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The built environment

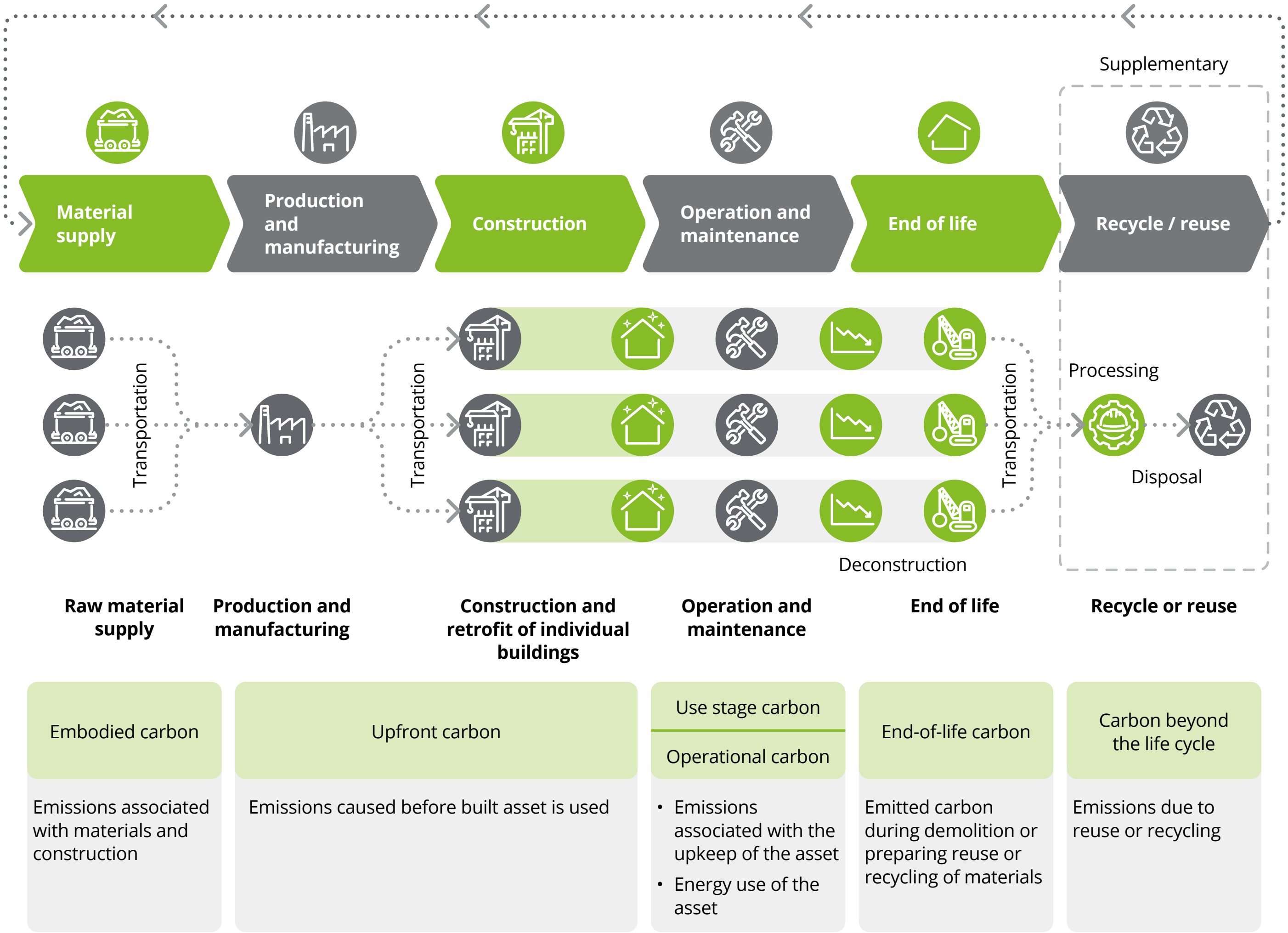
Pathways to decarbonization

Greening the built environment

The construction and real estate sectors play a critical role in the world's economic and social well-being. Taken together, they constitute the "built environment"—a broad definition that, in this context, encompasses the construction sector as well as the commercial and residential real estate sectors. Yet, despite its positive impact on society—driving job creation and supporting the infrastructure in which humans live and work—the global built environment is responsible for more than 37% of global carbon emissions.[1]

These global carbon emissions include both operational carbon—the day-to-day carbon emissions generated through the operation and maintenance of buildings—as well as embodied carbon. Embodied carbon comprises of carbon emitted during earlier stages of the value chain before an asset is commissioned for operational use, including as a result of material supply (e.g., extraction, transportation), production and manufacturing, and construction. It also includes the carbon emitted during end-of-life activities, such as demolition, disposal, and repurposing (Figure 1).

