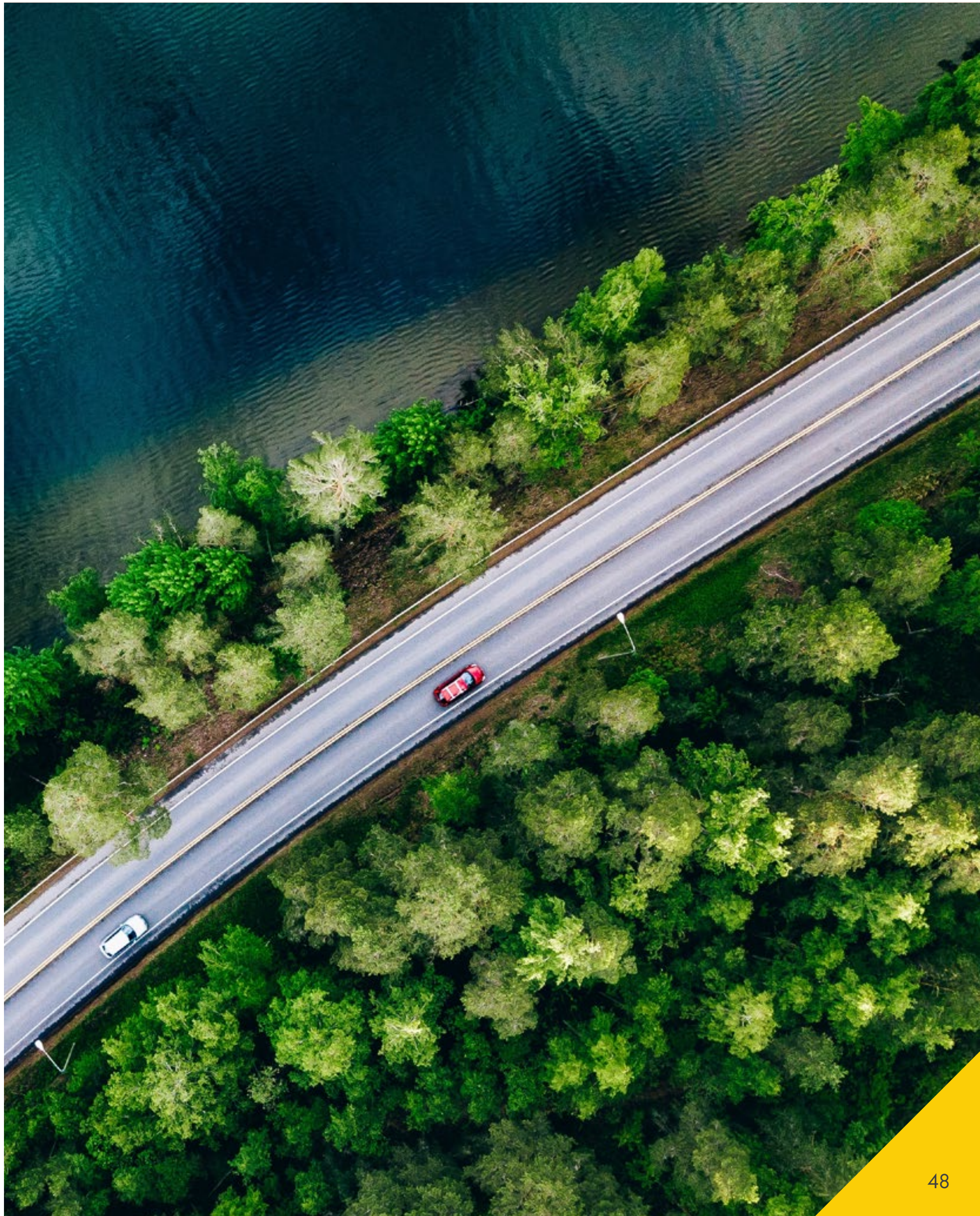


Exhibit 29. Solution themes and relevance by end market

Readiness questions	Readiness factors		Solution theme	Description	End-market		
					Build	Infra	Ind.
Why should the sector change?	**Demand**	1	Increase awareness around embodied carbon.	Elevate embodied carbon on the agenda for society and industries, and define a common language.	High	Moderate	High
		2	Activate and aggregate demand.	Demonstrate growing demand and willingness to pay by asset owners and contractors to create clear signals for investment.	High	High	High
		3	Generate green financing standards and expand investment.	Use access to capital as an incentive for those looking to move first and raise minimum standards.	High	Moderate	High
	Regulation	4	Adopt policies to stimulate demand for low- and zero-carbon assets.	Make low-carbon construction necessary for any building, infrastructure or industrial project.	High	High	High
		5	Stimulate development of low-carbon solutions through policies.	Support solutions to increase production capacity of low-carbon construction materials and equipment.	High	High	High
Can the sector change?	**Technology**	6	Invest in low-carbon cement and concrete pathways.	Determine cement's winning decarbonisation technologies and begin investing in commercial pilots.	High	High	High
		7	Scale low-carbon steel production.	Increase production capacity of low-carbon steel.	High	High	High
		8	Develop and adopt alternative materials.	Embrace innovation of new building materials as alternatives to cement and steel.	Moderate	Moderate	Moderate
		9	Roll-out low-emissions equipment.	Accelerate adoption of electrified equipment first, and hydrogen next.	Minor	Minor	Minor
	Roles	10	Develop talent and increase knowledge sharing.	Increase decarbonisation capabilities in the sector.	High	Moderate	Moderate
		11	Adopt more holistic contract models and public-private partnerships.	Integrate actors across the supply chain and government more effectively, and adopt contracts which allow for more flexiblity and prioritise decarbonisation.	Moderate	High	Minor
How fast can the sector change?	**Implementation**	12	Make design and execution more efficient.	Implement known solutions to use less materials and energy in design and onsite.	High	Moderate	High
		13	Update design and material standards.	Allow for new and improved materials and equipment to enter the market.	High	High	High
		14	Secure supply of renewable energy and build distribution infrastructure.	Increase capacity and access to renewables for the construction sector.	High	Moderate	High
		15	Increase circularity and systems thinking.	View (old) buildings, infrastructure and industrial sites as a 'bank of materials'.	High	High	Moderate

Revelance
High / Moderate / Minor

Source: Interviews; Deloitte analysis

DEMAND

Solution 1: Increase awareness around embodied carbon.
One of the primary challenges identified around embodied carbon is the lack of awareness from both within the sector and outside of it. More visible sectors like aviation, agriculture and transport have seen growing societal pressure translate to political action, and increased commitments from companies in those sectors. Examples of this can be seen through Germany and France's flight bans over short domestic routes, and the increasing number of net-zero commitments from airlines.[24] Starting this change will require a consistent language and set of definitions to be defined around embodied carbon, and a campaign to raise awareness in broader society, and within the sector.

Within the sector, sharing best practices across the sector will be essential to ensure new solutions, tools and ways of working are adopted and scaled quickly. This will need to be done across end markets, geographies, and throughout the value chain. Technology options exist and should be more widely used to gather examples of best practice in a database, allowing companies to search for potential solutions when needed. Change will also require a cultural shift, as noted by one EPC's executive: "People need to realise that decarbonising embodied carbon is like safety was decades ago; sharing best practice is in everybody's best interest and will not put anyone at a competitive disadvantage."

Supporting a cultural shift can be done by creating coalitions of like-minded businesses and helping early adopters connect and learn from one another. Regional fora and cross-value chain coalitions can be a way to encourage commitment and collaboration, while smaller, more focused working groups with similar geographies or project types can also help accelerate progress locally. Digital solutions like a common platform that enables filtering or searching of existing commitments or like-minded players, would also help facilitate collaboration.

To generate more interest, commitment and investment, we need to raise embodied carbon up on the global decarbonisation agenda, and make sure we have a common language to speak about it – only then will we start to be able to work on other solutions

Steel manufacturer

4. **RESEARCH HIGHLIGHT**

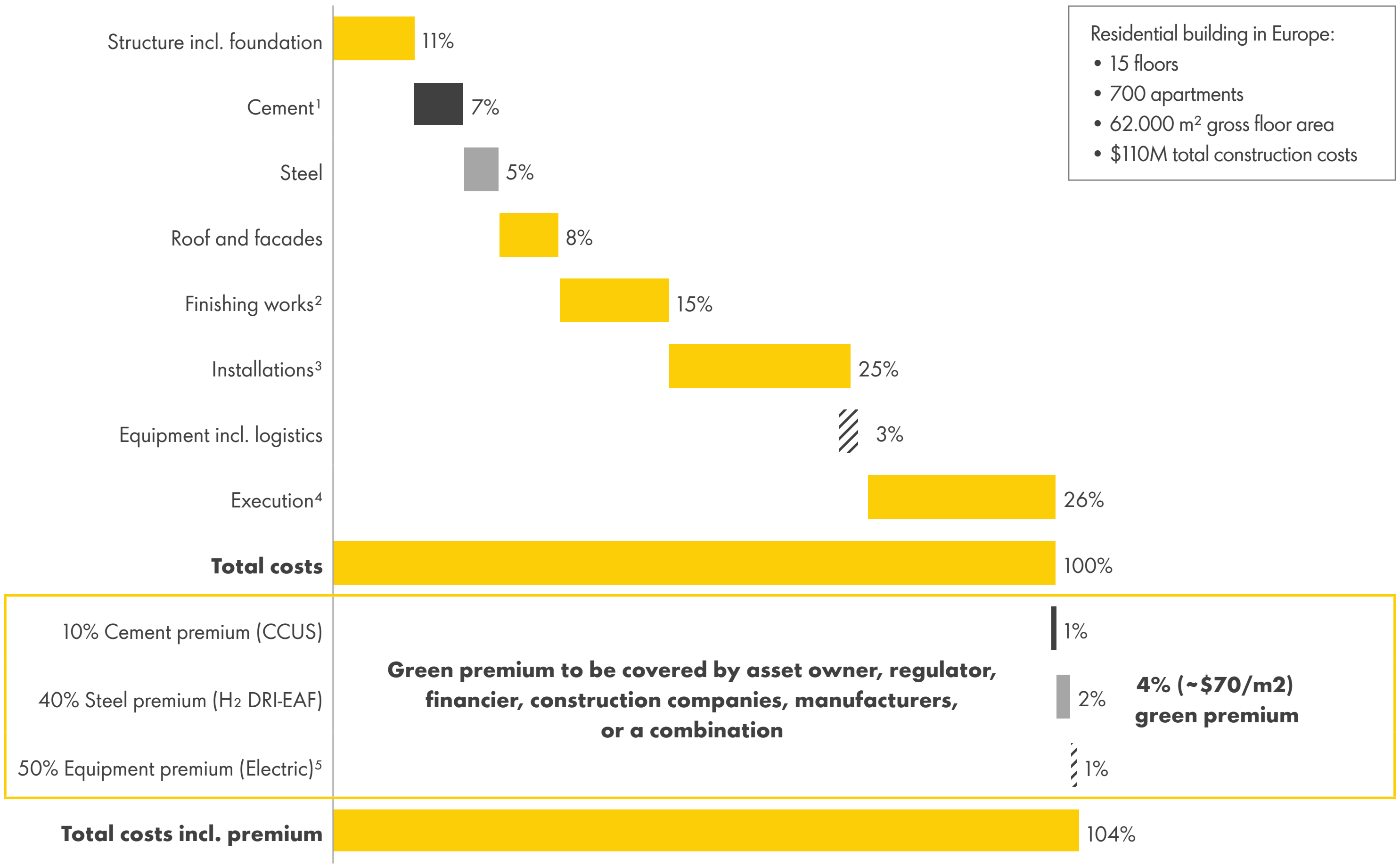
Most of the existing carbon reduction efforts have been focused on operational carbon. Creating better visibility for embodied carbon and developing solutions to reduce it will be critical – only then will we start to be able to work on other solutions.

Solution 2: Activate and aggregate demand.

Activate demand for low-carbon materials, equipment and construction processes by establishing contracts with suppliers for multiple projects, and by aggregating demand through joint sourcing and buyer coalitions. When forming such agreements, antitrust risk can be reduced by limiting the coalition's impact on the market and by not sharing sensitive information with the other organisations. These clear demand signals would give producers greater confidence to invest in research and development, launch and scale pilot programmes and ultimately replace infrastructure and plants.

The sector as a whole requires significant investment in low-carbon materials, equipment and processes to the industry. For example, the capital cost for a low-carbon steel plant (DRI) is around $960 million per megatonne of steel per annum production capacity[25], with nearly 2,000 megatonnes of annual steel production needing to be replaced[26]. "We need to be able to demonstrate there is demand for these higher cost products if we want to be able to unlock bank financing or board approval for investment," said the CEO of a large cement producer. The Head of Strategy for a large asset owner said that "If we want to hit our Scope 3 targets, we need the materials to be available, and the only way that is going to happen is if we show suppliers we are willing to pay for them."

Exhibit 30. Typical green premium (in 2030) as percentage of residential building construction costs (%)



Notes: Costs for cement (as share of concrete) and steel subtracted from subsequent categories; Premiums for cement, and steel are based on economic analysis, premiums are based on solutions with regular production process + CCUS in 2030. For equipment based on interview insights 1) Assumes 50% share of cement cost in concrete 2) Finishing works includes non-load bearing walls, flooring, doors, windows and ceilings. 3) Includes plumbing, electrics, heating, elevators and general home equipment. 4) Includes all on-site construction activity costs plus other costs; 5) Based on interviews
Source: Interviews; Deloitte analysis

Examples of strong demand signals from end markets include:

- Green procurement policies, which specify the minimum requirements that projects or materials must meet, or higher consideration for tenders with lower embodied carbon;
- Centralised purchasing contracts between end markets and construction subsectors beyond projects to procure larger volumes of low-carbon materials; and
- End market users co-investing in projects like new green steel or cement plants for preferential access to materials or prices.

Such demand signals are beginning to emerge. Outside of the construction sector for example, Apple recently invested in a low-carbon aluminium production joint venture that includes the re-use of discarded devices.[27] Within the construction sector, the Netherlands and Belgium in 2009 already introduced the CO_2 Performance Ladder for public sector procurement, starting in the infrastructure end market on rail projects. Companies seeking to tender can be certified on the ladder and, depending on the maturity of their carbon management, receive a corresponding discount on their cost of tenders. The better their performance, the better the discount.[28]

5. **RESEARCH HIGHLIGHT**

Asset owners have a leading role to play to generate demand, kickstart collaboration, and increase investors' confidence to take the leap of faith necessary to invest in emerging technology.

Ultimately, the economic barrier to overcome is smaller than many in the sector would expect. As exhibit 30 shows, by 2030 the green premiums as percentage of total construction costs are within reach. And as the use of these materials expands, and markets grow, economies of scale and improvements in production processes will continue to decrease the green premium.

Asset owners in the buildings end market may already be motivated to pay green cost premiums in order to capitalise on growing demand for low-carbon buildings. Interviewees believed that demand is rising for both residential and commercial buildings, like global brand offices and distribution centres, and first niche customers are actually willing to pay the premium. On the other hand, regulatory and financial instruments can be used to cover part of the premium.

Construction end markets should learn from other sectors when forming coalitions that aggregate demand. For example, the Sustainable Aviation Buyers Alliance (SABA) includes the largest corporate customers of aviation and has already begun to make meaningful forward purchasing commitments for sustainable aviation fuels. Similar coalitions are starting to emerge in the construction sector and include: the First Movers Coalition, the Mission Possible Partnership, Build Ahead, SteelZero and ConcreteZero although specific, meaningful commitments must be made (see exhibit 31).

> We all know that this is something we need to do. To hit our individual targets, we need to be better at working together.
>
> Managing Director, industry association

Exhibit 31. First Movers Coalition – World Economic Forum

- End market coalitions are forming at a global and country level to promote green resources. For example, more than 50 global companies with a combined market cap of ~$8.5 trillion across five continents have joined the First Movers Coalition. This is a publicly stated declaration to purchase a part of their primary resource inputs from low-carbon emission sources.
- The coalition covers a variety of materials such as steel or aluminium. For each of these, it has set specific targets. For example, for steel, members commit to buying at least 10% of the volume they require in 2030 from steel plants with near-zero emission technologies. This has been defined as having less than 0.4t CO_2 /t steel.
- Material producers say this helps give them the certainty they need to invest in low-carbon technologies by helping them manage long-term risk.

Source: WEF, newscientist.com, Deloitte analysis.

Solution 3: Generate green financing standards and expand investment.
Financiers will play a key role in providing the capital needed for more sustainable investments. Interviewees said that traditional financiers are reluctant to invest while uncertainty prevails around new technologies and the market for more sustainable solutions. To address this, financiers could form investment coalitions to spread the risk, participate in technology pilots or provide preferential financing to projects that meet higher emissions standards.

Like with demand coalitions mentioned in solution 2, coalitions of financiers will allow like-minded sources of capital to more efficiently deploy resources into the sector and spread risk. Through coalitions like the Poseidon Principles, which created a framework for responsible investing in the shipping sector, financiers can create a new norm for what it takes to get investment in new projects.

Interviewees also suggested that financiers can provide more incentives within their financing structures to help accelerate their clients' decarbonisation. For example, they could set tighter emission intensity standards in return for a lower cost of capital, or provide preferential interest rates. The head of infrastructure investing at one fund noted: "We need to appreciate that climate change poses a risk to our portfolios as well. We must find a way to price in that risk and reduce the emissions profile of the assets we hold."

Examples of providing preferential rates can already be seen around operational carbon. For instance, green mortgages offer preferential rates for energy-efficient homes. In the UK, 60% of the top 10 UK mortgage lenders now offer a form of green mortgage.[29] Extending these schemes to embodied carbon using certification programmes like Building Research Establishment Environmental Assessment Method (BREEAM) or Leadership in Energy and Environmental Design (LEED) would create a stronger incentive for investment in low-carbon materials or construction.

More extreme than preferential rates, financiers can also begin to restrict access to capital for projects that do not meet minimum emission standards. These measures allow financiers to reduce the emissions in their broader portfolios to hit decarbonisation targets. Examples of this can already be seen by financiers in other sectors, like coal where the majority of development banks have committed to cut investment in new projects[30].

Non-traditional sources of capital can also play a role. Organisations like energy majors are well positioned to make strategic investments in the early stage of these decarbonisation pathways. As noted by one banking executive, "There is an opportunity for energy companies to support their own transitions by helping reduce their emissions profiles, while also helping expand the markets for renewables and other new energy projects they are investing in."

> When everything is about money, it is no surprise that financiers will have a big role incentivising players to decarbonise.
>
> CEO, industry association

REGULATION

Solution 4: Adopt policies to stimulate demand for low- and zero-carbon assets.

