Centre for Energy and Materials

Emerging Insights for Achieving Circularity in the Built Environment

BRIEFING PAPER

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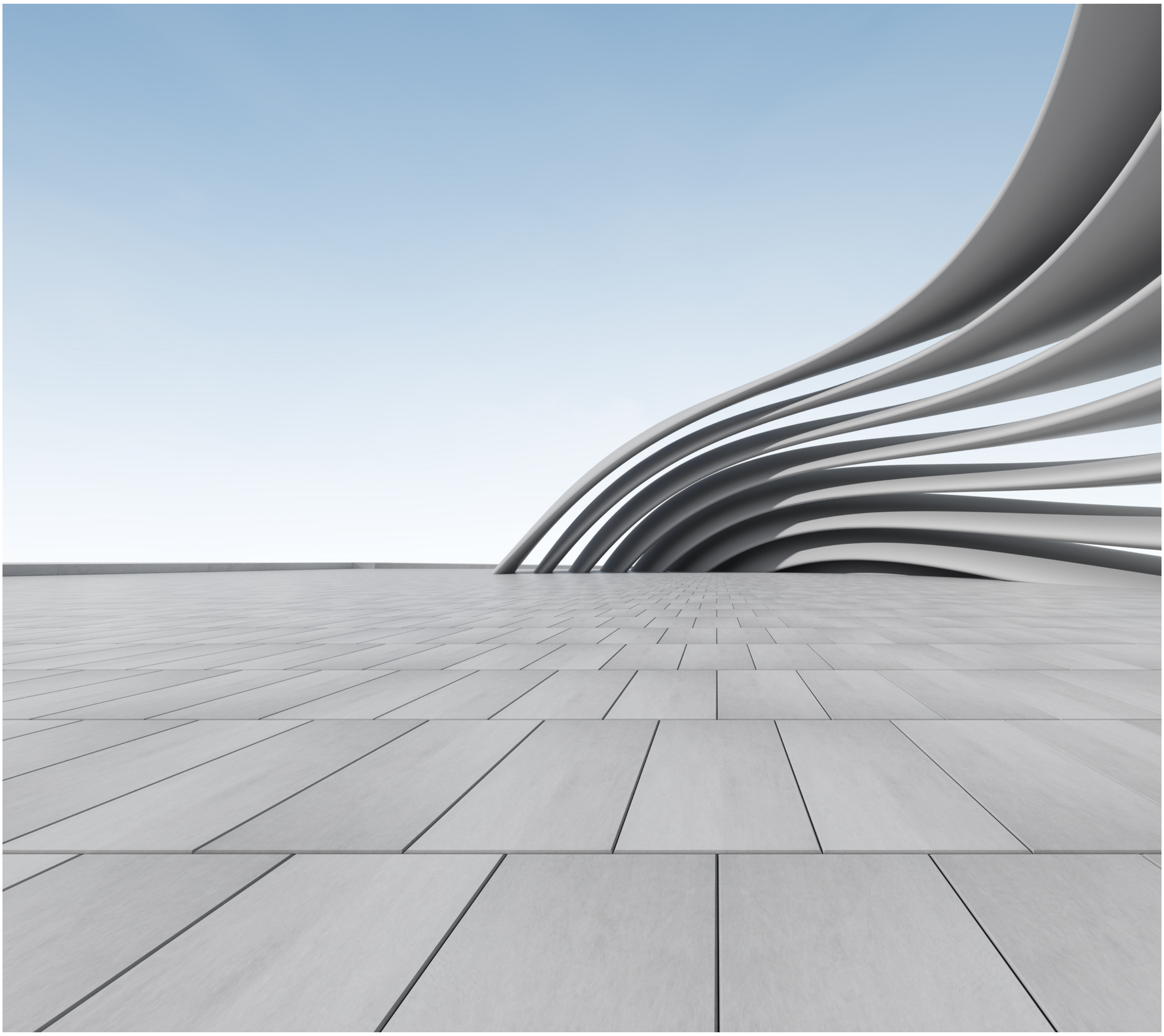
The built environment, which encompasses real estate and infrastructure, is the largest economic ecosystem, accounting for 13% of the world's GDP. Yet with a share of approximately 40% of global CO_2 emissions, it is also one the highest-emitting sectors.[1] To achieve net zero, it will be crucial to accelerate decarbonization efforts in the built environment.[2] Doing so, however, entails a number of challenges, not the least of which is reducing the embodied-carbon emissions of construction materials.[3]

The circular economy presents one way to not only achieve a reduction of embodied-carbon emissions, but also conserve resources and mitigate supply chain risks and create value.[4] Circularity in the built environment focuses on designing products for reuse, incorporating modularity in the building phase, reducing the consumption of materials, recycling construction and demolition waste, and making repairs to existing buildings and infrastructure.