Figure 1
Built environment value chain and carbon emissions



Source: Deloitte analysis

The complexity of this value chain introduces endemic challenges to decarbonization. For instance, the sourcing and manufacture of materials alone (such as iron, steel, and cement) generates approximately 11% of the sector emissions.[2] Additionally, the sector remains a major consumer of electricity, natural gas, traditional biomass, and even coal.

To help address some of these challenges, industry players are increasingly examining the economic and operational feasibility of adopting sustainable materials and execution methods. Digital technologies such as AI and generative design can help support stakeholders across the ecosystem in tracking and evaluating potential decarbonization scenarios, as well as the potential emissions generated by their activities. Additionally, the use of low-carbon construction materials, prefabrication, modular construction, and the trend of designing for end of life are contributing to the move toward decarbonization.

These shifts not only support the transition to net zero but also help enable industry players to attract funding and financing for sustainable projects through both government incentive programs and the growing number of private equity and venture capital funds focused on sustainable investment. At the same time, as value chain participants continue to invest in sustainable solutions, they are positioning themselves to potentially realize higher returns, fostering a virtuous circle that can help drive ongoing decarbonization in the sector.

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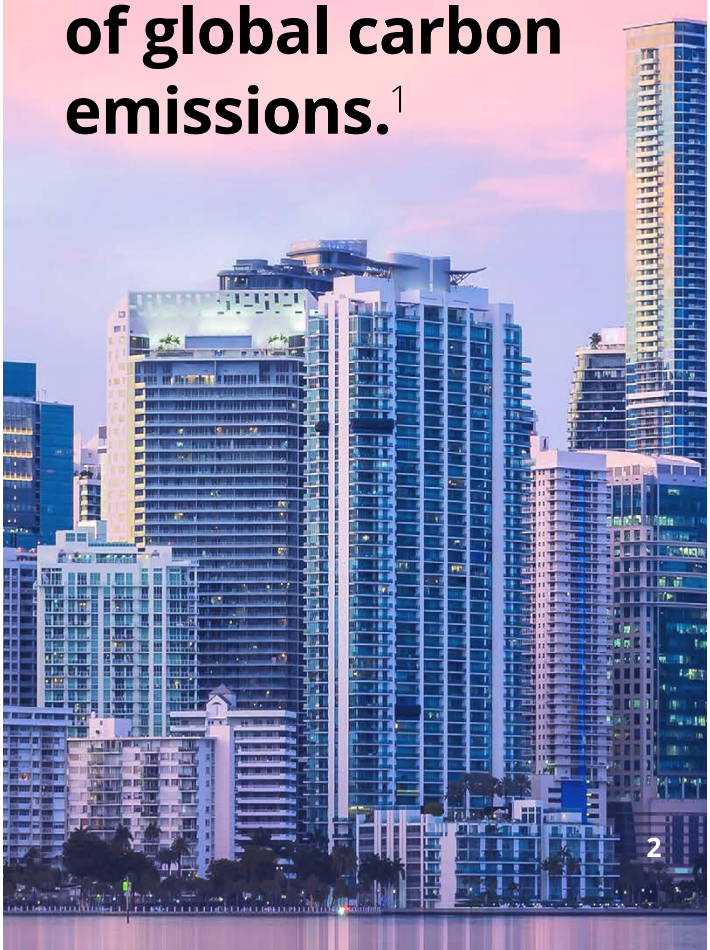

A shift to systems thinking

While emissions from different products, activities, and value chain participants vary in quantum, it is important for industry players to gain an understanding of the impact of their combined assets and work collaboratively along the value chain to help minimize each part of the emissions profile. This underscores the need for the built environment sector to adopt both a global approach and a lifecycle approach to meet its Paris Agreement commitments. Rather than focusing on incremental progress, industry players should embrace systemic change to help achieve net zero by 2050.

Amid growing regulatory, investor, and consumer demand for sustainable business practices, global stakeholders—including developers, builders, subcontractors, designers, architects, suppliers, and operating owners—will need to engage across the value chain and integrate sustainability into their delivery and execution processes. Notably, as industry players apply systems thinking to the sector's challenges, a lifecycle approach appears to be emerging—one that begins by considering the environmental impacts associated with material extraction and production, examines how the choice of materials affects each phase of the value chain, and assesses how those materials can be recycled and reused following deconstruction and demolition.