Policies targeted at the asset owners and buyers across end markets are essential to help bridge the price gap between traditional construction technologies and lower-carbon solutions. Interviewees agreed that positive regulatory measures like grants and subsidies (the 'carrot') and coercive measures (the 'stick') will both be necessary simultaneously to accelerate decarbonisation. While a range of demand policy levers were discussed (as illustrated in exhibit 33), those most frequently mentioned by interviewees include mandatory project lifecycle assessments (LCAs) and embodied carbon limits.

6. **RESEARCH HIGHLIGHT**

Synchronised regulations and standards for embodied carbon will create the conditions required for action, including consistency on how embodied carbon can be measured.

> In the biggest transition of our life, the government can take the lead to help the market feel that it is not doing this alone.
>
> Sector banker, financier

LCAs are used to calculate the total embodied carbon of an asset throughout its lifecycle. Mandatory LCAs for projects would allow carbon to be included in design and procurement decision making criteria. For example, companies bidding to build Dutch highways are required to perform LCAs using certified LCA-methodologies and software to be accepted as a possible option. In London, all building development proposals are required to perform LCAs before receiving building permits.[31]

LCAs can be used as a benchmark for establishing an embodied carbon limit, which could be mandated in structural engineering codes. One of the most mature **embodied carbon regulations** exists in Denmark, where embodied carbon in new buildings is limited to a maximum amount per square metre of floor area.

Such policies should set different limits by project type and be flexible in their enforcement to win support from industry participants. For example, requirements should be adapted for projects such as a national defence facility or a building with historical significance. As an HSE director at a building contractor said: "It is important that we strongly incentivise the projects that can go further and avoid penalising projects that have to be over the baseline due to constraints out of the project owner's control."

While policies set by national or international bodies would have a broader reach, smaller jurisdictions could play a critical role. For instance, a city municipality may be able to move more quickly and adopt regulations tailored to the local market conditions. Cities taking the initiative include London with its LCA implementation requirement and Amsterdam increasing the percentage of recycled asphalt content required for new roads. The important role of local jurisdictions was raised by the head of Technology for a large EPC: "Construction is a more localised industry than a lot of other hard-to-abate sectors like shipping and aviation. While we are a global company, we need to take a local approach to projects and local or national policy can have a huge impact." Actions by smaller jurisdictional bodies can also allow larger jurisdictions to better understand the implications of particular measures and more quickly adopt similar changes.

Exhibit 32. Life cycle assessment (LCA)

A life cycle assessment or life cycle analysis is the evaluation of the environmental impact of an asset across the lifecycle, from raw material mining and processing, to use and eventual recycling or disposal. This includes the impact of handling equipment, transportation and repairs required during the lifetime of the asset. For a typical asset, this assessment is performed for each of the thousands of components in the asset, and the results are compiled to show the total LCA of the asset. An LCA typically measures a variety of environmental impacts. However, for this report LCA is used only in the context of carbon emissions.

All interviewees highlighted the importance of transparency when it comes to policies, as knowing what to expect, and when, would increase confidence around major investment decisions, particularly those with longer time horizons.

Solution 5: Stimulate development of low-carbon solutions through policies.

Mandates and incentives will also be needed to accelerate investment in the production and supply of low-carbon materials, equipment and fuels. Interviewees most frequently mentioned cap-and-trade schemes, import tariffs, Carbon Contracts for Difference, green subsidies and grants for research and development. Interviewees also noted the importance of aligning these measures with the demand-side measures seen previously. A more detailed summary of instruments to encourage construction subsectors can be seen in exhibit 33.

Cap-and-trade schemes are already in place in 46 countries.[32] These schemes place emissions caps on industrial assets and the caps typically diminish over time. There are financial penalties for those who go above the limits and opportunities to realise a financial gain for those who have lower emissions and trade their excess cap space.[33] Numerous examples exist, such as the EU's Emissions Trading System and Tokyo's Cap-and-Trade Program. However, more ambition globally is required. For example, the emission caps are often not shrinking fast enough to make producers want to invest adequately in lowering their own future emissions. Lower emissions limits could accelerate decarbonisation. When paired with a carbon-based import tariff (see below), this can incentivise producers to decarbonise while still shielding them from foreign competition.

Carbon-based import tariffs
There is concern with any form of carbon taxation mechanism (like cap-and-trade) that producers move production outside of the taxable jurisdiction. This leakage often results in higher net emissions as production processes stay the same and transport emissions are increased. Import tariffs – such as the Carbon Border Adjustment Mechanism proposed by the EU – combined with a local carbon taxation scheme, will prevent emitters from importing carbon-intensive materials to evade carbon taxes.

Carbon Contracts for Difference
(CCfD) are signed between governments and a private agent, in addition to existing market-based carbon pricing mechanics such as cap-and-trade schemes. The CCfD acts as guarantee for a pre-agreed carbon price, which the private agent uses in its investment decisions for emissions reduction. There are two common options: 1) two-way CCfD, where both the government and private agent pay the difference when the actual carbon price is below or above the pre-agreed carbon price; or 2) one-way CCfD (commercialisation contract), where only the government pays the difference when the carbon price is below the pre-agreed price. Both routes allow governments to support initial investment decisions and decrease support over time as carbon prices gradually increase.

R&D grants can stimulate fundamental research in new technologies by supporting the initial costs incurred by first movers, while also helping them develop expertise and establish themselves in the market. As a sustainability director at a cement manufacturer said: "Getting support for the initial investments which are not commercially viable today gives us a huge advantage. It helps us learn about the technologies, lower costs and get to market earlier. It is critical to get the sector moving." Some examples of funds are already being seen in this space. For example, the American Advanced Research Projects Agency-Energy and EU-administered Horizon Europe are innovation funds that focus on financing projects that might be considered too risky for private investors.[34]

Subsidies will also be essential to help increase adoption of more sustainable technologies which may be more expensive than today's options, and scale up the required infrastructure. For example, the recent Inflation Reduction Act in the USA provides subsidies to support the scaling up of carbon capture and green hydrogen infrastructure.

Environmental Product Declarations (EPDs), the outcome of an LCA. This requires producers to track the environmental impact of their products, similar to a material passport. Just as food labels state what is in each product, EPDs set common metrics to compare emissions data against other producers and products. In the construction context, EPDs could be required for anything from air conditioning units to toilet seats. The upcoming EU Construction Products Regulation (CPR) lays down harmonised rules for the marketing of construction products in the EU.[35]

> Governments are not the only solution, but their visibility and high degree of influence means that they are one of the most important ones.
>
> Head of Sustainability Strategy, cement manufacturer

Exhibit 33. Potential policy instruments (non-exhaustive)

Stakeholder	What gets regulated	How it could get regulated					
Developers	Asset design	Tax credits (e.g. tax discount for lower embodied carbon assets) (+)	Incentives for reuse and renovation (i.e. to reduce material demand) (+)	**Mandatory lifecycle carbon assessment** (−)	**Embodied carbon limits** (e.g. building code, incl carbon cap per m²) (−)	Fit for purpose material standards (e.g. no over engineered standards) (−)	
Financiers	Portfolio composition	Minimal embodied carbon criteria before providing a loan (+)	Reduced interest rates for lower embodied carbon assets (+)				
Construction companies	Equipment footprint	Carbon-based machine taxation (+)	Incentives for accelerated fleet renewal (+)	Mandatory use of low emission fleet pools (−)			
	Logistics footprint	Include transport emissions in emission trading scheme (ETS) (+)	Tailpipe operational target (potentially including offsetting) (−)				
Material producers	Materials and construction products	**Carbon Contract for Difference (CCfD) for low-carbon vs traditional material** (+)	**Subsidies for low-carbon production technologies** (+)	**R&D incentives** (e.g., innovation funds materials) (+)	**Cap and trade scheme** (e.g., emission trading scheme) (+) (−)	**Carbon based import tariff** (−)	**Mandatory material carbon footprint reporting** (−)
Energy companies/ infrastructure developers	Fuel mixture sold	**Subsidies for low-carbon energy** (+)	**Increase fuel taxation (e.g. VAT)** (−)				
	Infrastructure development	**Subsidies for renewable energy infrastructure development** (+)	**Subsidies for CO_2 infrastructure development** (+)	**Carbon Contract for Difference (CCfD) to reduce investment risk** (+)			

Bold = specified in report, based on interview sentiment

☐ End markets

■ Construction subsectors

(+) 'Carrot' – incentive or reward

(−) 'Stick' – punishment or penalty

Source: Interviews; Deloitte analysis

TECHNOLOGY

Solution 6: Invest in low-carbon cement and concrete pathways. Decarbonisation options for concrete and cement exist but they require increased investment from cement manufacturers, financiers, research institutions and governments to test viability and scale pilots. These options include alternative fuels, low-clinker content, substitutions, and CCUS. The future potential and current adoption for each of the options can be seen in exhibit 35.

First, **manufacturers can adopt alternative fuels to power the cement-making process**. Cement production relies mainly on coal to provide heat. Even a shift to natural gas as fuel would reduce emissions by about 20%, as natural gas produces about half the CO_2 per unit of energy while burning versus coal, but process carbon emissions will remain.[36] Further reductions in process emissions are offered by additional pathways: biomass or waste; green hydrogen; and electrification.[37] Of these, the first two approaches are well developed, while additional R&D is needed to smooth the technological challenges of electrification, given the high temperatures required.

Second, **manufacturers can reduce clinker in cement** by substituting alternative materials, such as slag or fly ash. There is innovation happening but the industry needs additional investment to research, certify and scale across multiple geographies. Additional studies and technical assurance should help to prove that cement with lower percentages of clinker is reliable. Exhibit 34 provides an example of how using recycled minerals helped lower embodied carbon for the London Olympics.

Cement manufacturers will need to consider the finite supply of some materials to develop solutions that will be feasible in the long term. Fly ash and slag are currently used in 15% of cement production, but this will drop to less than 10% in the future due to decreasing supply as mentioned in Chapter 2: Barriers.[38] Some cement manufacturers interviewed believe that limestone calcinated clay is the most promising clinker substitute due to it being more available. Although it still requires heating, the production of limestone calcinated clay has a much lower carbon footprint than clinker production. One example of calcinated clay in use is Limestone calcined clay cement (LC^3), which reduces clinker content by 45%, through using a mixture of 30% calcinated clay and 15% ground limestone.[39]

New solutions are emerging which have the potential to **eliminate process emissions** associated with cement production. These solutions use alternative raw materials to limestone, like basalt, to generate clinker using **new chemical processes** without the associated process

7. **RESEARCH HIGHLIGHT**

Low-carbon cement and concrete are within the sector's direct influence; it should focus on incremental investment in alternative raw materials as carbon capture matures.

Exhibit 34. Sustainable concrete at the London Olympic Park

- The Olympic Park in London collaborated with concrete suppliers and other supply chain partners to decrease embodied carbon in their new structures. They achieved this by adopting recycled concrete and replacing part of the clinker with slag. This allowed them to save ~24% of embodied carbon.
- Beyond using a lower carbon concrete, they reduced embodied carbon emissions by an additional 15% by simply using less concrete as a result of using more efficient designs.
- Centralised procurement with strong guidance on sustainability requirements, early supply chain integration and clear understanding of concrete specification requirements at an early stage were key in improving the carbon performance of the concrete in the park.

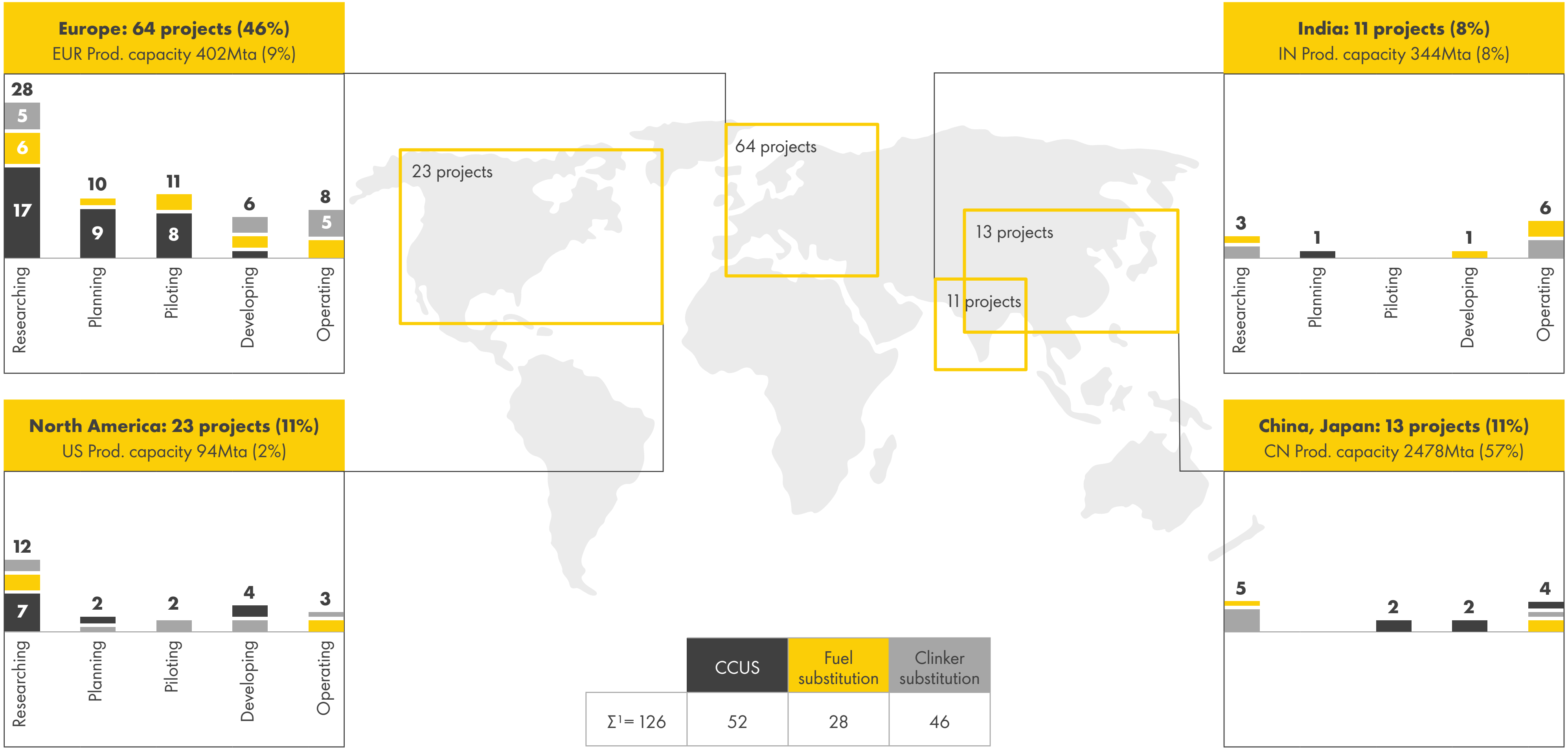
Source: Olympic Delivery Authority, European Commission, Deloitte analysis.

Exhibit 35. Cement and concrete decarbonisation options

	Clinker			Cement				Concrete	Asset structure
				Clinker substitution[1]					
	Production	Carbon capture	Alternative chemical process	Fly ash	Blast furnace slag	Calcinated clay	Other	Production	Design and construction
Description	• Multiple levers: - Improve kilns' thermal energy efficiency - Adopt low-carbon energy carriers for high temperature heating	• Capture process and combustion carbon in clinker production and utilise (inject, reuse or supply to adjacent industries) or store	• Process whereby clinker is generated using alternative chemical processes than limestone calcination, eliminating process emissions	• Industrial by-product of coal-fired power plants	• Industrial by-product of steel blast furnace	• Calcined clay stems from kaolin, sourced from clay deposits or industrial by-product	• Multiple supplementary cementitious materials e.g. natural pozzolans and bio-binders	• Shift from on-site pouring to industrialised off-site production	• Reduce concrete in structures • Substitute concrete with alternative materials (e.g. CLT) • Reuse concrete / lifetime extensions
Challenges	• Infrastructure for selected low-carbon energy carriers • Limited supply of selected energy carriers (e.g. biomass)	• CAPEX for CCUS infrastructure • Availability of storage sites (geological or industrial) • Energy efficiency	• Immature technology • Raw material supply chains • CAPEX needed (although smaller than CCUS)	• Limited and declining supply • Performance constraint: slower setting time	• Limited and declining supply • Performance constraint: harder to grind	• In pilot phase • Limited market acceptance but theoretically sufficient supply is promising	• In pilot phase • Limited market acceptance • Not included in standards	• CAPEX for industrialising production • Logistics from off to on-site • Not included in standards	• Limited market acceptance • Existing standards • Supply constraints recycled/alternative materials
Emission reduction potential 2050 (%)	30 – 40%	~90%	~90%	~40%				20-30%	20-30%

Note: 1. Part of clinker substitution can take place at concrete production stage
Source: Global Cement and Concrete Association; GNR; IEA; Research participants; Deloitte analysis

Exhibit 36. Cement decarbonisation projects and production capacity by country



	CCUS	Fuel substitution	Clinker substitution
Σ[1]= 126	52	28	46

Note: (1) The sums do not match due to initiatives addressing multiple technologies; Researching is the feasibility study stage; Planning is the concept selection and pre-investment stage; Piloting is the initial small-scale implementation stage; Developing is the project implementation stage; and Operating is the post commissioning stage; research cut off July 2022
Source: Deloitte Energy Transition cube

emissions. While these technologies are still emerging, they present an opportunity to generate zero-carbon cement, and are viable in regions where CCUS is not available. Concrete producers should look to invest in pilots to mature the technology, bring the costs down and help build the supply chains around alternative raw materials.

Finally, **alternatives to cement** exist which can be used in concrete. Admixtures with specific chemicals (e.g. hydroxylated carboxylic acids) can partially replace cement in concrete mixtures[40]. While these cement alternatives can help reduce the emissions profile of concrete, research participants expressed concerns around comparable strength and workability.

Next to the emissions reduction potential of the solutions mentioned above, **carbon capture, utilisation and storage (CCUS)** might be needed to capture remaining emissions. CCUS technology is advancing but is not available at scale, and interviewees noted cement producers are behind other sectors when it comes to exploring applications. Some CCUS pilots have been started in recent years, using technologies of varying maturity levels, such as absorption, membranes, and separation of heating and process emissions through Low Emissions Intensity Lime And Cement (LEILAC).[41, 42] The industry must now shift from studying a breadth of solutions to choosing the most suitable, and developing deep expertise. This will allow investment and focus to be centred on the best solutions, thereby accelerating expansion more quickly. Developing the infrastructure to support CCUS will take time but necessary investments can start immediately. See solution 14 for more details on CCUS infrastructure.