Considering an end-to-end perspective of the construction value chain, these methods can help reduce carbon emissions and create additional value either by mitigating rising carbon and landfill costs, or by reducing materials and production costs. In addition, circular construction will likely be more resource efficient and resilient against external shocks, such as supply chain disruptions or unanticipated price spikes for materials.

Moreover, circularity has a crucial role to play in tackling the unprecedented energy crisis, recently illustrated by high prices and mounting concern for supply security. Circularity addresses energy and material scarcity in upstream supply and can create further benefits in cost savings, or offer a solution for legacy waste from mid- and downstream actors such as delivery partners and customers.

This paper offers a summary of findings from a recent study by the World Economic Forum in collaboration with McKinsey. It explores the idea that circular construction materials are a key commercially viable lever for decarbonization, not a niche solution. It also provides insights on the potential of circularity to abate a significant share of CO_2 emissions while creating value opportunities.



1 Circularity and the built environment: An overview

Operational emissions from energy used to heat, cool and light buildings account for approximately 76% of the built environment's total global CO_2 emissions, and embodied-carbon emissions make up the remaining 24%. Both sources of emissions can benefit from circularity.[5]

Circularity in the built environment has the potential to reduce the cost of materials, accelerate project delivery, improve the resiliency of supply chains and increase the operational life of assets. It can also reduce risk stemming from externalities such as rising carbon and landfill costs. On the first point, carbon prices in the European Union have reached nearly €100 per ton of CO_2,[6] and on the second point, the cost of landfill from construction and demolition waste (CDW) has reached €150 per ton.[7]

Given these developments, significant value is at stake in the built environment. For cement and concrete – which together form the linchpin of the built environment – the total value at risk from CO_2 and landfill is approximately $210 billion by 2050.[8]

The technologies that support circularity typically fall into three clusters: CO_2, materials and minerals, and energy (Figure 1). These clusters are based on the principles of eliminating waste and pollution, circulating products and materials, and regenerating the natural world. Although materials and minerals is the most prominent of the three, spanning the full value chain, each has the potential to contribute significantly to CO_2 abatement across the built environment.