As this type of lifecycle approach gains traction, there has been mounting evidence that the decisions made during the design and planning phases significantly influence a project's long-term carbon footprint. For instance, following a "design for disassembly" process—which facilitates the dismantlement of future buildings—may help reduce greenhouse gas (GHG) emissions by 10% to 50%.[3] Regenerative and circular building principles, including concepts like urban mining, may hold similar promise by accounting for the second life of assets and buildings as mere material stores before construction ever begins, while simultaneously limiting demand for carbon intensive materials.

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Proponents of a lifecycle approach are also looking beyond new construction to consider decarbonization pathways for existing assets. In highly developed regions such as the European Union, where much of the existing building stock often falls short of meeting regulatory carbon reduction targets, there appears to be a growing emphasis on retrofitting, enhancing energy efficiency, and encouraging behavioral changes among users.[4]

Continued understanding and integration of these trends is helping to activate a more nuanced approach to decarbonization throughout the built environment, unlocking opportunities to support greater collaboration not only across the value chain, but across sectors and geographies.

Yet, accelerating this transition likely requires prioritizing workforce reskilling, affordability, technological innovation, and transformation of existing assets for reuse or repurpose. It can also mean proactively managing challenges associated with embodied carbon, limited regulatory incentives, industry fragmentation, ongoing reliance on carbon-intensive machinery, technological adoption, and inconsistent data standards.

As part of Deloitte's Pathways to decarbonization collection of insights on hard-to-abate and high-emitting sectors, this paper explores current industry trends and challenges, and identifies a range of opportunities and levers industry players can employ on their journey towards net zero for the built environment.

Regional context

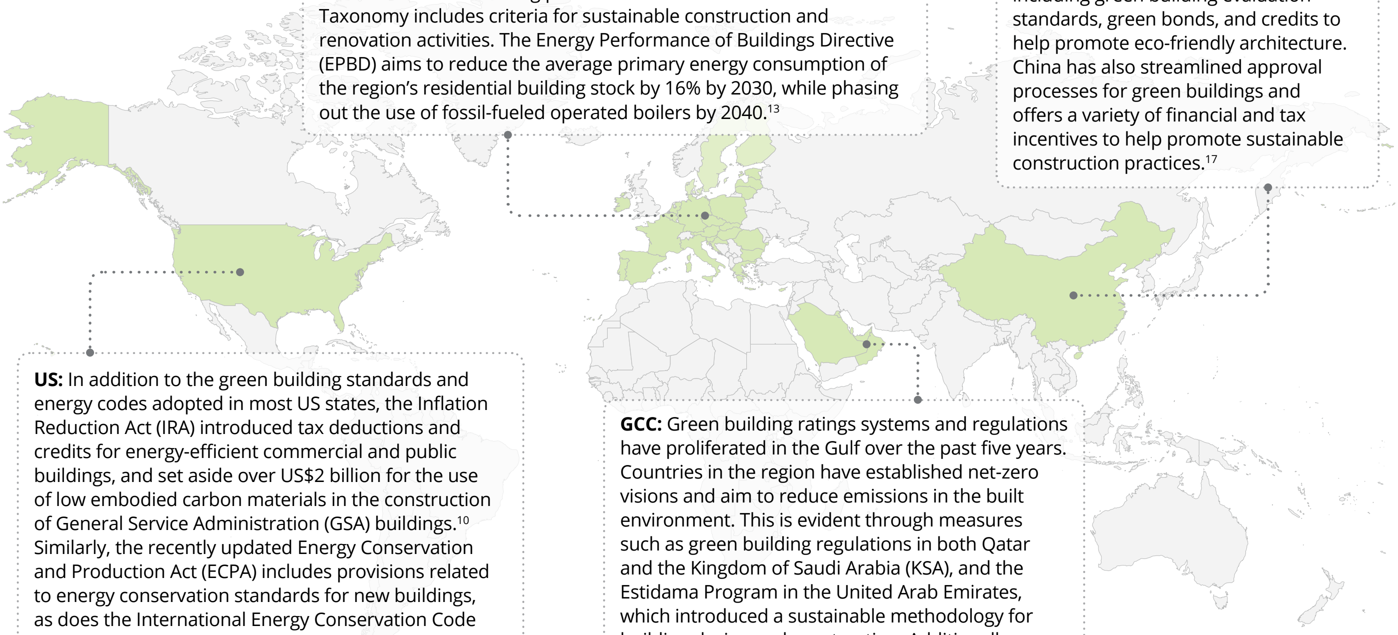
Evolving regulatory standards

For the built environment sector to meet the mandates of the Paris Agreement, the United Nations has indicated that the sector must halve its emissions by 2030 and achieve net zero across the development of all new initiatives and existing assets by 2050.[5] At COP28, the United Nations specifically tasked the sector to minimize climate-related impacts on infrastructure—and increase the resiliency of infrastructure to the impacts of climate change—to ensure basic and continuous essential services for all.[6] To help meet these aggressive targets at the local, national, regional, and global levels, both policy incentives and regulatory imperatives will likely be required.