Solution 7: Scale low-carbon steel production.

The carbon intensity of steel production can be dramatically reduced through the adoption at scale of new but proven technologies. Technologies will vary according to geographies and will differ according to the existing age of assets and incentives provided. Although there is already some demand for green steel in the construction industry, the supply remains insufficient. As a CFO at a real estate developer stated: "We want to be a front-runner in abating embodied carbon, and we will be there fast if the supply chain provides us with the right steel with reduced embodied carbon."

The roll-out of low-carbon steel may be sped up if financiers, governments and asset owners invest jointly in low-carbon steel process technology and supporting infrastructure. See exhibit 37 for ongoing initiatives in various low-carbon steel pathways. As solutions are implemented, programmes will shift from research to testing and developing. Once this happens, production will accelerate rapidly.

Once steel plant owners have decided to redesign their production process, installing new assets still takes several years. For instance, direct reduced iron (DRI) facilities can take at least six years to design and build. Key investment areas include the design and construction of production assets, development of high-quality pellets needed for DRI, and infrastructure (explained further in solution 13).

Because the construction sector is price-sensitive, it is unlikely to drive demand for low-carbon steel on its own. It will therefore benefit from growth in demand for low-carbon steel from other sectors, such as the automotive sector which is willing to pay a premiums. Some of the largest automotive manufacturers are even working with steel producers to accelerate programmes[43]. In contrast to subsectors where competition for supply will be a disadvantage (e.g., renewable energy), the construction sector will benefit from this demand for low-carbon steel. Because plants require total conversion to produce steel, once new technologies have been adopted, it will become available at scale to all sectors.

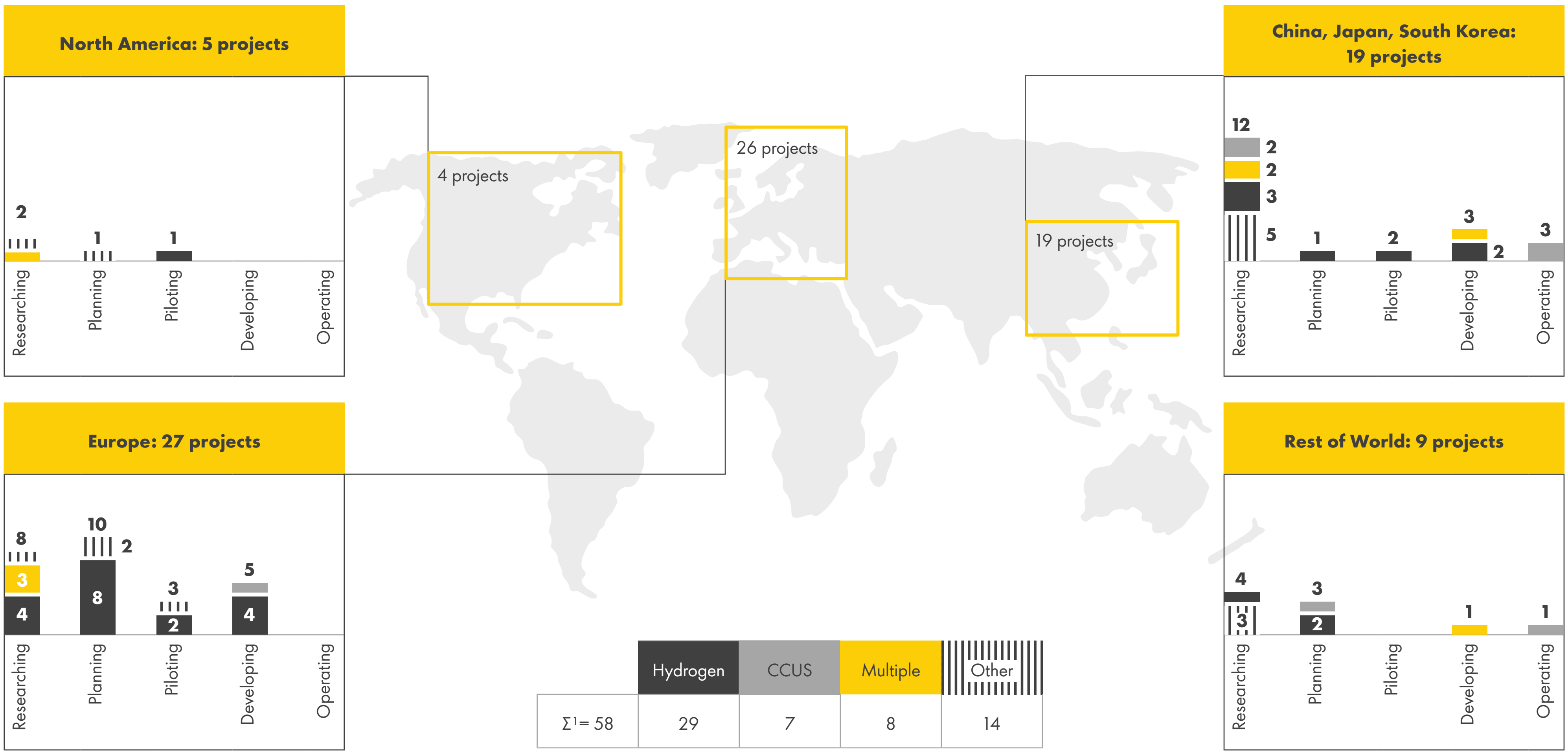
When end market demand is encouraged and subsector supply is incentivised, production will increase as companies invest in new technologies. With this increase in production, and the increasing carbon prices in cap-and-trade schemes, low-carbon steel will eventually reach cost parity with conventional steel. Construction's demand for low-carbon steel will likely increase as production capacity increases and the low-carbon price premium decreases.

For more information, read the report "Decarbonising Steel: Forging new paths together".

8. **RESEARCH HIGHLIGHT**

Demand for low-carbon steel from the automotive sector will also improve its availability for construction, while demand from many other sectors will lower production costs for low-carbon fuels and carbon capture.

Exhibit 37. Steel decarbonisation projects by region and stage



Note: (1) Researching is the feasibility study stage; Planning is the concept selection and pre-investment stage; Piloting is the initial small-scale implementation stage; Developing is the project implementation stage; and Operating is the post commissioning stage; Research cut off is July 2022.
Source: Deloitte Energy Transition cube

Solution 8: Develop and adopt alternative materials.

Developing alternative materials, scaling existing ones, and circularity through waste management and re-use will allow for the displacement of steel and cement from the sector, reducing emissions. Within the construction sector, alternative materials are emerging that present viable alternatives to today's materials, such as wood and bio-based polymers. Circular materials are also gaining traction, with the re-use of some materials and components increasing rapidly in certain end markets like road construction.

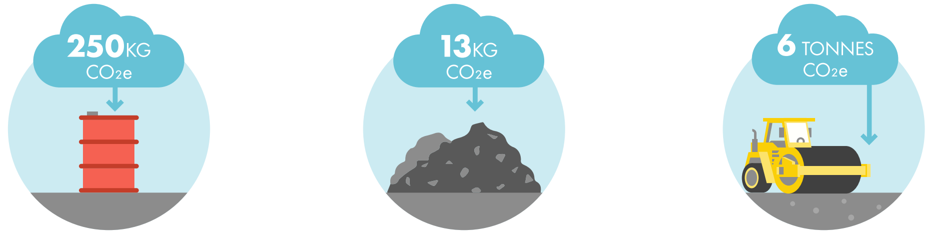
For example, **low-carbon asphalt** represents both an alternative and a circular material with up to 90% reuse of the material, directly in new roads.[44] In addition, there are advantages of enhancing a well-established material. As an academic observed: "Rather than introducing another alternative, the conversation should be about how to get there faster for asphalt. We need to build trust, capacity and carbon solutions of these existing materials." Asset owners will be an important influencer to create demand for low-carbon and recycled asphalt in order to build net-zero roads. In order to do that, they need to consider decarbonisation as one of their strategic priorities. As seen previously, and unlike the majority of the other players in the construction value chain, many of the asset owners in construction still don't consider it as one of their top three priorities. A CEO of an infrastructure owner said, "We need roads. Without them, you can't have an economy – but we also have to decarbonise rapidly. If we don't decarbonise, we won't get investment in the road network."

In addition to innovation in traditional materials, we also expect to see new materials enter the market that we haven't even conceptualised today.

Sustainability Director, industrial EPC contractor

Reducing the emissions of asphalt can be done in the production and subsequent use phases. In the production phase, the key technologies are low-carbon energy to heat the asphalt mixture, use of alternative asphalt mixtures with specific additives that require less heat, or bio-based binders. In the use phase, key options are asset-lifetime extension, or increased asphalt recycling (see exhibit 38 for an example of Shell and Aggregate Industries' biogenic asphalt).

Exhibit 38. The effective carbon sink created by Shell Bitumen CarbonSink reduces carbon footprint by



per tonne of bitumen[1] | per tonne of asphalt[2] | locked per km of road[3]

Carbon reduction on its own might reduce our footprint but won't counteract ongoing emissions.

Carbon removal and storage is key to achieving and maintaining net zero.

UK's first biogenic asphalt

- Shell and Aggregate Industries launched the UK's first commercially available biogenic asphalt. This asphalt contains a special binder with biological materials. As biological materials trap carbon from the atmosphere while growing, this effectively turns a road into a technical carbon sink without affecting performance.
- Biogenic components remain locked in the road surface even when it is recycled at the end of its life, preventing the release of biogenic carbon back into the atmosphere. The high recycle rate of asphalt not only supports a circular economy, but also ensures the carbon remains locked in the road.

Notes: 1) Based on the biogenic carbon component used. 2) Based on 5% binder content within the asphalt mixture. 3) Based on a model single surface layer with 50mm depth, 3.5m wide, 5% binder content.
Source: Shell, Aggregate Industries, Deloitte analysis.

Another example is **cross-laminated timber** (CLT), a promising alternative to traditional structural building materials. In some cases, CLT is already cost-competitive with steel or concrete[45]. CLT is being used in low-rise residential buildings and its potential for large-scale projects is demonstrated by its use in some skyscrapers, such as the Mjøstårnet tower in Norway[46] or the C6 building in Perth, Australia[47]. The use of CLT could be accelerated if the construction sector secures supply from forestry and educates architects, engineers, and contractors how to use it effectively. Though CLT can provide a valuable low-carbon alternative to steel, global timber supplies are limited.

Solution 9: Roll-out low-emissions equipment.
Low-emissions equipment must be rolled out faster and this depends on grid accessibility, supply of renewable power and the development of hydrogen fuel cells, especially for use in remote locations or heavy-equipment applications where batteries may never be viable.

Several interviewees anticipate that their fleets will be fully electric by 2030. The production and supply of electrified equipment is likely to increase in pace with the supply of electricity from renewable sources required to charge it.

As one Head of Construction at an EPC contractor said: "We convinced our client to buy their solar panels on the first day of the project. We then used them to power our cabins for more than a year before we installed them at their building to use for decades." This example demonstrates how early installation of energy infrastructure can power construction activities and, after completion, the asset itself.

A key consideration is how to organise access to existing infrastructure, and this requires diligent forward planning to minimise unnecessary start-up delays. New ways of working, like digital planning tools, are needed to manage when and how machinery connects directly to the grid, charges electric batteries or refuels with hydrogen. In this regard, manufacturers that offer more advanced machines and smarter working methods (e.g. fastest and most convenient charging) will have a distinct advantage over those who have not invested in such research and development.

As infrastructure is developed, manufacturers can continue to build these advanced machines and methods in order to create and maintain a competitive advantage. Most equipment weighing less than 30 tonnes can be electrified, but heavier equipment on remote sites might require much larger power sources than onsite solar panels or grid connections can provide. In such cases, hydrogen-powered equipment may be a better fit. Exhibit 40 outlines the decarbonisation pathways for a selection of common construction equipment. A sustainability director of an equipment manufacturer said: "It is reasonable to have hydrogen fuel cell machines commercially viable in the second half of this decade. And, with more battery electric machines, we expect that we will see more and more machines being rolled out from now on." Another way contractors can speed up their transition is by sharing the required investments – for instance, by using shared equipment pools (see exhibit 39).

In the short term, biofuels can be a solution, as they can be used as drop-in alternative fuel for most equipment in use today. However, interviewees highlighted that in the intense competition for low-carbon molecules across sectors, it is unlikely that biofuels will be a long term viable solution for the construction sector.

Exhibit 39. Zero-emission construction site

- As part of Oslo's climate strategy, all construdion sites on behalf of the municipality must be fully electric by 2025.

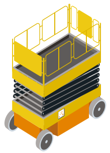
- To get initial pilots off the ground, the city incentivised electric construction sites by covering all electricity costs and it has presented a roadmap that highlights the need for electric vehicles in the future. Additionally, the city has guaranteed an equipment leasing company that their machines would be used in the pilot project.

- Results are promising. By using electrified construction equipment, one project saved 92,500 kg of CO_2 while reducing ambient noise and local air pollution, compared to the use of regular machines.

Source: Eurocities, European Commission, Deloitte analysis.

Exhibit 40. Decarbonisation pathway selected equipment

○ Not adopted
◑ Partially adopted
● Fully adopted

		Power	Earth moving			Material handling	Access		
		Generator	**Excavator**	**Wheel loader**	**Mini excavator**	**Telehandler**	**Mass boom lift**	**Articulating boom lift**	**Scissor lift**
									
Max. load (tonne)		-	8 - 90	6 - 240	1 - 30	4 - 15	1 - 3	5 - 15	1 - 7
Current energy carrier		Diesel	Diesel	Diesel	Diesel	Diesel	Electricity	Electricity	Electricity
Emissions (tonne CO_2/year)		**23**	**10**	**7**	**4**	**5**	**1**	**1**	**0**
Decarbonisation	Pathway[1]	Hydrogen Short term: biofuels	Heavy equipment: Hydrogen or off-board electric Light equipment: Battery electric Short term for all types: biofuels			Battery electric			
	Current adoption	◔	◔	◔	◔	◑	◑	◑	◑

← ~80% of equipment sales volume → (Generator to Mini excavator)

Note: (1) Pathways depend on asset type and asset use, including factors like location, fuel availability, proximity to infrastructure, environmental conditions etc.
Source: Climate Neutral Group, CECE, Interviews, Deloitte analysis

ROLES

Solution 10: Develop talent and increase knowledge sharing.
New skills, such as low-carbon material development and data analysis, will be needed to help develop the required technologies to support decarbonisation and deploy them when they are ready.

Attracting new and diverse talent is key to innovation in the sector. Transformational technologies and ways of working must be developed, which can often be helped by bringing in a new perspective from younger people. As noted by the CEO of a large EPC: "It's tough to expect someone who has done the same thing for 25 years to think outside the box; they have never known anything different. We need to bring in leading thinkers from outside of the sector to challenge the way things have always been done." Many interviewees mentioned that although the sector often struggles to attract younger workers, the challenges of decarbonisation could offer them exciting opportunities to build careers in an area where large changes are likely to occur. Another option for the sector is to attract skilled workers with decarbonisation knowledge from other sectors or to engage more actively with start-ups.

9. **RESEARCH HIGHLIGHT**

Improving workforce capabilities around sustainable and digital solutions will drive efficiencies across the project lifecycle.

Upskilling the existing workforce's skills will also be needed to change the sector mindset and establish the ways of working required to decarbonise. Existing workers will need to learn how to operate new equipment, such as 3D printers, and use new fuels or digital solutions (e.g. building information modelling [BIM], analytics and data reporting). This can be done at scale through investment in training institutions, new on-the-job programmes and collaboration within the value chain.

As noted by the Head of Sustainability for one contractor: "We are taking our 4,000 – 5,000 suppliers on an awareness journey for the next two years. Nearly 100% said they don't have a sustainability policy, so we are going to hire an ESG supply trainer to teach them." Governments and companies can provide incentives by asking employees to meet qualification standards or by sponsoring programmes. Together with industry associations, they can play a role by helping develop new programmes and rolling them out across their membership base.

Elevating sustainability professionals within an organisation will help them shape business decisions more effectively. Sustainability experts are increasingly sitting on executive boards and reporting to chief executives. Between 2011 and 2020, the number of chief sustainability officers (CSOs) across Fortune 500 companies increased by 228%.[48] Interviewees expect this trend to extend to the construction sector, which will help ensure a serious focus on decarbonisation. A CSO at a leading building contractor said that: "When the role was created and I was promoted into it, I noticed that I was viewed with greater credibility than before and that it has been easier to propose and implement new initiatives." As a first step, organisations can divide the Health, Safety and Environmental Officer position into two roles: one for health and safety, and another for environmental sustainability. This will ensure sustainability leads can have necessary time and resources to make an impact on decarbonisation.

> We are embedding green skills across every level of seniority and in every business unit. Everyone will need to have some form of new awareness or skills in order to support [our company's] net-zero goals.

HSE Director, building owner and operator

Solution 11: Adopt more holistic contract models and public-private partnerships.

The sector should improve collaboration across project lifecycles by expanding the contract models to include all project stages and value chain participants (see exhibit 41). When combined with tools like LCA, this would allow for more holistic decisions to be made around reducing carbon emissions of construction.

