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GLOBAL INFRASTRUCTURE INITIATIVE

Decarbonizing the built environment

Voices on Infrastructure | October 2022

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Introduction

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The $11.6 trillion global infrastructure industry is hard at work constructing the buildings, structures, and assets that will house and transport generations to come. But many of the projects that make up the built environment—our buildings, water and electrical systems, roads and bridges, and transportation systems—are not being constructed in line with the world's net-zero goals. According to McKinsey estimates, construction is directly or indirectly responsible for 40 percent of global CO_2 emissions from fuel combustion and 25 percent of greenhouse-gas emissions overall.[1]

In this issue of *Voices*, leaders offer perspectives about how best to decarbonize our built environment and erect a sustainable future.

Moving the needle on net-zero emissions will be difficult. Our research shows that the world will need to invest $9.2 trillion each year until 2050 to achieve net-zero emissions in the built environment. Yet doing so will create a number of exciting opportunities around green-business building. With this in mind, McKinsey and the Global Infrastructure Investor Association (GIIA) discuss the pathways to decarbonization: understanding and mapping emissions sources across sectors, and describing how portfolio managers can provide the detail and transparency necessary to measure real progress against net-zero goals.

Indeed, measuring progress, communicating it well, and predicting risk are all critical to success. Gordon Reid and Mark Williams from Scottish Water, Scotland's national public water and wastewater service, share their insights on how achievable net-zero emissions goals are and how effective high-level strategy can be when it's communicated properly. McKinsey's Brodie Boland speaks to Ashurst's Alex Guy about planning and delivering climate resilient capital projects. And Tariq Taherbhai of Aon grapples with the question of how to account for project risk effectively, from assessing the risks posed by suppliers and subcontractors to dealing with volatile climatic events in large construction projects.

Decarbonizing our built environment will also require the industry to embrace greener construction methods and materials. An article from McKinsey's Zak Cutler, Taylor Dayton,

[1] "Call for action: Seizing the decarbonization opportunity in construction," McKinsey, July 14, 2021.

Matthew Grant, Shu'aib Mahomed, and Jemilat Ojetayo offers a perspective on the importance of reducing embodied emissions—that is, the emissions associated with construction. And we share a summarized overview of a recent report on achieving net-zero emissions in the steel industry, written in collaboration by McKinsey and the Energy Transition Commission.

To round out the issue, the fifth and final article in the series by senior adviser Richard Westney and McKinsey's Capital Excellence team illustrates how doing good demands doing better when it comes to delivering net-zero capital projects. In this case, doing better means establishing a new framework for procurement, engineering, and construction. The article also includes an interview with Greg Lawton, cofounder and CEO of project-delivery company Nodes & Links.

We hope you find this issue of *Voices* insightful as it relates to your own ongoing conversations about how to decarbonize buildings at every scale.

News from the Global Infrastructure Initiative

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Welcome to the October 2022 edition of *Voices on Infrastructure*, which focuses on decarbonizing the built environment.

The built environment—which includes everything from our roads, buildings, and bridges to other critical infrastructure—is essential to the world's net-zero imperative. The construction value chain accounts for nearly a third of the world's greenhouse-gas (GHG) emissions, including embodied and operational carbon. This means the industry will need to adopt greener materials and project delivery methods to reduce its impact on nature and avoid jeopardizing global climate goals.

Climate change and the energy transition are also creating new challenges and opportunities in the infrastructure value chain. In response, owners, investors, construction leaders, and operators are rethinking risk, resilience, and capabilities to thrive.

This issue of *Voices* coincides with our upcoming GII Summit, which centers on the relevant theme of creating a pathway to sustainable infrastructure. The Summit meets in Tokyo from October 19 to 21, and our final agenda and roster of speakers are now available. With more than 200 C-suite leaders from more than 30 countries set to join us in Japan, we are excited to engage in discussions, site visits, and problem-solving workshops to help our GII community scale solutions and ideas.

Following the Summit, we will host a roundtable in Washington, DC, on November 15, focused on creating the capacity to deliver infrastructure. More information on our recent and upcoming roundtables can be found on the GII website.

As for publishing, this is our final themed edition of *Voices* for the calendar year, and you will next hear from us at the year's end with a special issue recapping our 2022 Summit in Tokyo.

As we look toward our 2023–24 cycle, we welcome your feedback on our events, publications, and industry initiatives. Is there a theme or idea you think is critical to discuss in *Voices*? Or is there a site visit we should highlight in the year to come? Let us know at info@giiconnect.com.

Sustainable spaces for work, rest, and play: Climate resilient capital projects

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Climate change is creating new levels of complexity for infrastructure and capital projects such as roads, bridges, buildings and utilities. Long-term planning has become fraught with uncertainty, as leaders seek to invest in projects with long lifespans and pursue net zero targets that are decades away. At the same time, extreme weather is already impacting our built environment in a real and immediate way, from electricity outages to flood damaged roads. These phenomena affect lives and livelihoods. They alter project economics and they create costly service interruptions. Understanding and mitigating these climate risks will be essential to manage costs and ensure critical continuity. In particular, new projects must be planned, designed, built and operated to account for climate transitions.