Although governments and regulatory bodies are helping to address this challenge, sustainability regulations continue to vary significantly around the globe. For instance, while construction emissions are highest in rapidly growing economies, such as China and India, regulations around embodied carbon in these markets remains nascent[7,8] and the management of operational carbon also presents challenges. In fact, it's estimated that approximately 82% of the population expected to be added by 2030 will be living in countries with no, or only voluntary, building energy codes.[9]

Despite uneven progress, regulatory levers are increasingly being deployed to help restrict both operational and embodied emissions. Here, we consider some of those measures in four key regions: the United States, the European Union, the Gulf Cooperation Council (GCC), and China (Figure 2).

Figure 2
Regional overview



EU: Following the implementation of the Emissions Trading System (ETS), the EU has introduced a range of policy incentives designed to foster sustainability in the built environment sector. For instance, the Circular Economy Action Plan promotes the reuse and recycling of construction materials in a bid to reduce waste and encourage more sustainable building practices.[12] The EU Sustainable Finance Taxonomy includes criteria for sustainable construction and renovation activities. The Energy Performance of Buildings Directive (EPBD) aims to reduce the average primary energy consumption of the region's residential building stock by 16% by 2030, while phasing out the use of fossil-fueled operated boilers by 2040.[13]

China: Construction represents almost 46% of China's energy consumption and 51% of its carbon emissions.[16] This has prompted the country to implement stricter environmental regulations, including green building evaluation standards, green bonds, and credits to help promote eco-friendly architecture. China has also streamlined approval processes for green buildings and offers a variety of financial and tax incentives to help promote sustainable construction practices.[17]

US: In addition to the green building standards and energy codes adopted in most US states, the Inflation Reduction Act (IRA) introduced tax deductions and credits for energy-efficient commercial and public buildings, and set aside over US$2 billion for the use of low embodied carbon materials in the construction of General Service Administration (GSA) buildings.[10] Similarly, the recently updated Energy Conservation and Production Act (ECPA) includes provisions related to energy conservation standards for new buildings, as does the International Energy Conservation Code (IECC), some version of which has been adopted by most US states for commercial buildings. In April 2024, the US Department of Energy released the first sector-wide federal strategy and blueprint to reduce greenhouse-gas (GHG) emissions from buildings by 65% by 2035 and 90% by 2050.[11]

GCC: Green building ratings systems and regulations have proliferated in the Gulf over the past five years. Countries in the region have established net-zero visions and aim to reduce emissions in the built environment. This is evident through measures such as green building regulations in both Qatar and the Kingdom of Saudi Arabia (KSA), and the Estidama Program in the United Arab Emirates, which introduced a sustainable methodology for building design and construction. Additionally, the Green Building Regulations and Specifications (GBRS) in the UAE and Dubai aim to reduce energy consumption in the construction industry and improve the environmental performance of both new and existing assets.[14,15]

Challenges

The built environment sector faces a range of interconnected challenges that may hinder global decarbonization efforts. Given the complexity of the sector's value chain, for instance, meaningful progress tends to require the collaboration of disparate stakeholders, the adoption of a lifecycle approach, and coordination across multiple sectors and global jurisdictions. This is further complicated by the need to reduce both operational and embodied carbon emissions across different markets, with varying socioeconomics and political environments and encompassing regions with extreme temperature variations.

At the same time, participants across the value chain walk a tightrope when it comes to financial viability. Given the costs potentially associated with sustainable practices and materials, industry stakeholders require long-term business cases to justify upfront investment. Those that respond by maintaining a "business as usual" stance will likely face reputational risks and regulatory hurdles. On the flip side, those that adopt a wait-and-see approach may struggle to meet market demand while simultaneously creating a supply crunch.

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While initiatives for cross-sectoral cooperation are emerging, here are some of the challenges industry stakeholders likely still need to address:

Embodied carbon emissions.
The embodied carbon emissions released by activities such as material supply, manufacturing, transportation, construction, demolition, and disposal are responsible for a third of all building-related emissions, and accounts for approximately 10% of all energy-related global greenhouse gas emissions.[18] Of those, up to 85% are attributable to the supply, manufacturing and transportation of materials such as cement, steel, glass, aluminum, timber, and asphalt.[19] Yet, despite this impact, initiatives aimed at reducing carbon emissions often focus narrowly on operational aspects. Tipping this balance will likely require not only the widespread availability of alternative and sustainable building materials, but also sufficient financial incentives to help make them cost effective. It also could mean considering the full downstream impact of using alternative materials. For instance, while engineered wood such as mass timber can cut a building's carbon footprint, its harvesting and transportation are not carbon neutral and the relative carbon impact of long-lived wood products versus stable forests remains unclear.