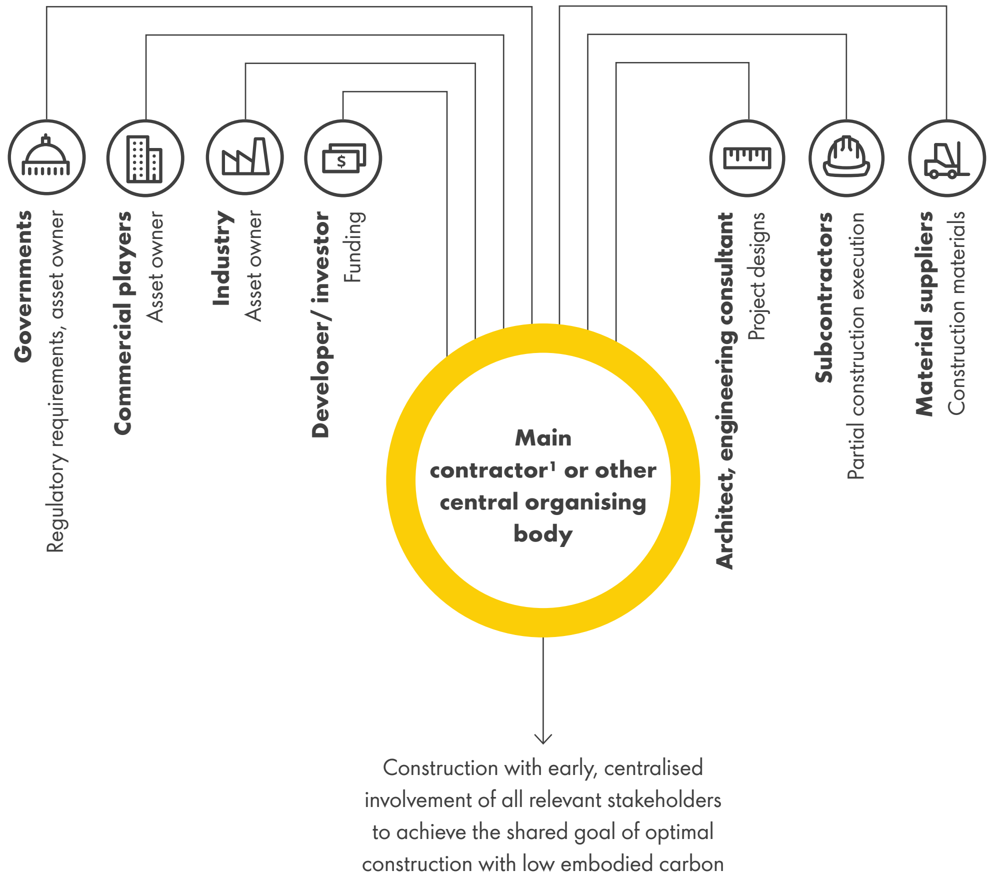
Early contractor involvement (ECI) includes contractors in the early project stages alongside the clients, consultants and suppliers. ECI brings deeper technical understanding of new solutions into the decision making process, and results in improved construction efficiency. It also helps ensure the teams on the ground are bought into the broader objectives of the project. A project director at an industrial EPC contractor emphasised: "We will always be restricted by time in ways our clients are not. We finish a project in three years, but they own it for 60. So, we always consider how to partner with our clients to offer elements they might not have asked for, but that will benefit them in the long run."

Other examples of new contracting models include "design and build" (D&B) and "design, build, finance, maintain, operate" (DBFMO). D&B and DBFMO contracts give contractors greater influence than with ECI models in the design and construction stages, or even expand responsibilities to financing and operations of the asset. This aligns priorities across the value chain, as the contractor can also be the designer and, in some cases, the financier and operator. These aligned priorities will encourage considering lifetime emission trade-offs and the adoption of green premiums. These contract models also offer contractors more opportunity to influence the budget, design and choice of suppliers for projects and set timelines that include the use of low-carbon materials.

> When clients ask us for input early on, we can give advice based on previous work and help them bring both their carbon and costs down.

Executive at a building contractor

Exhibit 41. Early contractor involvement model - ILLUSTRATIVE



Note: 1) An EPC contractor typically does have inhouse engineering
Source: Interviews, Deloitte analysis

IMPLEMENTATION

Solution 12: Make design and execution more efficient.
Construction sector participants should implement designs, processes and technologies that enable them to manage materials throughout the design and execution of projects more efficiently (see exhibit 43). Designing projects in modules and using digital tools, such as LCA calculators, can help reduce over-specification and waste by allowing for an easier comparison of the amount of embodied carbon in various materials and designs.

Designing projects in modules can reduce waste by more than 80%, thanks to repeatable, standardised, indoors and industrialised production processes.[49]

Although this is common in industrial construction projects, it is not for buildings. Modular designs can be adopted en masse with the right incentives from governments and asset owners to invest in production facilities, as done in Singapore for instance (see exhibit 42). Economies of scale can reduce both financial cost and carbon emissions.

Exhibit 42. The world's tallest modular building

- In 2019, construction was finalised on the tallest modular buildings in the world, two 56-story apartment buildings in Singapore.

- Modular construction is a relatively new approach in the construction sector. By standardising modules and building mostly off-site, the required time and manpower can be reduced while potentially improving work site safety and reducing both absolute and local impact of construction. In the Singapore example the team estimated that local environmental impact was reduced by 70%.

- Singapore's strategy is to increase adoption of Design for Manufaduring and Assembly (DfMA) to 70% by 2025. Modular building of components and modules is a key component of DfMA, and will therefore likely become much more commonplace.

Source: BCA Singapore, Deloitte analysis.

Exhibit 43. Efficiency improvement options

◔ Limited adoption today
● Strong adoption today

	Asset design efficiencies			Construction activity efficiencies				Material manufacturing efficiencies
	Reuse	**Lightweight design**	**High-strength materials**	**Industrialised, modular and off-site components**	**Planning**	**Procurement**	**Execution**	**Operational optimisation**
Description	Reuse and renovate existing assets' foundations, structures and/or components (e.g. facades) to eliminate need for new materials	Design lightweight assets (e.g. through better 'generative' structural designs) to reduce amount of materials required	Specify high-strength materials (at lower volume) rather than high quantity	Increase use of modular design, manufactured off-site with higher efficiency through industrialisation	Use advance planning tools (e.g. BIM, simulation) to optimise procurement, logistics and working methods	Procure specified material amounts (e.g. through mass customisation) to avoid wastage of over ordering and cutting losses	Deploy innovative execution tools (e.g. 3D printing) with higher precision and less wastage	Optimise manufacturing processes (e.g. cement, steel) for higher material and energy efficiency
Emission reduction potential 2050[1] (%)	30-50%	20-30%		30-50%[2]	20-30%			10-20%
Current adoption	◔	◔	◔	◔	◑	◔	◔	◑

Note: 1) Potential based on interviews with research participant; options overlap; 2) Based on a single study on 879 homes in the UK
Source: Interviews; American Institute of Architects; E&T (2022); Mohammed et al. (2020); Deloitte analysis

Decarbonisation, and also the advancements in technology, can act as catalysts for change and help embed efficiencies in construction activities across the value chain.

Sustainability Director, building contractor

Digital tools, such as LCA calculators, Building Information Models (BIM), and Internet of Things (IoT) platforms can allow for greater precision during planning and execution. Advanced engineering tools can also allow for more complex structural needs. For example, 'generative design' allows engineers to input a project's requirements into software. Artificial intelligence then presents solutions based on the parameters.[50]

Using the same tools and information in the design and execution phases can ensure that planned carbon reductions actually occur in practice, something that is not always evident in the sector's siloed way of working today. An industry association's CEO said: "Using 4D BIM will reduce timelines, but also the need for people sitting about doing nothing with their engines running." These tools could also be used to assist procurement or sub-contractor selection (see exhibit 44 for an overview of how digital tools may be integrated in the future).

During construction, processes can be optimised through improved logistics or reduced materials waste. This could include initiatives like smart logistics through city hubs, where deliveries to urban construction sites are merged in an efficient and timely manner, or real-time materials tracking to make sure all materials are delivered just in time and at the right quantity. Another example is onsite 3D printing, which improves adherence to schedules and the efficient use of materials by automating manual work. It also increases precision and allows more optimised computer-generated designs to be built. 3D printing can also offer cost savings, but a reliable figure has yet to emerge. For instance, the Dubai Future Foundation projects that Dubai's goal to construct 25% of buildings using 3D printing by 2030 will reduce building costs by 90%.[51] However, Apis Cor, a construction 3D printer start-up, projects more modest savings of 25 – 40%.[52]

More complete and accurate data allows project teams to make better informed decisions. As a sustainability director at a building contractor said: "3D design is only as good as the information that is added to it." This should not inhibit the construction sector to start working with the tools and data available today. As a topic expert at an industry association said: "Perfect shouldn't be the enemy of good. We need to be developing and improving systems, but we need to keep acting with what we have."

Beyond companies' own data initiatives, industry associations or government bodies can collect data and host databases for all organisations to access. Over time, tools will be improved and organisations should be able to access the same datasets.

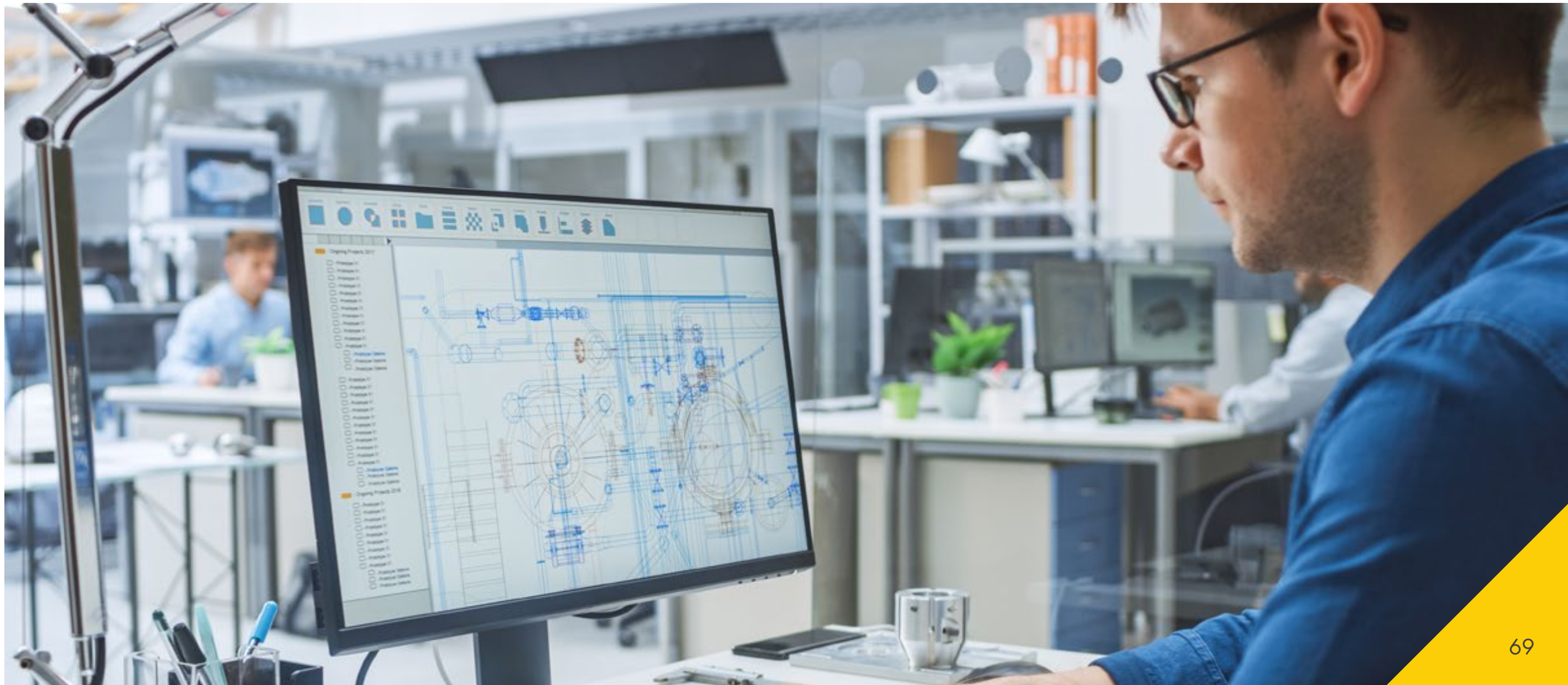
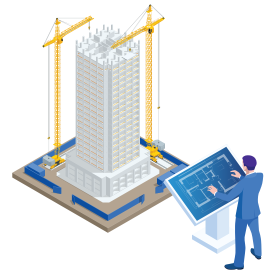


Exhibit 44. Digital tools used in a construction project across its life cycle

Design and engineering		Construction			Use	Deconstruction and reuse
						
As the architectural team creates asset design concepts, they quickly evaluate design choices based on material **Lifecycle Assessments** (LCAs) using LCA calculators' generic emission data. The design tool identifies possible improvements, e.g. through parametric design modelling. As a result, embodied carbon is forecasted for the asset.	The chosen concept is uploaded to the **Building Information Model** (also used for infrastructure), which will serve as the central database for all information about the asset throughout construction. It uses a shared data model with the 3D model, and additional dimensions such as costs, project timelines, the construction method and the forecasted embodied carbon of the asset. This provides optimised process planning.	As the procurement teams evaluate subcontractors, they reference supplier specific **material passports** to track the emissions and potential to reuse each component. **Environmental Product Declarations** inform suppliers how to produce the material passports, so they can exchange emissions data based on common methodology. When the material passports are collated, they form a building (asset) passport.	The procurement team finds materials with equal or lower emissions data than forecasted in the design stages. As they finalise decisions, they update data in the information model. This updated embodied carbon forecast replaces the previous LCA forecast.	As contractors complete construction, they monitor the materials and energy used, and how that impacts the asset's emissions. The information model is used to efficiently plan timelines (including when to charge/refuel equipment), manage deliveries and reduce waste. This helps the actual emissions to stay accurate to plans. By monitoring emissions, the actual embodied carbon of the asset is measured and reported.	As the building or infrastructure is used, every renovation updates the Information Model with the new material passports. This way, a continuous building passport can be maintained.	When the asset is at the end of its life, the material passports are used to identify which materials can be reused and how. Their material passports follow them to the next stage of use. This allows future assets to reduce their embodied carbon.

Solution 13: Update design and material standards.
Updated design and material standards will accelerate the adoption of low-carbon materials and new ways of working. They help create a common understanding across the sector of the emissions and technical attributes associated with materials and activities, and are needed before new technologies can be deployed. Decarbonising construction will require existing standards to be updated, new standards to be created, and a more agile process to ensure standards keep up with the pace of technological change in the market. As an example, a new type of cement with a low-carbon substitute for clinker needs to be accepted by regulators and construction companies as a viable alternative to other types of cement before it will be used.

Governments will play a critical role in establishing enforceable standards, but industry groups and private companies can establish voluntary standards that go beyond what is legally required. Voluntary standards are already being widely adopted with the goal of reducing operating emissions and have been shown to drive change (see exhibit 45). Individual companies can also set their own standards and encourage others in the sector to follow. Certification companies like BREAAM and LEED can also provide frameworks for standards which must be met to achieve a certification. While some authorities require certification, some organisations can choose to opt in for marketing purposes or to follow guidance on best practices.

Existing standards need to be updated to reflect embodied carbon. For materials, this means adding emissions data to make it easier to perform carbon footprint calculations and understand emissions trade-offs between products. For design, this would include specifying maximum material amounts to avoid waste. One building contractor's Business Unit Managing Director noted, "We tend to over-engineer buildings. Because cement is very cheap, it is easier and faster to add more than we need." This can be seen on the supply side as well, with one cement producer's Head of Sustainability noting, "People always say 'better to put a few more kilos into the mixture', which is due to the situation 40 years ago when the quality control inside cement factories was not as advanced as it is today. We can reduce 15%–20% production if you use just what is needed in the calculations."

Design standards especially must be updated to enable the use of emerging technologies and building processes. A lack of approved standards has become the bottleneck in some cases, resulting in higher-emission alternatives being chosen.

Faster standard-setting processes are needed. If standards do not keep pace with the rate of technological change in the market, they will be, and already are, an obstacle to innovation. Performance-based standards can set new benchmarks that will need less-frequent updating. Instead of specifying specific feedstock or ratios, performance-based standards allow any process to be used as long as it meets necessary specifications around, for example, strength, shrinkage, or permeability. Some companies are shifting to performance-based standards, but it is not yet sector-wide.

> The more standards are harmonised across end markets and geographies, the bigger the drive for innovation becomes.
>
> Executive, engineering firm

Exhibit 45. UK RICS standards on LCAs

- Whole life carbon assessments were not mainstream and when they were performed, companies interpreted European standards differently, using a variety of assessment plans and reporting structures.
- The UK's Royal Institution of Chartered Surveyors (RICS) recently demanded members to adhere to its guidance on whole life carbon assessment, aligned with European standards.
- The standards include a minimum requirement that every project must complete an LCA before the technical design stage of the project. It also lays out minimum requirements for the assessment, such as parts and life stages to be included, and standardises elements.
- The standards ensured that member practitioners had clarity and could create consistent outputs, which increased uptake of LCAs.

Source: Royal Institution of Chartered Surveyors.

Solution 14: Secure supply of renewable energy and build distribution infrastructure.

Significant amounts of renewable energy will be required to power the technology pathways described in this report. This will require security of renewable energy supply and distribution infrastructure. It will also require infrastructure for the carbon flows from CCUS technologies.

As other industries decarbonise, competition for renewable energy will increase. Exhibit 46 indicates the amount of energy that will be needed to decarbonise steel, for example.

In the short term, there will be high demand for renewable energy but insufficient supply. To secure supply, construction sector participants can set up power purchase agreements, co-invest in new generation projects with energy providers, or work with regulators to ensure the increased energy production reaches the sector. For example, a German cement company recently secured a fixed price hedge for renewable electricity by signing a 10-year power purchase agreement with a provider.[53]

Where possible, materials producers should look to locate new facilities close to industrial hubs where early green hydrogen and green electricity projects are beginning to emerge. An example of this is the UK's East Coast Cluster across the Humber and Teesside, where coalitions of industrial (including steelmakers) and energy companies aim to

Exhibit 46. Decarbonising steel using H_2-DRI – high-level infrastructure sizing (2020)

~1000 Mt steel used in construction

Requires 2700× (81 Mt) the 2020 global green hydrogen production (30 kt)

which is 5× (477 GW) the total global electrolysis pipeline until 2030 (91 GW)

Notes: 1) Assuming 1t steel requires 80 kg hydrogen with H_2DRI-EAF; 2) Assuming 1 GW electrolyser capacity delivers 170 kt H_2 p.a.
Source: Worldsteel; IEA global hydrogen review 2021; PBL & TNO – Decarbonisation options for the Dutch steel industry; Deloitte analysis

deliver and use 70% of the UK's 5 GW 2030 hydrogen production capacity target.[54]

Construction projects often need temporary power supply in remote areas, or to connect to permanent infrastructure like municipal power grids. The first electric construction pilots and vehicles should be rolled out in areas where grid connections are available. Where possible, construction planning should be adjusted to ensure the power supply for electric equipment is available early in the process, for use by electric construction equipment and logistics. As electric fleets scale, contractors will need to work with utilities and governments to upgrade grids and ensure access to power.

Finally, **new infrastructure will be needed to capture, transport and store CO_2** as CCUS begins to scale. Partnerships should be established with other sectors who also need CO_2 transport and storage infrastructure, like agriculture and industrial manufacturing plants, to help expand the market. Partnerships or long-term offtake agreements can also be set up with industries looking to use carbon in industrial processes – like the production of synthetic fuels (see exhibit 47). This dynamic was summarised by a large steel producer's CFO: "We are not the only industry who needs to move and store carbon. It is going to be expensive, but if we can share that cost with these other sectors, it will move faster and ultimately be better for all of us."