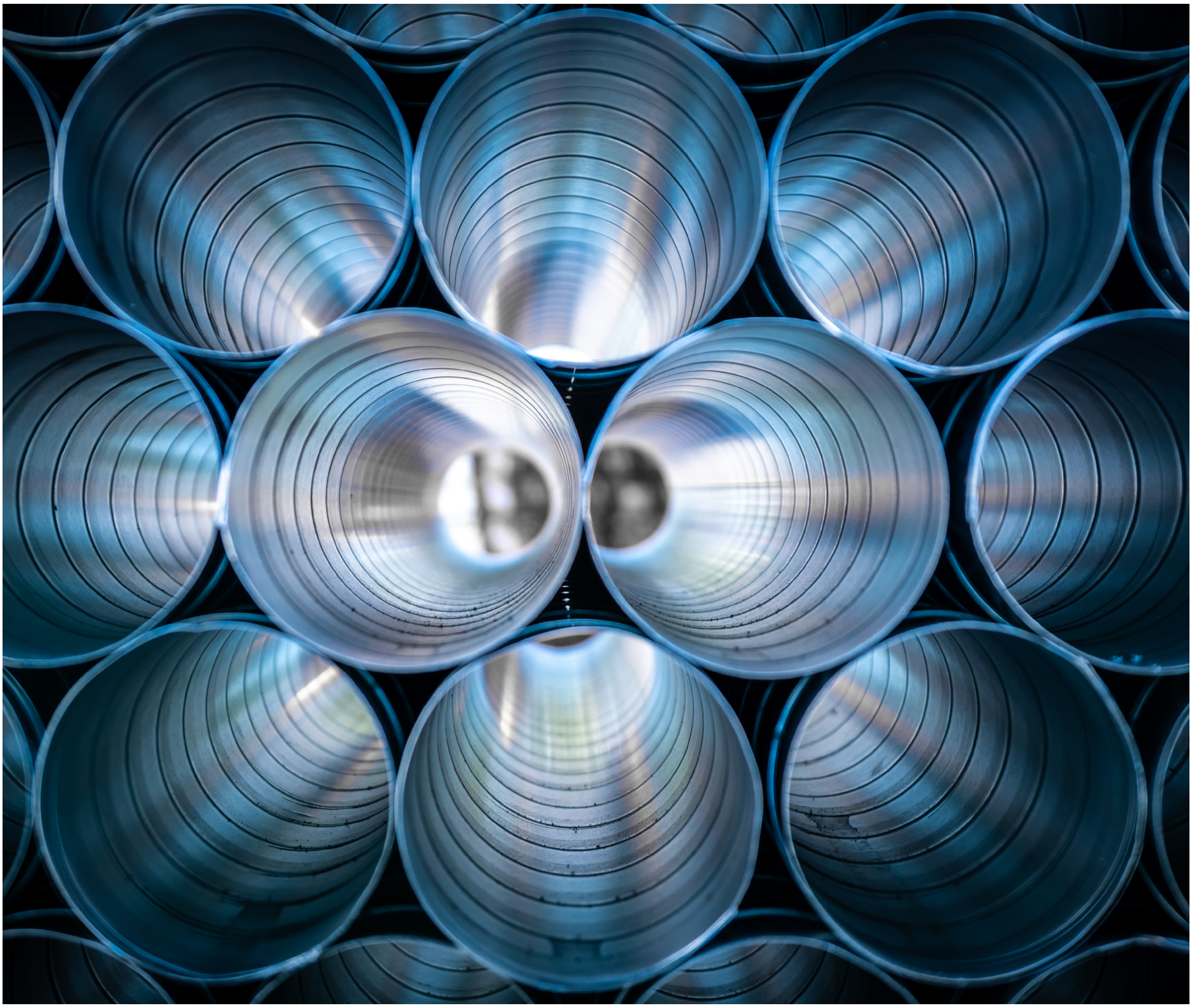
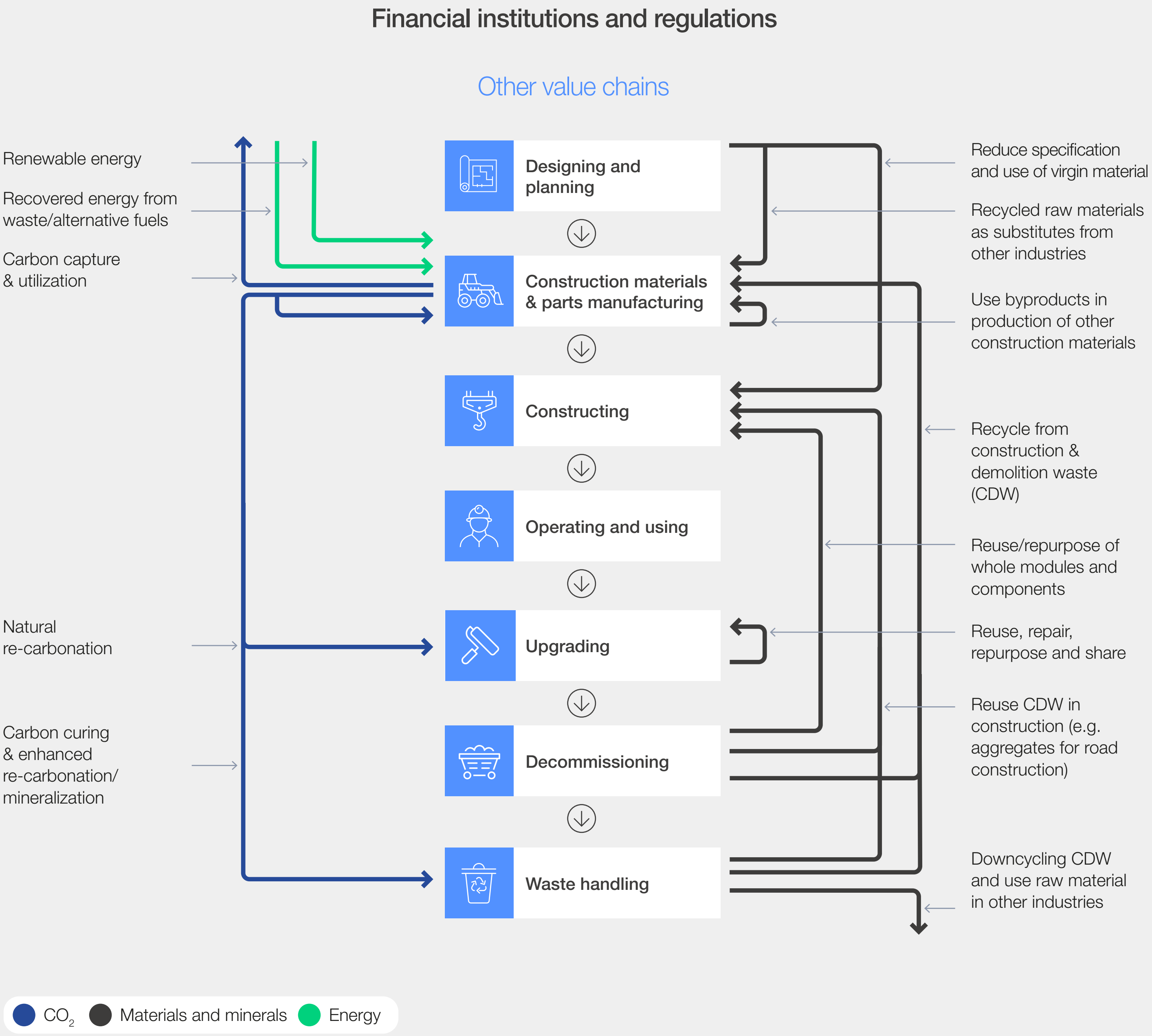