Resource scarcity.
With both materials and labor in short supply, industry stakeholders will likely face ongoing decarbonization hurdles. Sustainable materials are costly and difficult to source, especially as demand mounts to meet the need for large infrastructure builds, retrofits, and new developments. In addition, building sustainably tends to require a level of technical experience and skills that is not yet widely available in either developed or developing markets.[20] Solving these challenges will likely take not only cross-industry collaboration, but a long-term commitment to workforce reskilling.

Limited regulatory incentives. Lengthy regulatory approval processes, uncertainty about compliance standards, and a lack of supportive policy measures may hinder decarbonization efforts across the value chain. Although measures such as energy efficiency standards, green building mandates, taxes on landfill waste, and carbon trading schemes help support the decarbonization agenda, additional incentives and innovation funding are likely required to help spur the adoption of low carbon materials, processes, and technologies and to further encourage recycling and reuse.

Industry fragmentation. As noted earlier, the complexity of the built environment value chain may constrain the adoption of sustainable practices. In addition to incentivizing multiple ecosystem players that often have divergent priorities, reaching net zero may also require new business models and unprecedented levels of collaboration among government entities, material suppliers, manufacturers, developers, designers, engineering firms, technology service providers, and recyclers. Property owners and occupants will likely also have a role to play in helping to drive this transition, as will financiers and investors. The complexity of this extended ecosystem underscores the need for policy support, alternative funding, and improved process transparency.

Continued reliance on carbon-intensive machinery. On a worldwide basis, heavy construction equipment powered by fossil fuels is estimated to emit roughly 400 Mt of CO_2 every year.[21] Although there appears to be a push towards electrifying many of these machines—such as excavators, bulldozers, and loaders—achieving commercial viability remains challenging. For instance, battery-electric machines powered by renewable energy often come with higher costs compared to traditional internal combustion engine (ICE) technology. They also tend to face challenges such as limited access to convenient charging infrastructure and may require workforce upskilling. To help encourage adoption, equipment manufacturers may need to enhance their energy efficiency equations by engaging in ongoing research, development, and investment.

Barriers to technological adoption. In many ways, achieving net zero in the built environment sector hinges on the adoption of new technologies capable of both measuring and reducing carbon emissions across the value chain. However, there are several barriers to overcome for industry players to easily embrace these solutions—including regulatory frameworks that may struggle to keep pace with rapid technological advancements, the high costs of initial investment, and a lack of awareness of the long-term economic benefits these solutions may deliver. Cost concerns are a particular sticking point but could potentially be overcome through access to greater subsidies and third-party funding, as well as by passing some of the costs along to end users (e.g., tenants).

Inconsistent data metrics and guidelines. While the adoption of technology can help industry stakeholders weigh the pros and cons of various decarbonization pathways, measure and report on their carbon footprint, and monitor their decarbonization performance, the proliferation of a myriad technology tools is introducing challenges of its own. For instance, a lack of consistent metrics, methodologies, and data comparability can make it hard to arrive at a consensus around decarbonization progress and outcomes. This speaks to the need for enhanced data transparency, standardization, and reporting guidelines to help promote leading practices and ensure consistent data measurement, visualization, and verification.