Exhibit 47. CCUS in practice – high-level sizing (2050)

Notes: 1) CO_2 processed into synthetic fuels will eventually still be emitted into the atmosphere, therefore emission reduction through synthetic fuels only accounts for 50% emission reduction; 2) Requires significant amounts of green hydrogen from renewable electricity to gain full emission benefits; 3) Production facilities (e.g. steel, cement) typically not placed with CO_2 storage/renewable energy availability in mind, increasing need for pipeline infrastructure
Source: IEA – about CCUS (2021); Shell – Decarbonising Aviation: Cleared for Take-off; Deloitte analysis

Solution 15: Increase circularity and systems thinking.
Designing construction projects that support circularity is one of the most significant ways to reduce emissions. Rather than demolishing structures and rebuilding new assets, projects should be designed to transform, renovate and upgrade existing structures. For example, the retrofit of a London office used the existing foundation, steel frame, and façade to save 90% of the embodied carbon of a new build.[55]

10. **RESEARCH HIGHLIGHT**

A system-level approach is needed to optimise decisions around emissions, with better linkages between different parts of the value chain.

11. **RESEARCH HIGHLIGHT**

Decarbonisation will be a catalyst for embedding efficiency and minimising unnecessary emissions throughout the sector.

We need to apply the carbon-reduction hierarchy, and step one is to build nothing at all.

CEO, infrastructure owner and operator

Other circularity improvements include initiatives like:

- Design for reuse, e.g. modular design; replaceable facades;
- Trace materials through their life, e.g. using building material passports (see exhibit 48);
- Urban mining and waste management, which ensure the materials are physically disassembled, stored and distributed to be reused, rather than being demolished and landfilled.

If this is done correctly, materials can retain value over their lifetime and be recycled, so the need for manufacturing new virgin materials declines.

In addition to how assets are designed, they can be planned in a way that will support the growing population's needs. It will be key to consider the function of an asset, its role in its surroundings, and the societal value it creates. If assets are designed with this in mind, they will likely be more fit for future purpose, reducing the amount of new construction necessary. For example, placing housing, amenities and places of employment close to each other decreases the need for travel, which could require less infrastructure to be built per capita. Another example is to build apartments rather than single-family homes. A former CEO of a building contractor said that "Meeting our current housing demand and being net zero is not feasible."

We need to be smarter about how we build homes and designing them to fit more people.

In order to support such systems-planning, **integrated systems-thinking is critical**. Across the value chain, from materials manufacturing to asset planning and design, companies can support (and be supported by) other industries. The construction industry will interface with urban planners, regulators, energy and utilities providers, retailers and numerous other sectors to help each other decarbonise in a way that builds better and smarter spaces.

Exhibit 48. Material Passport – Building As Material Banks (BAMB)

- Recovery and reuse of components or materials from buildings requires detailed information to be effective. The electronic Material Passport as developed by the BAMB project (Building As Material Bank) aims to assist by describing defined characteristics of materials in products that give them value for recovery and reuse. This allows buildings to be "stripped for parts" rather than be demolished, because the owner knows exactly the value of the building's components.

- Material Passports allow for the creation of new business models where the reusable material value of the building is a known part of the asset and buildings are designed with such values in mind. This supports the transition of the building industry from linear to circular.

Source: BAMB, TU München, Deloitte analysis.

The Roadmap: Accelerating Decarbonisation in Construction

HOW THE SOLUTIONS COME TOGETHER

The 15 proposed solutions encompass both the measures required to decarbonise the construction sector and the conditions needed to adopt them. Interviewees recognise that no single solution will be enough, but that all solutions must play a role. Overall, actions to decarbonise construction should follow this sequence:

- **The short term (2023 – 2030)**: Adopt ready-now solutions and lay the foundation for lower-carbon alternatives;
- **The medium term (2030 – 2040)**: Expand adoption of lower-carbon alternatives
- **The long term (2040+)**: Scale all solutions across regions and end-markets.

The short term (2023 – 2030)

During this phase, the industry will focus on accelerating activity that is already underway by implementing technical solutions that are available today and creating the conditions required for future change. Immediately and over the next few years, the industry, especially construction companies and engineering consultants, can make design and execution more efficient by using modern tools and practices to reduce waste and cost, thereby improving the bottom line and carbon footprint at the same time.

Increasing awareness around embodied carbon will be foundational to create the momentum and accelerate emission reduction initiatives. Industry associations can play an important role.

It is also important to offer construction subsectors stronger encouragement to invest in the early-stage technologies which will enable a net-zero emissions future. This can be achieved if coalitions of asset owners and construction companies activate and aggregate demand, financiers create new incentives through green financing standards and investment, and regulators put in place stronger polices to stimulate low-carbon assets and low-carbon solutions. Regulators must update design and material standards to help implement new technologies and ways of working. The sector as a whole must also develop the new skills required, where engineering consultants and industry associations can make an impact to both asset owners and construction companies.

Continued R&D and pilot programmes will be essential to develop new alternative materials and continue to scale technologies and lower costs, even though for some, such as low-carbon cement and low-carbon steel, it is unlikely they will be economically viable at scale before 2030. There may be some exceptions. Projects that are close to the first point of supply or with customers willing to pay high green premiums may scale more quickly. To illustrate, rolling out zero-carbon equipment is likely to increase in the short term because this technology is already becoming available and adopted. The city of Oslo, for example, requires zero-carbon equipment to be used on municipal construction sites. These cases can provide valuable insights for the rest of the sector.

> Decarbonising construction is not like decarbonising aviation – it is not just about changing fuels. We need new energy carriers, new processes, new materials, and new ways of building. We are going to need to use every technology available to us to get to net zero, without everything being ready today.
>
> Head of Sustainability, engineering consultancy

The medium term (2030 – 2040)

The solutions that were the focus of the short-term phase are continuously strengthened through bolder commitments, tighter regulation and new standards to maintain the environment for change. Having now put in place the supporting conditions, the medium-term phase entails widely adopting the more foundational technologies required to decarbonise, such as low-carbon materials which drive the majority of construction emissions. These solutions have started developing in the short-term phase, but become more widely available in the medium-term (2030 – 2040). Material manufacturers and researchers play a pivotal role, with asset owners and financiers as a critical enabler. This includes expanding investment in low-carbon cement and concrete, scaling low-carbon steel production, and adopting alternative materials, all of which are enabled by increasing circularity and systems-thinking.

Adopting more holistic contract models and public-private partnerships between asset owners and construction companies will enable them to align strategic priorities between stakeholders, which facilitates making more low-carbon decisions at a project level.

Finally, securing the production and transportation infrastructure for renewable energies is important given it is a key technological enabler for low-carbon materials and construction activities as they begin to enter the sector beyond the pilot phase. This is where energy companies can make a huge impact.

As noted by the CEO of a large infrastructure contractor, "The first investment and regulation only gets us to the starting line. Once we start to see the first green projects, these things need to intensify to make sure we get to the finish".

The long term (2040+)

At this point in time, the solutions described in this report will be in practice but that does not mean they will be widely deployed globally or that the sector will be at net zero. As low-carbon construction projects become common practice, the industry and regulators will need to maintain the conditions for change and expand the infrastructure necessary to allow decarbonisation to occur at scale, globally.

Note that solutions are not exclusive to each of these phases. All proposed solutions have a role over the entire timeframe explored, but the focus should shift over time.

The sector must organise to deliver this broad range of solutions. Many of the solutions require participation from multiple stakeholders across the value chain. As noted by an EPC executive: "No one can do this by themselves. The solutions we are talking about will require effective collaboration across the sector". Exhibit 49 summarises which stakeholders will need to initiate solutions by playing a leading role, and other stakeholders who will need to be engaged to play a supporting role.

Overall, asset owners and developers play an important role in initiating and funding low-embodied carbon projects. Regulators and financiers can reinforce this by helping to create the incentives required for investment and drive the demand for low-carbon construction. Construction companies play a central role in orchestrating the transformation. Their role covers everything from creating demand signals for low-carbon materials and equipment at scale, to applying these in their operations and developing talent to do so. Materials and equipment manufacturers will be responsible for leading the development in their areas. Meanwhile, energy companies can provide the renewable infrastructure to power the transition.

Coalitions can help accelerate action by bringing actors together from across the value chain around a shared objective. This could reduce the risk associated with early investments by sharing it across multiple parties. For example, the Hybrit consortium brought together an iron ore producer, steel maker and power company that, in 2021, made the world's first consumer delivery of steel produced with hydrogen instead of coal.[56] Similarly, end market coalitions can be vital in ensuring a strong business case for materials producers to switch to low-carbon production.

Exhibit 49. The roadmap for decarbonising construction

Short term (2023 – 2030)

The sector should look for opportunities to adopt medium-term solutions as early as possible while keeping the focus on adopting all ready-now solutions.

Adopt ready-now solutions and lay the foundation for zero-carbon alternatives

1. Increase awareness around embodied carbon
2. Activate and aggregate demand
4. Adopt policies to stimulate demand for low- and zero-carbon assets
5. Stimulate development of low-carbon solutions through policies
8. Develop and adopt alternative materials
9. Roll-out low-emissions equipment
10. Develop talent and increase knowledge sharing
12. Make design and execution more efficient
13. Update design and material standards

Medium term (2030 – 2040)

Expand adoption of lower-carbon alternatives

3. Generate green financing standards and expand investment
6. Invest in low-carbon cement and concrete pathways
7. Scale low-carbon steel production
11. Adopt more holistic contract models and public-private partnerships
14. Secure supply of renewable energy and build distribution infrastructure
15. Increase circularity and systems thinking

As the adoption of lower-carbon alternatives begins to expand, short-term solutions should continue to be strengthened and adopted in markets where decarbonisation is just beginning.

Long term (2040+)

Scale all solutions across regions and end markets

Commitments and incentives should continue to evolve, and technology solutions and required infrastructure should be rolled out at larger scale as demand increases and new use cases become viable.

Exhibit 50. Lead and supporting roles in decarbonisation solution themes

Term	#	Solution theme	Construction companies	Material manufacturers	Equipment manufacturers	Engineering cons. and architects	Research and academia	Owners and operators	Financiers	Regulators	Energy companies
Short term (2023-2030)	1	Increase awareness around embodied carbon.	Lead	Supporting	Supporting	Lead	Lead	Lead		Lead	Supporting
	2	Activate and aggregate demand.	Lead			Supporting		Lead	Lead		
	4	Adopt policies to stimulate demand for low- and zero-carbon assets.	Supporting				Supporting	Supporting		Lead	
	5	Stimulate development of low-carbon solutions through policies.	Supporting	Supporting	Supporting	Supporting	Supporting			Lead	Supporting
	8	Develop and adopt alternative materials.	Supporting	Lead		Lead	Lead	Lead	Supporting	Supporting	
	9	Roll-out low-emissions equipment.	Lead		Lead						Supporting
	10	Develop talent and increase knowledge sharing.	Lead			Lead	Supporting	Supporting	Supporting	Supporting	Supporting
	12	Make design and execution more efficient.	Lead	Supporting	Supporting	Lead					
	13	Update design and material standards.	Supporting	Lead		Lead	Supporting	Supporting		Lead	Supporting
Medium term (2030-2040)	3	Generate green financing standards and expand investment.	Supporting					Supporting	Lead	Supporting	
	6	Invest in low-carbon cement and concrete pathways.	Supporting	Lead		Supporting	Lead	Supporting	Supporting		Lead
	7	Scale low-carbon steel production.	Supporting	Lead		Supporting	Lead	Supporting	Supporting		Supporting
	11	Adopt more holistic contract models and public-private partnerships.	Lead	Lead		Lead		Lead			Supporting
	14	Secure supply of renewable energy and build distribution infrastructure.	Supporting	Supporting			Supporting		Supporting	Supporting	Lead
	15	Increase circularity and systems thinking.	Supporting	Supporting		Lead	Supporting	Lead		Lead	Supporting

Source: Interviews; Deloitte analysis

Lead role ■ Supporting role

A PATHWAY TO DECARBONISATION

In this report we have summarised the views of a wide range of construction experts on the sector's biggest decarbonisation challenges, outlined existing and potential solutions, and set out who must do what, and by when.

Through this research, we have identified a clear pathway to decarbonisation, which suggests the construction sector can significantly reduce its emissions by 2050 and achieve net zero by 2060, with 82% decarbonisation reached by 2050. Such a lengthy timeframe is a reflection of the industry's huge scale, the complexity of its ecosystem, the hard-to-abate nature of its component subsectors and its long asset lifetimes.

But we are already seeing steps being taken in the right direction that show the will for positive change is there.

For instance, low-carbon construction equipment and logistics options are already available and in use and will grow steadily over the coming decades.

Meanwhile, we are also seeing more efficient designs and a more circular approach to reusing buildings. Improvements in material sourcing and manufacturing, recycling and reuse of material components will have the most immediate impact on emissions reduction throughout the 2020s. Research suggests this could amount to a 20–30% reduction in building materials demand, with an equivalent effect on emissions.

Looking further ahead, interviewees point to other developments on the horizon. During the 2030s, decarbonisation technologies will become increasingly available and scalable globally. Incremental improvements in cement emissions reduction, e.g. through clinker substitution, will start to make an impact and the first low-carbon steel plants will start to come online.

By the 2040s the speed of construction decarbonisation will have increased, and much of the physical and regulatory infrastructure will be in place. At this point, interviewees expect low-carbon steel, cement and other materials to start entering the market en masse. Other building materials (e.g. glass, aluminium) are expected to decarbonise at a similar speed, even though their impact on lowering carbon emissions will be limited.

Given the urgency of reaching net zero, it is likely that carbon offsets will play a role. The industry, however, knows that it must ensure these are not used as a substitute for investment in pathways to remove emissions from the sector.

Overwhelmingly, the message from industry is that decarbonisation must and will happen, despite the challenges. As one building firm executive put it: "The change is coming and will only intensify. We can either use it as an opportunity today or be out of business tomorrow."

Progress along the various decarbonisation pathways will differ. Some geographies – like Western Europe – are already putting stricter regulation in place and investing in lower-carbon materials. The same advances may take more time in developing economies, although they could accelerate by learning from successful initiatives in mature regions.

12. **RESEARCH HIGHLIGHT**

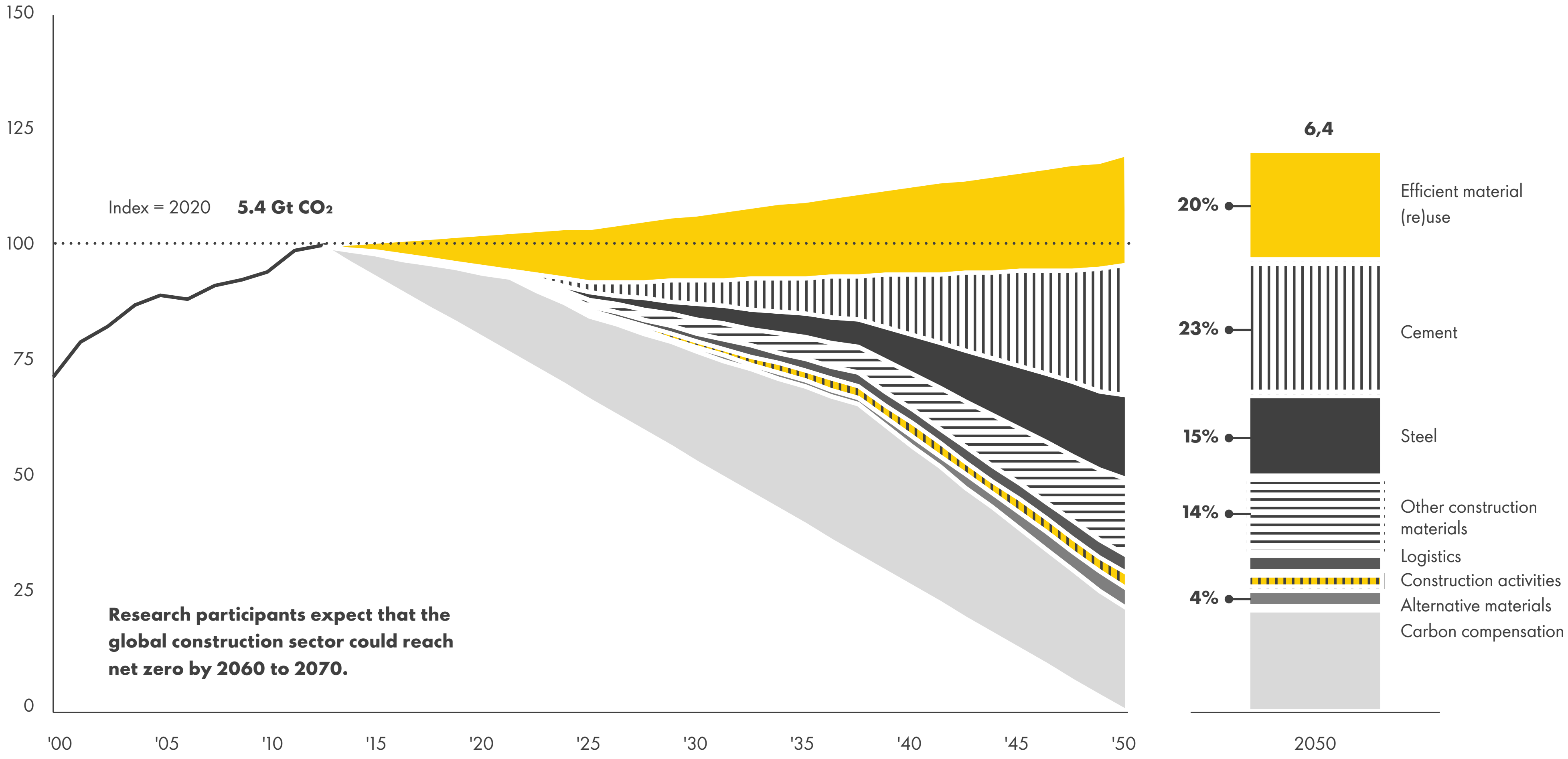
Sharing learnings will help each region accelerate progress towards net zero.

Each geography has a role to play, and Appendix B: Regional Differences breaks down these roles to provide a perspective on actions everyone can take today.

There are very valuable rewards for those who seize the opportunities: from the cheaper capital available to construction firms with an ambitious ESG agenda, to the chance to lead the reinvention of this essential sector and be in the vanguard of decarbonising construction. We already see early-movers investing in decarbonisation projects and piloting low-carbon technologies, but even more can be achieved if each player in the construction ecosystem understands they all have a role to play and action can be taken now.