FIGURE 1 **Circularity in the built environment can be clustered into three technological categories: CO_2, materials and minerals, and energy.**



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The impact of these technologies will likely have some regional dependencies. For example, countries with high CO_2 pricing will have earlier incentives to explore solutions of minimizing CO_2. Similarly, countries with high leakage of plastics waste could see additional potential because alternative fuels can be produced via pyrolysis of these materials. In addition, mineralization technologies are typically driven by regions with high carbon prices, such as Europe and North America.

2 Circularity in cement and concrete

The circular cement value chain—and, by extension, the circular concrete value chain—shows that the application of circular technologies is feasible while creating additional value for the entire ecosystem. Our estimates show that the increased adoption of circular technologies in cement and concrete could create new value of approximately $116 billion by 2050.[9]

Recirculating CO_2

CO_2 emissions from cement and concrete production can be reinserted into the value chain using mineralization of aggregates from concrete waste, enhanced recarbonation of construction and demolition waste, and carbon capture and utilization. With expected CO_2 prices either mitigating or outweighing the costs of these technologies, the annual net impact of recirculating carbon by 2050 could be as much as $6 billion.

Although most CO_2 recirculation technologies are not yet deployed at scale, they could eliminate up to 1.5 billion tons of CO_2 by 2050. Cement and concrete manufacturers can also consider CO_2-offtake opportunities in adjacent industries such as plastics and chemicals.

Recirculating materials and minerals

The recirculation of materials and minerals includes the direct reuse of entire structures and the recycling of concrete waste into aggregates for concrete, substitutes for clinker, and gravel for road construction. In the coming decades, the global supply of concrete waste from CDW is expected to increase from approximately 1.5 billion tons in 2020 to 4.0 billion tons by 2050, which highlights the opportunity for the recirculation of materials and minerals. Cement and concrete manufacturing can also reuse waste materials from other industries, including metal slags and fly ash, which can be used to replace clinker.

With a total net value gain of $85 billion by 2050,[10] the recirculation of materials and minerals is estimated to be the largest driver of financial impact. This includes the use of CDW as aggregates for concrete production, avoiding landfill costs, and the costs of virgin materials. Reusing concrete modules and structures can also create value of approximately $24 billion by 2050. By reducing the amount of virgin cement and clinker needed, these technologies could help abate 0.6 billion tons of CO_2 by 2050.

Recirculating energy

The use of alternative fuels from waste materials, together with the recovery of energy and heat throughout cement and concrete production, has the potential to reach $25 billion by 2050.[11] Given the low cost of waste materials and increasing prices of traditional energy sources such as petroleum coke, alternative fuels often come at a negative cost. By contrast, biomass, with its net-zero emissions, is expected to have a much greater impact on CO_2 abatement. The greatest value potential arises in countries and regions with a high availability of waste materials and high landfill costs.

3 Circularity in other construction materials: Steel, flat glass and gypsum

Although cement and concrete are responsible for a large volume of materials in the built environment, circularity can also be applied to other building materials; for example, steel, flat glass and gypsum.