Opportunities

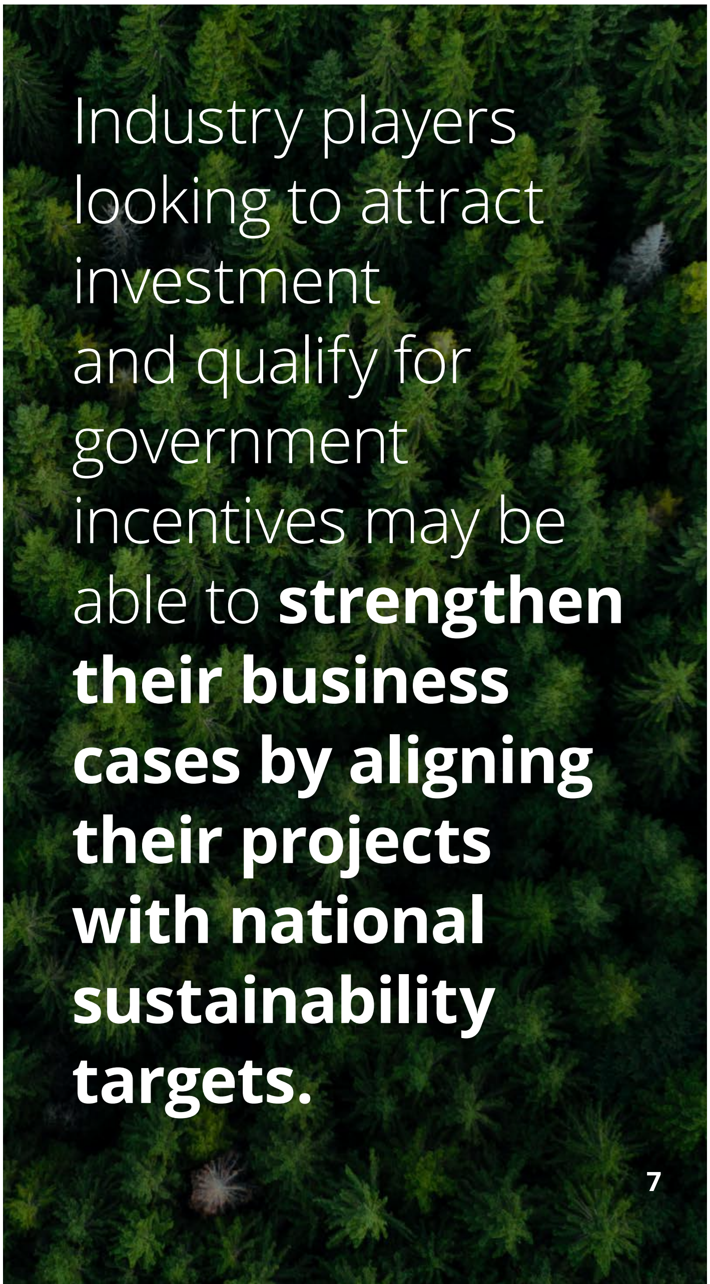
Although there are a range of actions the sector can take to help address industry challenges (see "Decarbonization levers"), the pathways towards decarbonization must first be charted. Beyond the benefits this can deliver to the built environment ecosystem, effective approaches to decarbonization stand to benefit other sectors as well. For instance, a growing demand for sustainable building materials, such as green steel or concrete, may induce suppliers to transition towards less carbon-intensive materials. Similarly, greater use of climate change mitigation solutions such as carbon capture, utilization, and storage (CCUS) technology can enable high emitters in other sectors to reduce their carbon emissions as well. To help set these impacts in motion, here are some ways forward:

WHO: Workforce reskilling

To help drive efficiencies around sustainable and digital solutions, workforce reskilling will likely be necessary. Additional skilled labor may be required to both modernize the built environment and help address the physical effects of climate change, such as damage to buildings and land, as well as the impacts caused by extreme temperatures. However, the transition to net zero itself stands to disrupt the way people work as emission-intensive activities and processes are replaced by low-emission alternatives and new installed technologies.

While conventional skills such as engineering, manufacturing, project management, construction, and operations will likely remain in demand, there is already a growing need for new skills in areas such as green building design, artificial intelligence (AI) and data analytics, sustainable construction, and renewable energy. However, avoiding mismatched job demand requires the coordination of workforce policy with decarbonization policy. This reinforces the need for governments, industry, and educational institutions to invest in the development of training programs, apprenticeships, and retraining initiatives to equip the workforce for the net-zero transition.

The Deloitte Economics Institute has developed a Green Collar workforce policy agenda to guide how decision-makers should consider supporting industries and workers to adapt to global decarbonization for equitable employment outcomes.[22] This agenda would see global governments setting ambitious interim emissions reduction targets, designing new industrial policy, creating high-value jobs for the various transition pathways, reforming education and training systems, and targeting workforce policy to direct skills where they are needed. By eliminating regulatory barriers and inconsistent policies, this approach can help pave a rapid path to net zero.



HOW: Affordability

As with major transitions, cost factors can strongly influence adoption rates. Industry players looking to attract investment and qualify for government incentives may be able to strengthen their business cases by aligning their projects with national sustainability targets.

In addition, there can be split incentives for different parties. For example, landlords may fund the cost of capital improvements in either retrofit or new build scenarios, resulting in reduced operational costs for end users, such as lower utility bills. Similarly, retrofitting upgrades (such as double-glazing or solar panels) may reduce power costs for tenants, while giving landlords the ability to defray those costs by renegotiating rental agreements. That said, many industry stakeholders are deterred from making these investments due to the added layer of complexity they introduce.