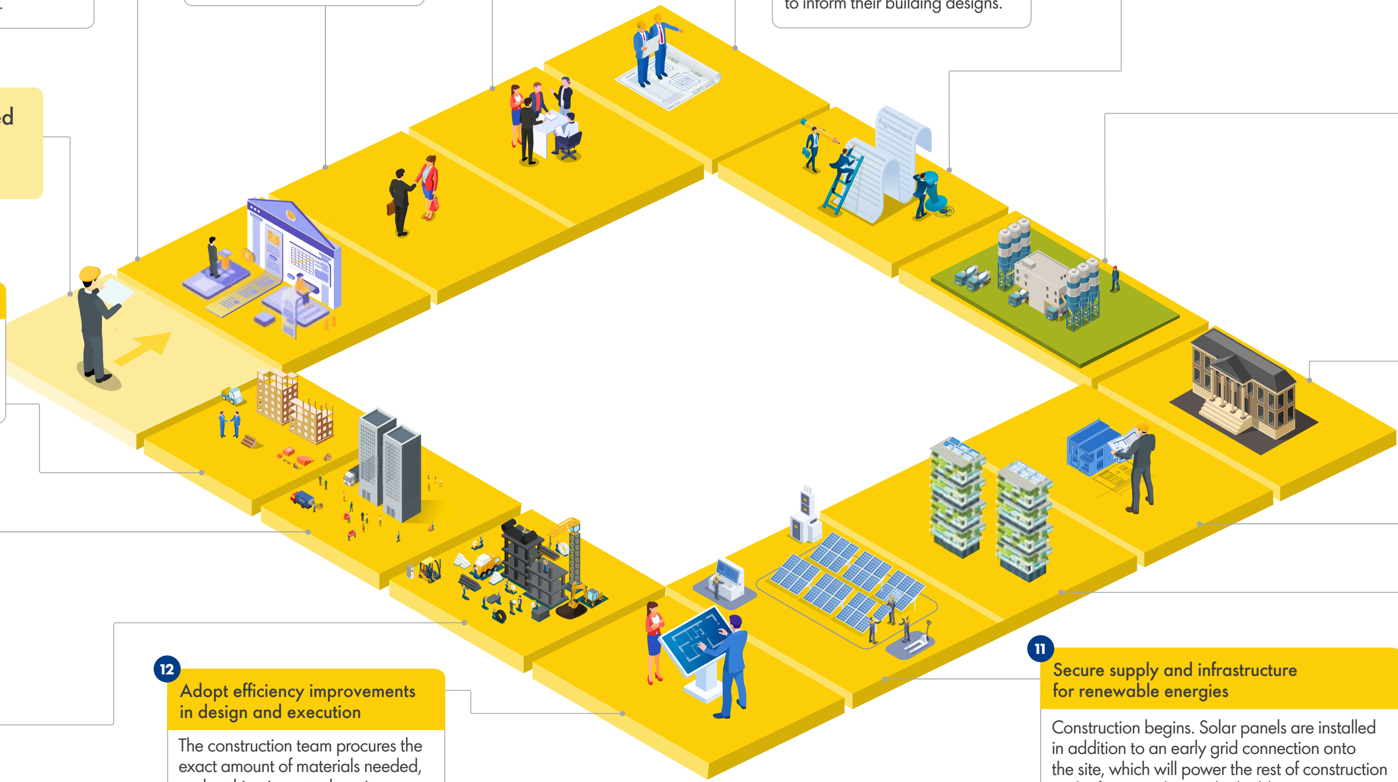
The decarbonisation pathway shared in this report clarifies the road ahead, so let's start building a low-carbon future for construction.

Exhibit 51. Decarbonisation pathway – sector sentiment



Note: Model assumes net zero without offsets by 2060 – Offsets considered last resort by industry and not preferred option
Source: Interviews, Deloitte analysis

Exhibit 52. The life cycle of a low-carbon construction project – a prospective view



1 Imagine, in 2040, a medium-sized real estate developer wants to build a new apartment building.

2 Expand embodied carbon financing

Because low-carbon assets receive financing benefits, the developer is committed to constructing a low-carbon facility.

3 Adopt collaborative contract and partnership models

After securing financing and approvals, they decide to partner early with a general contractor.

4 Develop talent and increase industry knowledge sharing

The contractor uses a repository of local best practices to build on that expertise.

5 Invest in low-carbon cement and concrete pathways; Develop and adopt alternative and circular materials

The architects and engineers use carbon assessment tools to inform their building designs.

6 Activate and aggregate demand

The contractor knows net zero concrete is available and affordable, because 15 years ago, he signed an agreement with other contractors to purchase large amounts.

7 Update design and material standards and definitions

Demand increased alongside carbon prices, making net-zero concrete production attractive. Updated standards also helped the acceleration of the production of low-carbon concrete.

8 Stimulate development of green solutions through demand-side policies

The government announced they will impose limits on embodied carbon in new residential buildings.

9 In order to stand out from competitors, they decide to make their apartment building fully net zero.

10 Scale low-carbon steel production

To meet the challenge, the designers amend the structure to use a modular design and net-zero steel.

11 Secure supply and infrastructure for renewable energies

Construction begins. Solar panels are installed in addition to an early grid connection onto the site, which will power the rest of construction and, after completion, the building.

12 Adopt efficiency improvements in design and execution

The construction team procures the exact amount of materials needed, and nothing is wasted on-site.

13 Roll-out low-emission equipment

The subcontractors use electrified equipment and hydrogen for the heavy equipment.

14 The building is complete, and the developer sells the apartment units for a green premium. Tenants are thrilled to own a net zero home.

15 Increase circularity and systems thinking

After 50 years, the developer sells the building. Rather than demolish it, the new owner decides to reuse the core structure and components; the cycle begins again.

Appendices

APPENDIX A
WAYS TO REDUCE EMISSIONS IN CONSTRUCTION

Industry stakeholders acknowledge that they have a range of options to decarbonise, as each step in the value chain has technological decarbonisation options. An overview of the main options for each construction subsector is provided here. The listed items are not exhaustive but represent the options most frequently referenced by interviewees.

Interpretation of when, where and why each options is preferred is explained throughout Chapter 2: Barriers to decarbonisation and Chapter 3: Potential solutions for decarbonising construction.

Material manufacturing and sourcing – Cement and concrete

In the most common industrial cement-making process, limestone rock is crushed, milled, mixed and dried before being burned in a rotary kiln. The traditional cement production uses whatever fuel is cheaply available for heating, which is often coal. During burning, the limestone is heated to such an extent that carbon is released (called process emissions). The resulting product is clinker. About 40% of emissions in clinker production are generated from fuel combustion to heat the kiln and around 60% are process emissions. By cooling, further grinding and blending with additives, the clinker is turned into cement, which is used as a binder in concrete through further mixing with other minerals and water.

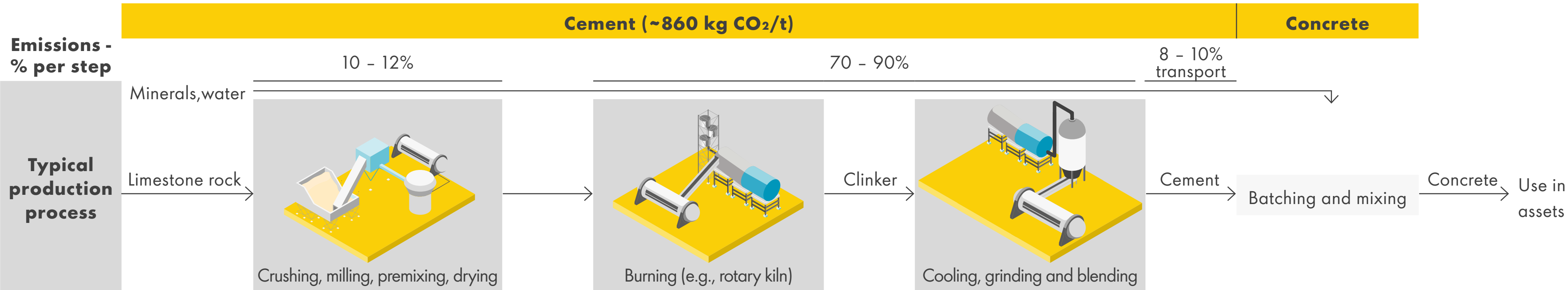
The **main decarbonisation options for cement** are:

- **Fuel substitution** – Reducing combustion emissions by adopting lower-emission fuels, such as natural gas, biomass or hydrogen, dependent on local availability of alternatives.
- **Carbon capture** – Capturing most CO_2 emissions using carbon capture utilisation and storage (CCUS) technologies, where CO_2 is either recycled or stored for long term.
- **Partial clinker substitution** – Reducing the amount of clinker in cement by substitution with supplementary cementitious materials (SCMs) e.g. fly ash, blast furnace slag or calcined clay, which potentially impacts the technical characteristics of the concrete.
- **Alternate chemical processes for clinker production** – Replacing limestone as a feedstock in the clinker production process and using different chemical processes to eliminate process emissions from limestone calcination.
- **Efficiency improvements** in materials and energy used.

Each of the above solutions can be combined, though carbon capture would be required to capture and store/utilise remaining (process) emissions.

In addition to these main options, innovations are emerging. One example is in the mixing and batching step: CO_2 can be injected into the hardening final product, which turns concrete into a carbon sink that offsets emissions. This carbon sink becomes a permanent one only if the concrete is recycled back into another product at the end of life.

Exhibit 53. Cement Production Process - carbon emissions – INDICATIVE



Source: CE Delft – Klimaatimpact van betongebruik van der Nederlandse bouw (2020)

Material manufacturing and sourcing – Iron and steel

The most common steelmaking process is the Blast Furnace (BF) with Basic Oxygen Furnace (BOF) process, accounting for around 70% of global steel production. The Electric Arc Furnace (EAF) is responsible for the remaining production. Minerals are pre-processed into cokes, sinter and pellets, before being processed into iron in the BF and converted to steel in the BOF. The BF and BOF steps are the major contributors to carbon emissions due to the combustion of coal.

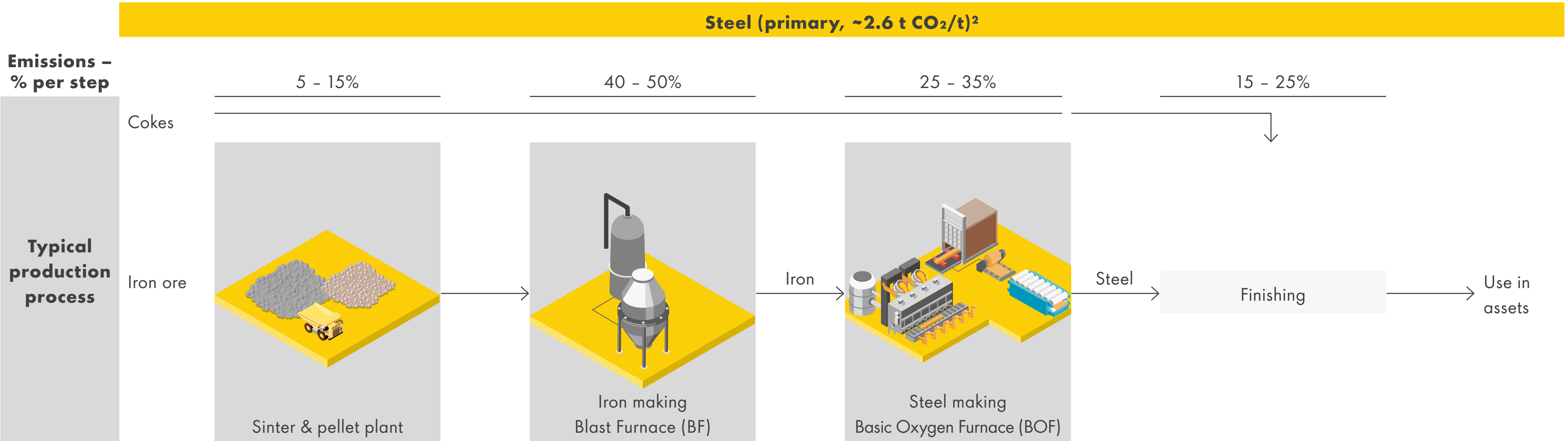
There are incremental decarbonisation options that can be implemented today. For example, up to 20% hydrogen can be injected in the production process to partially substitute use of hydrocarbons. However, significant portions of emissions remain.

The **main decarbonisation options for steel** are:

- **Carbon capture** – Adding CCUS technologies to the traditional process, as explained for cement, particularly for younger assets that were recently installed and have not depreciated.
- **Direct Reduced Iron plant powered by natural gas (DRI-NG), with EAF and carbon capture** – DRI-NG is a more carbon-efficient method of creating iron that largely bypasses sinter and coke-making and is already in use at about 80 plants globally today. CCUS captures the remaining emissions.
- **DRI powered by hydrogen (DRI-H2) with EAF** – As hydrogen becomes more widely available, it can replace the natural gas in option (2). As DRI-H2 EAF is nearly emission-free, carbon capture is no longer needed.
- **DRI in combination with a melting unit and BOF, and carbon capture** – Using DRI in combination with a melting unit, which allows traditional BOF to be used with a wider variety of iron ore qualities.
- **Increase scrap %** – Larger fractions of scrap metal can be used in steelmaking to largely bypass the sinter, pellet and BF steps. Waste management is required to collect and distribute scrap.
- **Efficiency improvements** in materials and energy used.

For a more comprehensive and nuanced view on decarbonisation of steel, see the report Decarbonising Steel: Forging new paths together.

Exhibit 54. Steel production process – carbon emissions – INDICATIVE



Notes: 1) Pellet plant decarbonisation out of scope for this research; 2) Global average
Source: Wang et al (2021) - Efficiency stagnation in global steel production urges joint supply- and demand-side mitigation efforts; Mission Possible partnership (2021) – Net-zero steel sector transition strategy

Material manufacturing and sourcing – Other construction materials – Asphalt

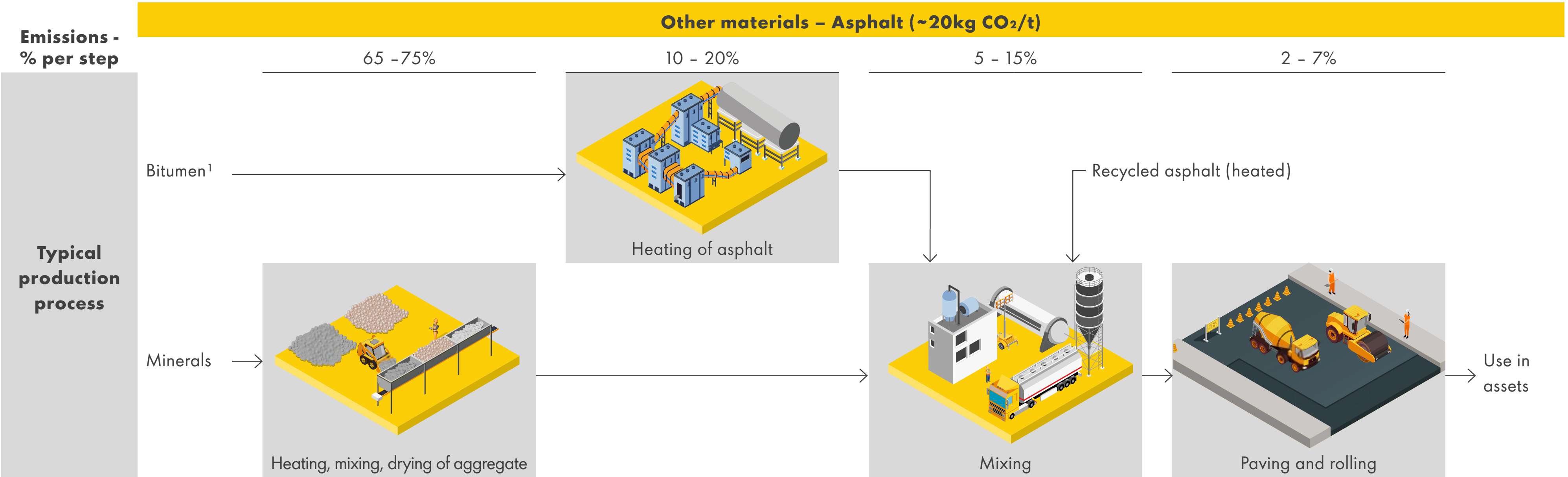
The most common industrial asphalt making process involves heating and mixing various minerals, which are then mixed with pre-heated asphalt binder, usually bitumen. At this point, heated Reclaimed Asphalt Pavement (RAP) can also be introduced. The entire mixture is heated during transport until it is used to build roads.

The **main decarbonisation options for asphalt** are:

- **Fuel substitution** – Lower carbon energy carriers, like natural gas, can be adopted for heating, with CCUS technologies for the remaining emissions.
- **Hydrogen or electricity** – Zero-carbon energy carriers can be adopted for heating, eliminating the need for carbon capture.
- **Temperature reduction through warm / cold mix asphalt** – Adding additives to the asphalt mixture, so it does not need to be heated to such high temperatures, reducing the total required energy.
- **Bitumen substitution** – Multiple bitumen substitutes are being developed, such as using lignin as a binder or converting bio waste into a substance similar to bitumen.
- **Increase recycled asphalt share** – Using recycled asphalt reduces the need for virgin materials and related emissions. This is already being done today, but more progress can be made in specific countries. Waste management is required to collect and distribute RAP.
- **Efficiency improvements** in materials and energy used.

In addition to these main options, innovations are emerging. These include the use of bio-based components to trap carbon. This turns asphalt into a permanent carbon sink which, even when recycled, will not be released into the atmosphere.