Steel

According to research, the total steel market is estimated at 2.2 billion tons, of which roughly 50% is used in the built environment. Steel is already a highly circular construction material with high recycling rates, but additional potential for circularity exists through the increased use of steel scrap in electric arc furnace steelmaking. This can be achieved by increasing the collection of postconsumer scrap through improved processes to avoid contamination of steel scrap and upgrading contaminated steel scrap.

Further potential comes from reusing or repurposing construction steel components, which is currently only done on a small scale. In addition, standardizing construction steel products, demolishing carefully, and implementing direct sorting and material passports for buildings can increase the potential of reusing and repurposing steel beams.

Flat glass

The flat-glass value chain is mainly linear, with low recycling rates (anywhere from 1-8%, depending on the country and value chain step). Furthermore, the majority of end-of-life flat glass is either landfilled or downcycled, where it is used as container glass.

The biggest opportunity for circular flat glass is increased collection of cullet and increased use of cullet in the production of glass. By contrast, the biggest challenge of using cullet as a raw material in flat-glass production is the high purity requirements. Thus, increasing the collection of high-quality cullet requires collaboration among value chain players, including designing for modularity and on-site recycling.

Gypsum

Theoretically, gypsum can be recycled and reused ad infinitum,[12] but the current gypsum industry is characterized by low recycling rates. One of the main challenges in gypsum recycling is the contamination of renovation and demolition waste gypsum with lead and asbestos.

In addition to the depletion of finite resources of natural gypsum, raw-material supply for synthetic gypsum is expected to face shortages as well. For example, flue gas desulphurization (FGD) gypsum, which accounts for roughly 75% of synthetic gypsum, is produced from a coproduct of coal-fired power plants. The phaseout of coal-fired power plants could thus lead to increased demand for recycled gypsum.

4 Collaboration and circular business models in the built environment

Collaboration improves the regulatory environment by providing incentives for circular practices and increasing the cost of noncircular practices, among other examples. It is also key to fostering the adoption of circularity levers and the creation of new business models, and it can help scale solutions by enabling standardization and a rethinking of the construction materials product offering.

There are several successful collaboration models across the construction value chain, ranging from horizontal and vertical networks to closed-loop partnerships, public–private partnerships and knowledge-exchange networks. Currently, industry stakeholders primarily use vertical networks to build collaborations and joint ventures with downstream players and start-ups. However, horizontal networks could be used more frequently in the future – for example, by creating markets for circular materials and knowledge exchange networks between different players of the value chain (such as architects, construction companies and real estate developers) to accelerate design for circularity. An example of a public–private partnership is the Dutch flat-glass recycling system, which is a collaboration among the Dutch government, recyclers, collectors and flat-glass producers.

Moving to a circular economy in the built environment will likely shift value pools, with traditional value pools declining as the need for raw materials goes down and new value pools are created. Examples include green materials based on recycled raw materials, such as green clinker from recycled concrete paste.

Offering green or circular materials will often be one of the first steps for players transitioning to a circular built environment. New business models, such as "materials as a service," are often relevant only for high-value materials and products with shorter life cycles or with global scarcity and competition. As additional opportunities, building materials and construction companies can offer maintenance services as well as new circular offerings, such as precast building models.

Furthermore, demolition companies and waste providers can offer new ecosystem services, such as digital marketplaces and logistics services for waste materials and reusable components. And technology providers and designers can use technologies that facilitate design and standardization, such as digital material passports and digital twins of buildings.

Finally, new business models related to CO_2 offtake can be established, such as capturing carbon at production facilities and transporting concentrated CO_2 to industrial production sites where it can be used as an input.

Although the circular economy in the built environment provides many opportunities in terms of both CO_2 abatement and financial value, it will also likely shift value pools away from traditional business models. To capture new opportunities, players in the built environment will need to rethink how they operate and assign value. Industry stakeholders along the entire value chain should act now to tap into the value pools created through circularity. The challenge will be to create viable circular business models along the entire value chain and across industries, which highlights the need for increased collaboration.

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Endnotes

1. McKinsey, *Accelerating green growth in the built environment*, November 2022.
2. For a comprehensive list of more than 5,000 decarbonization levers for different building archetypes in a variety of regions and climate zones, see: McKinsey and the Net Zero Built Environment Council, *Building value by decarbonizing the built environment*, June 2023.
3. "Embodied carbon" refers to CO_2 emissions released over the full life cycle of building materials, from extraction to disposal.
4. For more on circularity, see: *What is a circular economy*, Ellen MacArthur Foundation, accessed 2 June 2023.
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12. Eurogypsum, *Circularity*, accessed 2 June 2023.

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