Some common ways for stakeholders across the built environment ecosystem to help overcome these financial barriers and strengthen their business cases include:

- Enhancing supplier oversight through data transparency, empowering developers and operators to help accelerate construction timelines and lower expenses
- Balancing the potentially higher costs of adopting sustainable materials against lower construction and long-term maintenance costs, where possible
- Using sustainable methodologies, such as prefabrication and modular construction, to help reduce labor costs, enhance design and quality control, and shorten project schedules[23]
- Partnering on low-carbon projects with other players across the value chain in an effort to attract commercial funding by boosting consumer demand
- Collaborating with governments, central banks, commercial banks, institutional investors, and other financial actors to access innovative sources of climate finance[24]
- Lowering operational costs by investing in capital improvements that can deliver cost benefits throughout the asset lifecycle and incorporating them into leasing agreements from the outset
- Leveraging government incentives, such as tax credits, subsidies, or grants, that can encourage green building practices and investments
- Securing loans from financial institutions that offer financial products with favorable terms to help support green construction projects
- Accessing rebates and incentives available through energy efficiency programs for using energy efficient materials and technologies
- Standardizing green building practices and materials to help reduce costs associated with customization and encourage widespread availability

WHAT: Accelerated technological adoption

When it comes to reducing operational emissions, a range of smart technologies for the intelligent control of energy consumption has already proven effective, from heat pumps and low-carbon cooling systems to thermal insulation and LED lighting. At the same time, innovations promise to help tackle the embodied carbon challenge.

Emerging technologies—such as AI; carbon capture, utilization, and storage (CCUS); 3D printing; digital twin solutions; advanced manufacturing; simulation software; and generative design to optimize material use—can help support even greater alignment around carbon abatement across the value chain. The route towards net zero will further be bolstered as renewable energy use becomes more widespread.

The key now is to help accelerate implementation of these existing technologies by strengthening the business case for their adoption and demonstrating how long-term return on investment can outweigh initial investment costs. Policymakers will also have a role to play in implementing enabling policies that both mandate and financially incentivize the use of technologies that can help support the decarbonization agenda.

WHERE TO START:
Transforming existing assets

To help reach net zero by 2050, the built environment ecosystem must continue to reduce operational and embodied carbon emissions across the value chain. This can be done by repurposing and transforming existing assets to help bring them into alignment with modern energy and sustainability standards, promoting reuse over new construction—a practice that can accelerate as the demand for green buildings rises.

Admittedly, retrofitting existing structures may not make sense in every circumstance. Depending on an existing building's structure, usage, and location, economic advantages may favor a "tear-down and rebuild" strategy. In making this decision, stakeholders should consider regulatory factors, such as carbon pricing considerations and the existence of levies or charges based on carbon emissions. In many jurisdictions (particularly within the EU), this assessment may discourage the carbon-intensive tearing down of real estate that remains usable.

Depending on the age of a country's existing assets and the maturity of its regulatory framework, retrofitting activities can fall into a number of areas. These include integrating smart technologies into existing stock to help track and reduce energy consumption, promote waste recycling, and minimize water usage; upgrading electrification systems; and switching to renewable energy power generation. The opportunity also exists to begin replacing aging materials with newer, less carbon-intensive, more energy-efficient materials as part of the ongoing maintenance and renovation process in a bid to lower the energy demand of assets. This is especially true in regions such as the EU where 85% of existing buildings were built before 2000 but will likely still be in use in 2050.[25]

Beyond the capacity to help reduce energy and maintenance costs over time, transforming existing assets represents a critical pillar of the global decarbonization agenda, particularly given that renovation and reuse projects generate 50% to 75% fewer embodied GHG emissions than new construction.[26]

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Decarbonization levers

While there appears to be no single pathway to decarbonization for the built environment, a range of levers can be used by stakeholders across the value chain, both individually and collectively through partnerships and coalitions. Some of the technological solutions identified here are ready for immediate adoption, while others will likely be rolled out in phases as stakeholders ramp up the capacity to reduce emitted carbon. Real estate players, for instance, can already decarbonize on an asset-specific basis and share key learnings with the broader construction sector, particularly given the International Energy Agency's mandate for all countries to target zero-carbon-ready codes for new buildings by 2030.[27]

Materials

Now → 2030

Invest in the ongoing development of **green building materials** (e.g., advanced concrete, recycled materials, low-carbon asphalt, green steel, etc.), increasing usage to help grow global supply capacity and adoption.

Decarbonize the power supply and heat by electrification through **renewable sources** and **develop multi-purpose assets** for energy generation, storage, and charging facilities, helping to accelerate the shift to renewable sources of energy for construction and operation.