Exhibit 55. Asphalt production process – carbon emissions – INDICATIVE



Notes: 1) Asphalt binder usually primarily consists of bitumen and additional additives
Peng et al (2015) - Evaluation system for CO_2 emission of hot asphalt mixture; Bizarro et al (2021) - Potential Carbon Footprint Reduction for Reclaimed Asphalt Pavement Innovations: LCA Methodology, Best Available Technology, and Near-Future Reduction Potential; Interviews; Deloitte analysis

Construction activities – Equipment

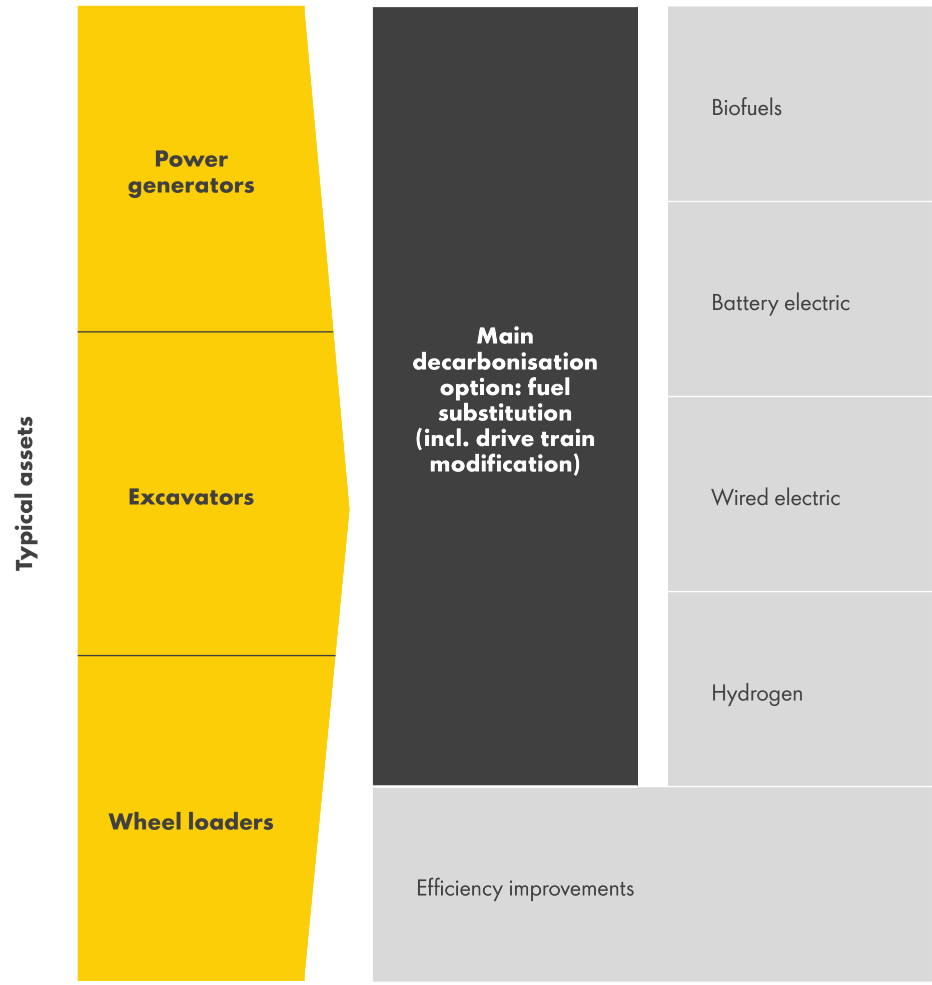
Around 80% of annual volume sales for (land based) construction equipment are generators, excavators and wheel loaders. Various technologies are applicable for specific situations.

The **main decarbonisation options for equipment** are:

- **Biofuels** – Suitable for most equipment types, biofuels are easy to use in current engines, but are challenged by limited feedstock availability.
- **Battery electric** – Battery technology can decarbonise both generators and lighter equipment, assuming low-carbon electricity is used.
- **Wired electric** – For heavy equipment, a wired electric solution is considered superior to batteries, depending on sufficient grid capacity or connections available.
- **Hydrogen** – As an alternative to electric technology, hydrogen is an option for both generators and heavy equipment.
- **Efficiency improvements** in energy used by drivetrain optimisation, equipment design and operational optimisation.

Because of similarities with heavy-duty trucks, for a more comprehensive view also see the report Decarbonising road freight – Getting into gear.

Exhibit 56. Decarbonisation options construction activities – equipment – INDICATIVE



Source: 1) Climate Neutral Group, CECE, Interviews, Deloitte analysis

Construction activities – Logistics – Road freight

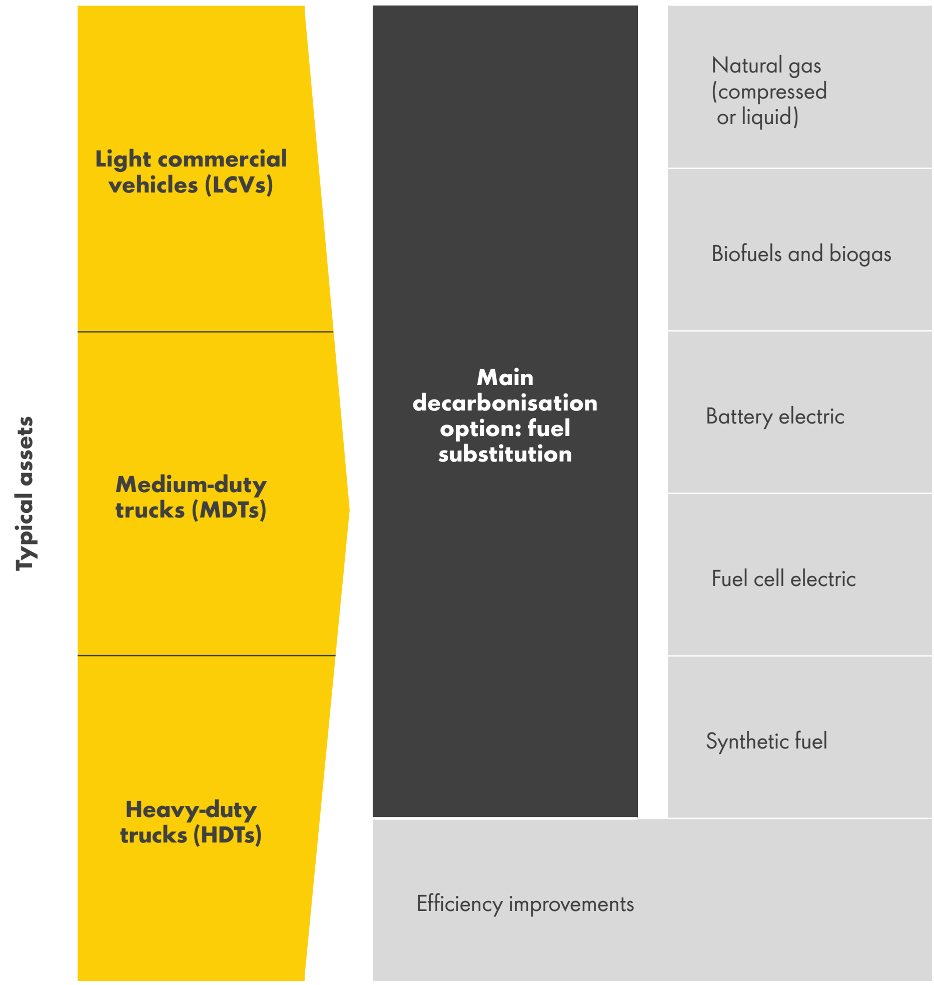
Road freight activities in for construction encompass light, medium and heavy duty trucks. The main decarbonisation option is focused on fuel substitution away from the diesel fuel typically used today.

The **main decarbonisation options for road freight** are:

- **Natural gas (compressed or liquid)** – Suitable for most asset types, not zero emission, but relatively available globally, which can help increase speed of adoption.
- **Biofuels and biogas** – Also suitable for most asset types, lower carbon, but limited in feedstock availability.
- **Battery electric** – A relatively mature technology, requiring less maintenance than conventional internal combustion engines, but technically most suitable for light commercial vehicles and medium duty trucks.
- **Fuel cell electric** – Enables a driving range and refuelling experience comparable to diesel engines. Fuel cell electric is an emerging solution for heavy-duty trucks where hydrogen refuelling infrastructure is available.
- **Synthetic fuels** – Synthetic fuels produced from low-carbon hydrogen and CO_2 are a possible alternative fuel for existing combustion engines. However, with limited availability at scale and high costs which are not expected to materially change in the near future, synthetic fuels remain an unlikely solution for the construction sector.
- **Efficiency improvements** in energy used by drivetrain optimisation, truck design and logistical routing.

For a more comprehensive and nuanced view on decarbonisation of road freight, see the report Decarbonising road freight – Getting into gear.

Exhibit 57. Decarbonisation options logistics – road freight – INDICATIVE



Source: Shell (2021) – decarbonising road freight

Construction activities – Logistics – Shipping

Shipping activities in construction mainly encompass bulk carriers, container ships, and offshore transport and installation vessels. Today's ships typically use heavy fuel oil. Therefore, the decarbonisation options are focused on fuel substitution.

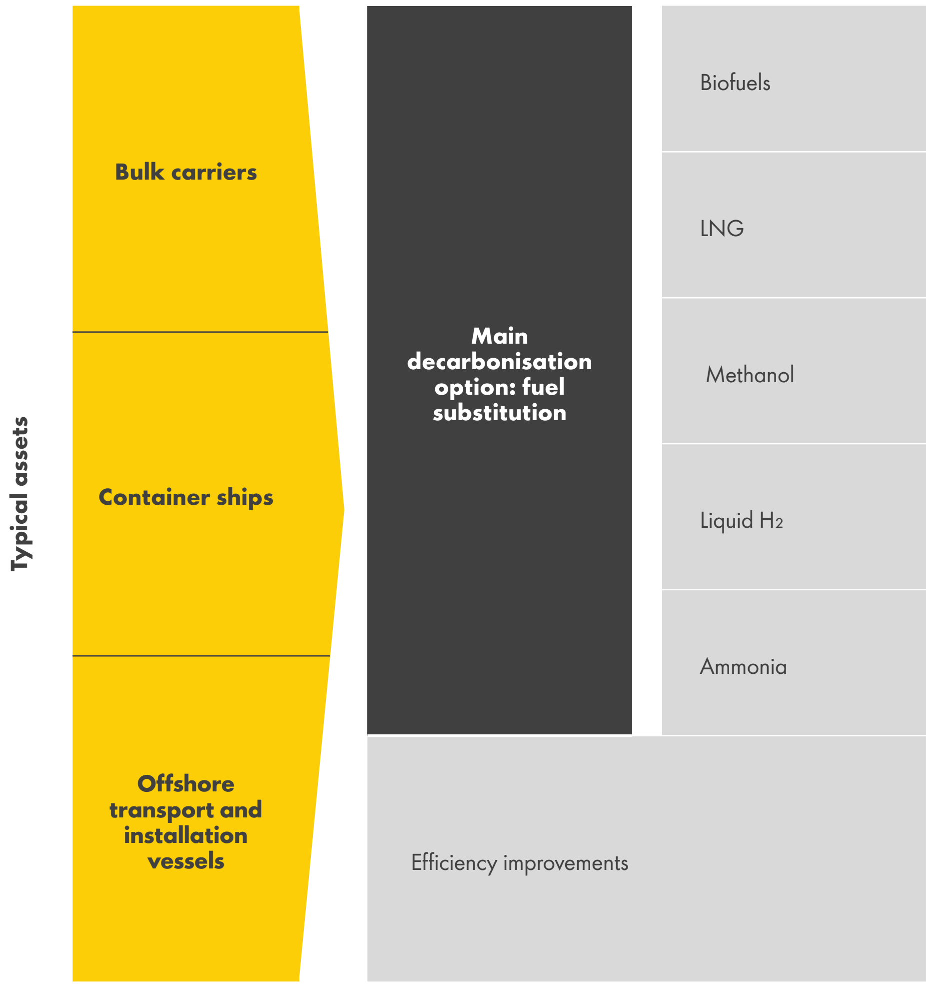
Liquefied natural gas (LNG) is considered a transition fuel, as it is relatively available and reduces emissions compared to traditional heavy fuel oil. To fully reach net zero, it is unknown which fuel source listed below will become dominant.

The **main decarbonisation options for shipping** are:

- **Biofuels** – Drop-in solution for existing fleet to reduce carbon intensity, but there are concerns about sourcing and availability of supply.
- **LNG** – Transition fuel to bio-LNG and e-LNG.
- **Methanol** – Using methanol requires engine modification. One of the feedstocks required to produce methanol is CO_2, which can be collected through carbon capture from cement production, for instance.
- **Liquid H_2** – Releases zero-carbon emissions at combustion, but needs to be stored at −253° Celsius and has a relatively low volumetric energy density, which means that it requires more frequent fuelling stops or compromised cargo space.
- **Ammonia** – Ammonia eliminates carbon emissions at the engine, but there are concerns about ammonia's toxicity and NOx emissions in combustion.
- **Efficiency improvements** in energy used by drivetrain optimisation, vessel design and logistical routing.

For a more comprehensive and nuanced view on decarbonisation of shipping, please see the report Decarbonising shipping: All hands on deck.

Exhibit 58. Decarbonisation options logistics – shipping – INDICATIVE



Source: Shell (2020) - Decarbonising shipping

APPENDIX B
REGIONAL DIFFERENCES

The construction sector will decarbonise at a different pace, and likely on different pathways, across geographies (See exhibit 59). This is because of differences in construction markets, government, economic conditions, and societal awareness around decarbonisation. Europe, USA, China and India have been highlighted as deep-dive markets due to their scale, and activity to-date around decarbonisation.

All of these markets have set net-zero targets, but on different timelines. Europe and the USA have committed to reach net zero by 2050, while China and India's targets are 2060 and 2070 respectively. The construction sector will play a key role in helping these countries meet their targets given its high contribution to emissions. Because there is no global regulatory body for the construction sector – like the IMO in shipping or IATA in aviation – each country or region must act. Exhibit 59 shows an overview of the key characteristics for each of the priority geographies, and they are explored in greater detail in this chapter.

Exhibit 59. Regional construction sector characteristics

End market	**1. Demand** End market interest for low-carbon construction with associated green premiums	**2. Regulation** Policies incentivising or enforcing low-carbon materials & equipment use, and material production	**3. Technology** Clarity and focus on technology options within construction subsectors	**4. Roles** Degree of concentration of end market owners	**5. Implementation** Availability of required infrastructure to decarbonise construction subsectors	**Decarbonisation readiness**[1] High-level assessment
Europe	**Emerging** focus on embodied carbon for both governments and leading businesses	**In place**; relatively mature legislation through e.g. cap and trade schemes and emerging legislation on LCA requirements and other select regions	**Partially aligned** major producers announcing technical shift to low-carbon production technologies	**Fragmented**; setup of owners (e.g. governments) across European countries	**Somewhat favourable**; significant investments in recent years in renewables and green hydrogen supply, but not enough to meet projected demand	●●◐○○
USA	**Emerging** focus on embodied carbon for both governments and leading businesses	**Emerging**; IRA policies provide strong incentives for carbon capture and green hydrogen, but political commitment to decarbonisation varies between election cycles	**Partially aligned** major producers announcing technical shift to low-carbon production technologies	**Fragmented**; setup of owners (e.g. governments) across states	**Somewhat favourable**; significant investments in recent years in renewables and green hydrogen supply, but not enough to meet projected demand	●●○○○
China	**Limited** focus on embodied carbon and associated green premiums	**Moderate**; adopted a range of cap and trade schemes, no full focus on embodied carbon in construction (yet)	**Not aligned**; Limited focus on decarbonising major assets in e.g. steel and cement making in the short term	**Concentrated**; centralised decision making in both government and business could allow quick and impactful progress	**Somewhat favourable**; significant investments in recent years in renewables, but not enough to meet projected demand	●●○○○
India	**Limited** focus on embodied carbon and associated low-carbon premiums, except from global brand offices	**Limited** focus on reducing embodied carbon; considered lower priority vs e.g. transportation emissions	**Not aligned**; Limited focus on decarbonising major assets in e.g. steel and cement making in the short term	**Fragmented**; setup of owners	**Limited**; investments in recent years in renewables	○○○○○

Note: 1) 5 full circles equals easy to decarbonise relative to regions, 0 stars equals hard to decarbonise relative to other regions
Source: Interviews; Deloitte analysis

Impact on readiness
High · Neutral · Low

REGIONAL DEEPDIVE
EUROPE

Europe is recognised by most research participants as the global leader when it comes to decarbonising construction (see exhibit 61). The UK governments and EU commission have set some of the strongest regulations to date, and European-based construction businesses have made more net-zero commitments than those in other geographies to date. This is beginning to translate into action with markets like Norway beginning to mandate zero-emission construction equipment, and construction on the first low-carbon steel production facilities. As only 60% of the European population lives in EU member states, alignment across borders will be critical to ensure progress across the region.

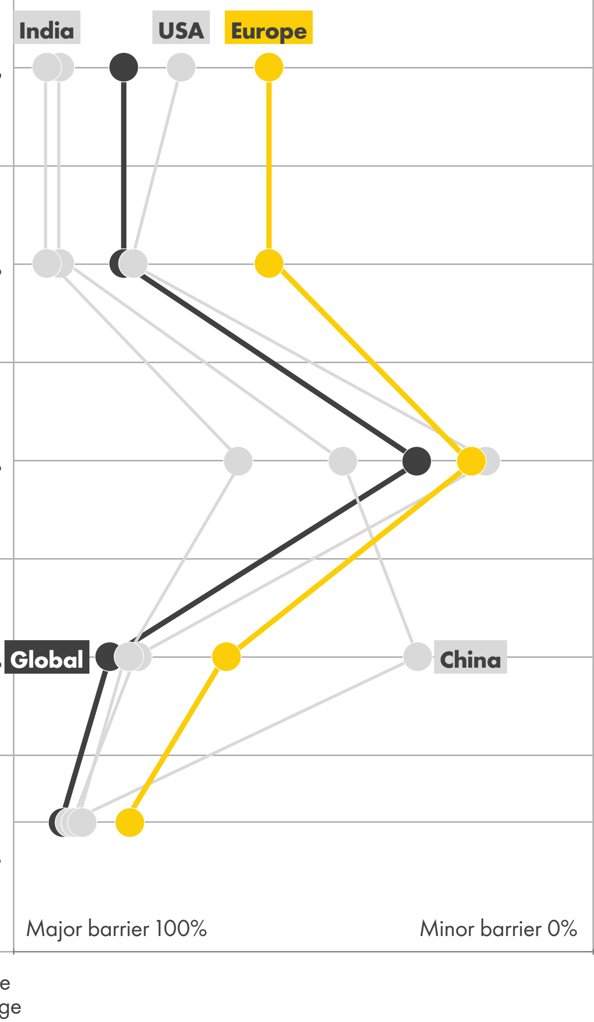
Exhibit 60. Country highlights – Europe (2021)

	GDP	Population	Population growth	Carbon emissions	Cement production capacity[1]	Steel production
Absolute	$17T	0.58B	-0.1%	3.0Gt	402Mt	205Mt
% of global	21%	7%		8%	9%	9%

Note: 1) 2019 values
Source: Worldbank; IEA (2021): Global Energy Review: CO_2 Emissions in 2021; 2021 UK department for business, energy & industrial strategy: UK greenhouse gas emissions, provisional figures; Cemnet; UN Comtradedatabase (2022); Worldsteel(2022): World Steel in figures 2022; Deloitte analysis