Reduce energy demand with solutions such as thermal insulation, double skin walls, vertical greenery systems, cool roofs, and phase change materials (PCM) wall systems to influence design and material selection impacting new builds and retrofits.

2030 → 2050

Environmentally **sustainable building materials** continue to advance and become the **industry standard globally**; production capacity has grown to meet market demand.

Carbon capture, utilization, and storage (CCUS) technologies on construction sites, for carbon-intensive processes, and during the production of materials such as cement and steel may be used exclusively.

Mass production, implementation, and subsequent generation of sustainable solutions become commonplace, potentially leading to a reduction in energy demand.

Construction

Now → 2030

Use **digital technologies**, such as building information modeling (BIM), digital twins, AI, and data analytics to improve efficiency, design, and resource management.

Reduce costs, emissions, and waste with **prefabricated and modular construction methods**. Employ **3D printing** to help facilitate the construct of new assets. Capabilities will likely increase over time.

Continue the **electrification and digitization of construction equipment and machinery**, to focus on energy usage, efficiency and safety and provide greater connectivity between asset and users.

Improve energy efficiency by using smart ventilation, thermal energy storage, and zero-carbon heating technologies in retrofits and new eco-friendly builds.

2030 → 2050

Exclusive use of **advanced encryption methods**, blockchain technology, and AI-based security systems, and **sustainable data centers** powered by renewable energy will likely require greater levels of cybersecurity.

Offsite manufacturing becomes an integral part of the construction process, allowing efficiencies and greater use of new build and design techniques and materials.

Increased automation including unmanned machinery can bring greater efficiencies and cost benefits—and has a positive effect on environmental impact and safety records.

Onsite renewable energy and green power sources, such as biomass, solar thermal, solar energy PV, and geothermal, become prevalent.

Negative emissions technologies, such as direct air capture and bioenergy with carbon capture and storage (BECCS), can help achieve net-zero/net-positive assets.

Operations and maintenance

Now → 2030

Engage tenants in decarbonization efforts with **green leases** and **smart buildings** that feature automated controls and electric vehicle charging facilities as their demand for more sustainable infrastructure increases.

Follow investor guidelines as they start requiring that assets meet sustainable finance standards and goals; minimum requirements will likely increase over time.

Expand the electric **charging infrastructure** to neighborhoods in collaboration with local suppliers as real estate assets become part of the wider sustainability infrastructure.

2030 → 2050

Widespread implementation of **smart traffic management systems**, development of **high-speed wireless charging** technology, and extensive digitization can enable greater interaction of private real estate assets and city infrastructure to help optimize management and utilization of assets and services.

Sustainable finance will become the standard and any assets not conforming with **sustainability targets or standards** will likely be unable to raise or retain finance and attract investors.

A **smart grid** as part of a public-private partnership to interconnect energy efficient assets and consumers to help optimize the utilization of sustainably generated energy has been implemented.

Achieve net-zero for majority of existing building stock.

The way forward

Despite some of the challenges that the built environment sector faces on its journey towards net zero, emerging opportunities and levers exist to help drive ongoing decarbonization efforts. In charting the way forward, however, it will be beneficial for businesses and governments to work together to help build collaborative global ecosystems, devise forward-thinking policies, and accelerate the adoption of supporting technologies. In the near-term, industry stakeholders can unlock some of these benefits by:

1. Accurately quantifying their carbon footprint throughout the entire value chain
2. Assessing climate-related risks and opportunities
3. Establishing robust decarbonization standards and strategies that set out clear targets and key performance indicators (KPIs)
4. Identifying and implementing technology solutions that can help enhance emissions monitoring and reporting
5. Developing robust regulatory compliance and risk mitigation programs
6. Creating a culture that promotes the benefits of decarbonization

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At Deloitte, we support stakeholders across the built environment value chain by helping them develop, finance, and implement the sustainable solutions required to help achieve a multi-faceted transformation. With in-depth knowledge of the evolving regulatory environment, extensive construction and real estate experience, and a vast client ecosystem, Deloitte can provide an invaluable hub for the development of enhanced business capabilities, transformation know-how, and behavioral change management.

This paper is part of a collection of insights on possible pathways to decarbonization for high-impact sectors. Each sector perspective offers a foundational starting point for leaders who would like to better understand the landscape across these critical sectors. For additional sector papers and links to in-depth reports, please visit [Pathways to decarbonization](#) on Deloitte.com.

To learn how Deloitte can help you identify your decarbonization pathway, ignite creative solutions, and help accelerate your organization's transformation, contact us.

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