Exhibit 61. Sector decarbonisation readiness – Europe

Readiness questions	Readiness factors	Participants' view on severity of barriers	Participants' view on barriers	Short-term (2023-2030)	Medium-term (2030-2040)
Why should the sector change?	Demand	50%	Embodied carbon is slowly becoming more of a design criteria in Europe, particularly for infrastructure. That said, it is not yet a true priority in procurement practices. Though awareness of embodied carbon is highest in Europe vs other regions according to our interviewees, it is still low compared to e.g. operational carbon. As the CEO of a building operator noted: "Premium building segment requires differentiation, and European customers are increasingly demanding sustainable buildings."	1. Increase awareness around embodied carbon	
	Regulation	50%	Regulations for construction subsectors are becoming more strict through (amongst others) the EU ETS. Individual European countries are slowly adopting standards and regulations on embodied carbon, but these regulations are comparatively new and not considered fully mature across the continent. As an infrastructure contractor noted: "Some European countries have much stricter legislation than others. France is particularly strict but fair."		
Can the sector change?	Technology	20%	Various pilot projects, both operational and announced, for low-carbon steel and cement can be found across Europe, making it a global frontrunner. That said, decarbonising material production subsectors is still in its infancy, even in Europe.		
	Roles	60%	Governmental agencies, leading municipalities (e.g. Oslo, Amsterdam, London), have started actively promoting low embodied carbon as a part of their procurement practices, forcing broader, cross-project visibility on embodied carbon impact in a region. As the CEO of a building operator noted: "London requires all building permits to have a net-zero building development scheme, and similar policies exist in the Netherlands and Germany."	10. Develop talent and increase knowledge sharing	
How fast can the sector change?	Implementation	80%	There are limited overarching European definitions on data and methodologies to account for embodied carbon, but initiatives for increased collaboration and the use of European frameworks do exist. Furthermore, Europe is investing significantly in increasing its supply of renewable energy and green hydrogen production.	12. Make design and execution more efficient	14. Secure supply of renewable energy and build distribution infrastructure 15. Increase circularity and systems thinking



Revelance
India average
Global average
USA average
Europe average
China average

Source: Interviews; Deloitte analysis

REGIONAL DEEPDIVE
USA

The USA was seen as a global leader in construction decarbonisation by interviewees, but progress is seen to be slightly behind Europe. The recent Inflation Reduction Act and state regulation like the Buy Clean California Act are expected to accelerate progress by expanding production of renewable fuels, and putting limits in place around embodied carbon in public works projects[57]. Despite these positive signs, the decentralised nature of regulation in the USA and lack of progress in some states are expected to be a challenge. Interviewees also noted concerns around making long-term investments given extreme differences in policy between administrations, as noted by the CEO of one cement producer: "California shaping policy is great, but we need clarity around policy at a national level before I can make the long-term investments which are needed"

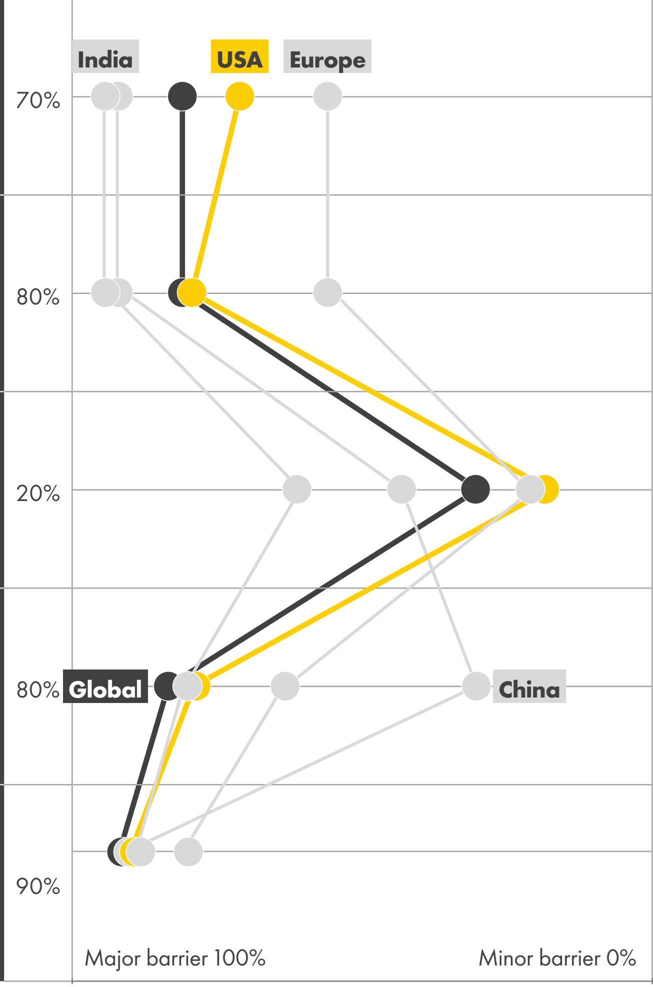
Exhibit 62. Country highlights – USA (2021)

	GDP	Population	Population growth	Carbon emissions	Cement production capacity[1]	Steel production
Absolute	$23T	0.3B	0.1%	4.6Gt	94Mt	86Mt
% of global	24%	4%		13%	2%	4%

Note: 1) 2019 values
Source: Source: Worldbank; IEA (2021): Global Energy Review: CO_2 Emissions in 2021; Cemnet; UN Comtrade database (2022); Worldsteel(2022): World Steel in figures 2022; Deloitte analysis

Exhibit 63. Sector decarbonisation readiness – USA

Readiness questions	Readiness factors	Participants' view on severity of barriers	Participants' view on barriers	Short-term (2023-2030)	Medium-term (2030-2040)
Why should the sector change?	**Demand**	70%	There is increasing focus on carbon emissions across end markets in the US, particularly in California. That said, the USA has mostly similar design and procurement practices as the rest of the world, and thus usually prioritises cost and speed over embodied carbon characteristics. As the CEO of an infrastructure operator noted: "We live in a competitive world. If we pressure our customers on decarbonisation issues, they'll go elsewhere."	1. Increase awareness around embodied carbon	3. Green financing standards and investment
	Regulation	80%	Regulations for construction subsectors and end markets typically do not incentivise action across the value chain. A major exception are new provisions in the Inflation Reduction Act (IRA) of 2022, which significantly incentivises the adoption of carbon capture technology and green hydrogen production for e.g. low-carbon steel and cement. However, at the federal level there is limited legislation enforcing the reduction of embodied carbon and the decentralised nature of regulation in the USA makes it difficult to implement policies.	4. Policies to stimulate demand for green assets 5. Stimulate development of low-carbon solutions through policies	
Can the sector change?	**Technology**	20%	With the new incentives from the IRA, carbon capture could become more mature relatively fast in the USA. Furthermore, USA steel industry predominantly uses EAF1, meaning there is already some familiarity with part of the key technology pathways for steel. As an executive of a cement manufacturer noted: "[the passing of the Inflation Reduction Act] means we don't need to convince our customers to pay a premium but can keep it mostly cost neutral, that will de-risk carbon capture a lot."		6. Invest in low-carbon cement and concrete pathways 7. Scale low-carbon steel production
	Roles	80%	The USA follows the global path of a focus on individual projects without adequate cross-project visibility and alignment of priorities. Similarly, the expertise around low-carbon practices is limited to a few large companies with no clear mechanism to disseminate knowledge across the value chain.		
How fast can the sector change?	**Implementation**	90%	Many definitions, data, methodologies and tools are set at the state level, not the federal level, which reduces collaboration across states or with the rest of the world. As an executive at a major contractor noted:"The fact is, there are so many frameworks today, especially when you start thinking about GHG and ESG, there really is a lot of overlap but no general alignment of how we will choose to count and report and say what is good, better, and best."		15. Increase circularity and systems thinking



USA average

Source: 1) Mission Possible Partnership – Net-zero steel sector transition strategy (2021); interviews; Deloitte analysis

Revelance
India average · Global average · USA average · Europe average · China average

REGIONAL DEEPDIVE
CHINA

China is the most important global geography when it comes to decarbonising the construction sector, due to its scale. Rapid urban development and investment in becoming a major steel exporter has resulted in China being responsible for over 50% of global cement and steel production. Interviewees expect decarbonisation of the construction sector in China to follow behind both Europe and the US. This is because of limited existing regulation, relatively low societal pressure to decarbonise, and competing priorities like supporting rapid economic growth and connectivity in the country through major infrastructure projects.

Interviewees also noted that the majority of steel and cement plants in the country are relatively new, meaning it will take longer for them to reach the end of their productive life and be transitioned to lower-carbon alternatives.

While interviewees expect decarbonisation progress to be slower in China than the USA and Europe, there were signs of optimism. As they have shown with regulation and development in the past, China is able to move more quickly than most markets when commitments are made.

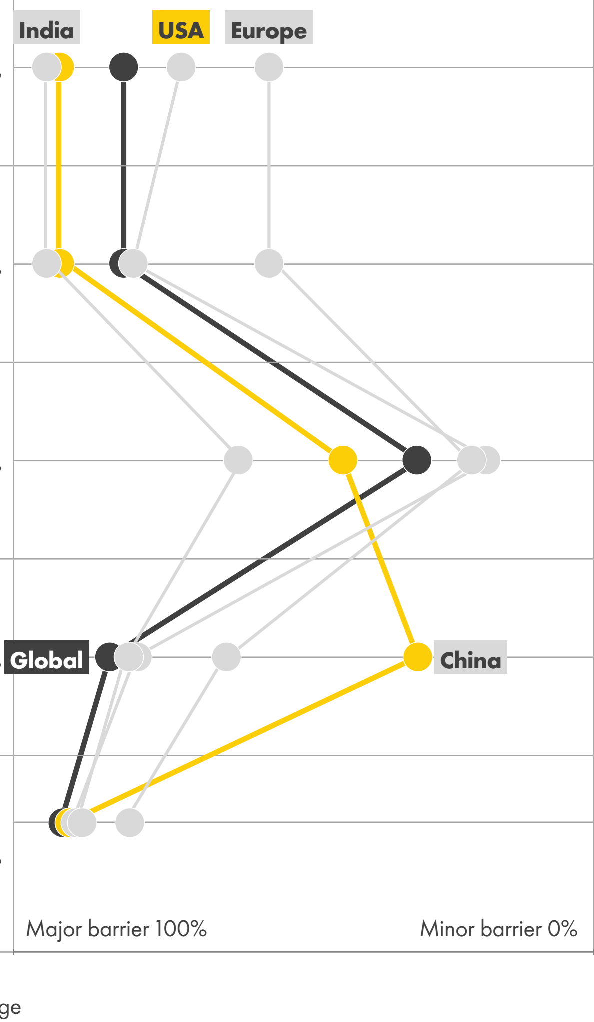
Exhibit 64. Country highlights – China (2021)

	GDP	Population	Population growth	Carbon emissions	Cement production capacity[1]	Steel production
Absolute	$18T	1.4B	0.1%	12Gt	2.47Mt	1.03Mt
% of global	18%	18%		33%	57%	53%

Note: 1) 2019 values
Source: Source: Worldbank; IEA (2021): Global Energy Review: CO_2 Emissions in 2021; Cemnet; UN Comtrade database (2022); Worldsteel(2022): World Steel in figures 2022; Deloitte analysis

Exhibit 65. Sector decarbonisation readiness – China

Readiness questions	Readiness factors	Participants' view on severity of barriers	Participants' view on barriers	Short-term (2023-2030)	Medium-term (2030-2040)
Why should the sector change?	Demand	90%	Respondents indicate there is limited appetite in the Chinese end market for low embodied carbon construction, neither in commercial nor from governments. As a Chinese materials manufacturer said: "The biggest challenge for the company is getting customers to pay a low-carbon premium."	1. Increase awareness around embodied carbon	
	Regulation	90%	China has a number of regulations that affect the construction sector, such as specific cap and trade schemes. That said, interviewees from construction subsectors suggest they are waiting for central government legislation before making significant moves on decarbonisation. The Chinese government has indicated that they want to achieve net zero by 2060, which is slower than Europe and the US.	4. Policies to stimulate demand for green assets 5. Stimulate development of low-carbon solutions through policies	
Can the sector change?	Technology	50%	Many of China's manufacturing assets for e.g. steel and cement are fairly young. As a result they have not been fully depreciated, which acts as a barrier (relative to other regions) to decarbonisation, as steel decarbonisation typically requires complete replacement of assets.		6. Invest in low-carbon cement and concrete pathways 7. Scale low-carbon steel production
	Roles	30%	China's more centralised government model and the concentration of construction subsectors in a few large players allow for relatively fast decision making once embodied carbon becomes a priority. As an executive of a Chinese materials manufacturer said: "China has the benefit of being a single-government country. Whenever it makes a promise, it has to deliver and can do so very quickly."		
How fast can the sector change?	Implementation	90%	There are no strong overarching Chinese definitions on data and methodologies to account for embedded carbon, but China's strong centralised government could improve this relatively easily with time. As a Chinese materials manufacturer said: "One challenge is the calculation of carbon being captured. This needs to be aligned because different companies and provinces have different standards. We are waiting for a national standard". Furthermore, China is investing significantly in increasing its supply of renewable energy and green hydrogen production.		15. Increase circularity and systems thinking



Source: 1) Mission Possible Partnership – Net-zero steel sector transition strategy (2021); interviews; Deloitte analysis

REGIONAL DEEPDIVE
INDIA

Interviewees expect decarbonisation in the Indian construction sector to follow all of the other deep-dive markets. Regulation and generational awareness around embodied carbon emissions are still relatively low within the country, as noted by a local construction company "I have never had a conversation about the emissions associated with my projects with either customers or suppliers."

Interviewees noted the focus in the country right now is on development and improving economic conditions, and that the only decarbonisation activity is taking place in less localised sectors like aviation where global companies are influenced by conditions in other countries.

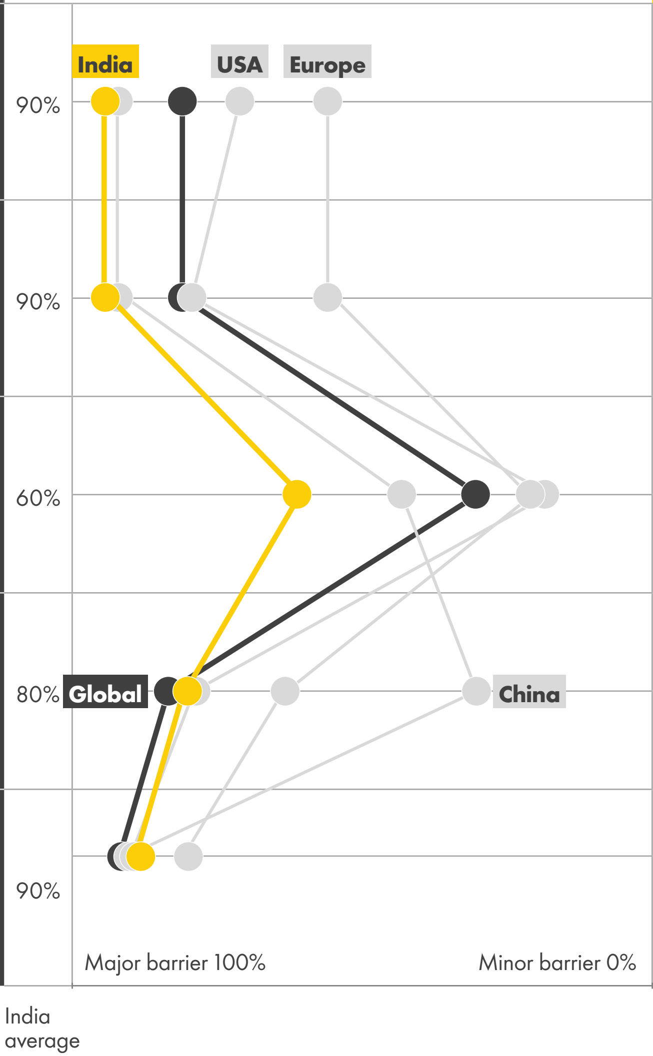
Exhibit 66. Country highlights – India (2021)

	GDP	Popula-tion	Popu-lation growth	Carbon emissions	Cement production capacity[1]	Steel pro-duction
Absolute	$3T	1.4B	1.0%	2.5Gt	344Mt	118Mt
% of global	3%	18%		7%	8%	6%

Note: 1) 2019 values
Source: Source: Worldbank; IEA (2021): Global Energy Review: CO_2 Emissions in 2021; Cemnet; UN Comtrade database (2022); Worldsteel(2022): World Steel in figures 2022; Deloitte analysis

Exhibit 67. Sector decarbonisation readiness – India

Readiness questions	Readiness factors	Participants' view on severity of barriers	Participants' view on barriers	Short-term (2023-2030)	Medium-term (2030-2040)
Why should the sector change?	**Demand**	90%	Interviewees indicate that market demand for low embodied carbon construction is very low in India, as the focus is on decarbonising other sectors such as transportation. That said, some pockets of demand do exist in niches, as they do in other parts of the world, such as with headquarters of large multinationals that have committed to net-zero operations. As an asset manager noted: "India has taken a target of net-zero in 2070. Therefore, government buildings are not in a hurry, corporates are ahead."	1. Increase awareness around embodied carbon 2. Activate and aggregate demand	
	Regulation	90%	Indian regulations are not yet focused on reducing embodied carbon and the government has set the goal to achieve net zero by 2070, 20 years later than Europe and the US. A research participant from the Indian construction sector noted: "Indian regulations do not really care about embodied carbon from buildings or infrastructure yet; first priorities are with more visible sectors like transportation".	4. Policies to stimulate demand for low-carbon assets	
Can the sector change?	**Technology**	60%	Though the key technologies are no different in India than in other regions, interviewees indicate that the Indian construction sector in general is not yet aligned on low-carbon materials and equipment as a priority.		6. Invest in low-carbon cement and concrete pathways 7. Scale low-carbon steel production
	Roles	80%	Similar to other regions, as India's awareness of embodied carbon is still developing, interviewees said that they are experiencing a lack of alignment of priorities, in particular that there is uncertainty around how the private and public sectors can collaborate.		
How fast can the sector change?	**Implementation**	90%	There are no strong enforced overarching Indian definitions on data and methodologies to account for embodied carbon as it is not perceived to be a government priority. As an asset manager noted: "We don't have a standard for green cement. I meet developers that ask questions on what green cement is." Legislation to enforce the use of green hydrogen in other industries by 2023 should increase green hydrogen infrastructure development, but will also increase competition for those assets.	12. Make design and execution more efficient	14. Secure supply of renewable energy and build distribution infrastructure



Revelance
India average · Global average · USA average · Europe average · China average

Source: Interviews; Deloitte analysis

ACKNOWLEDGEMENTS

We wish to thank all those who were involved in the development of this research. We appreciate your time, energy and enthusiasm.

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