This podcast, in collaboration with McKinsey Talks Operations, features Alex Guy, a partner at the international law firm Ashurst, and Brodie Boland, a partner from McKinsey's Washington, D.C. office. Their conversation looks at how climate risk and resilience can be built into capital projects, both early on and throughout the lifecycle.

Listen by scanning the QR code here:

Reducing embodied carbon in new construction

Three-quarters of the $9.2 trillion in infrastructure spending needed per year until 2050 will go toward new construction—offering opportunities to fight climate change by reducing embodied emissions.



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Embodied carbon—the greenhouse-gas (GHG) emissions associated with construction—is by nature irreversible once an asset is built. Embodied carbon includes the CO_2 emitted from extraction and manufacturing processes to create construction materials and the transport of materials and equipment to a project site, as well as all the emissions associated with the actual construction operations required for the installation of the materials.

These emissions during construction are a major contributor to lifetime emissions for capital projects (Exhibit 1). While operations may have decarbonization opportunities long after construction completion, the embodied-carbon emissions from construction are set in stone as the project is executed. Up-front carbon emissions account for up to 50 percent of total life cycle emissions.

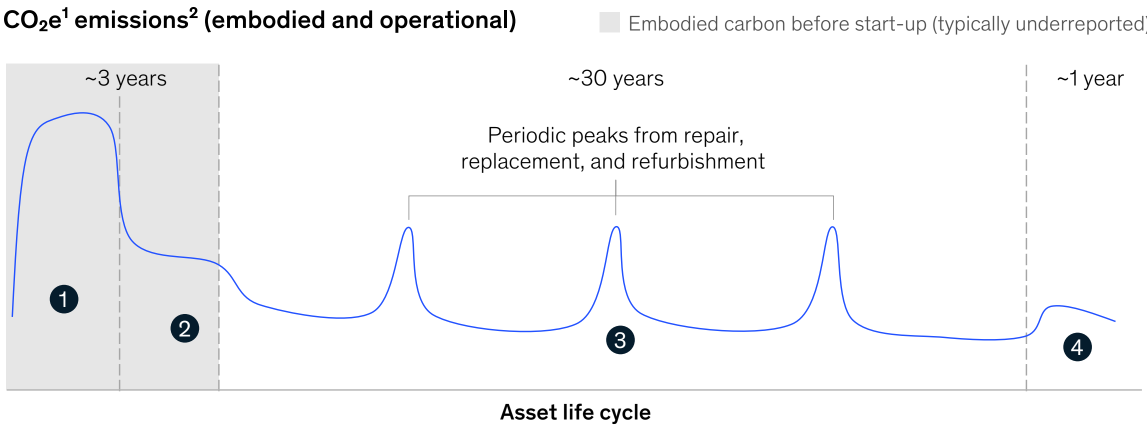
The building operations industry is seeing a clear push toward greener energy sources and optimizing carbon emissions[1]—but reducing embodied carbon during construction is a low priority at best and an afterthought at worst. The focus during design is usually on operational-carbon reduction, not embodied-

[1] For more, see "Building decarbonization: How electric heat pumps could help reduce emissions today and going forward," McKinsey, July 25, 2022.

Exhibit 1

Embodied carbon is irreversible once an asset is built and accounts for up to 50 percent of the asset's lifetime emissions.

CO_2e[1] emissions[2] (embodied and operational)



1 **Construction material procurement**
Driven by carbon-intensive manufacturing processes for bulk construction materials such as steel, concrete, aluminum, copper, and plastic

2 **On-site construction**
Driven by fuel consumed by heavy construction vehicles and other Scope 3 emissions (eg, workforce commuting)

3 **Operations**
Driven by heating and water utilities and electricity consumption, along with other Scope 3 emissions (eg, workforce commuting, purchased goods and services, and transportation and logistics)

4 **End of life**
Driven by demolition, waste processing; can gain credits for reuse and recycling

[1]CO_2 equivalent.
[2]Emissions can vary widely based on asset class, geography, and individual project environmental, social, and governance (ESG) approach, among other factors.
Source: "Embodied carbon and the industry's role in reducing global emissions," AECOM, 2022; *Methodology to calculate embodied carbon of materials,* Royal Institution of Chartered Surveyors (RICS), February 2015; *Whole life carbon assessment for the built environment*, RICS, November 2017

carbon reduction, and operational carbon is also the focus of several certifications (such as LEED) that allow a more structured approach to reducing those emissions. Buildings are also built with the materials available, and given that low-embodied-carbon materials are often more expensive than traditional building materials, companies are not compelled to use them unless they are industry leaders in the practice.

The time is now for industry leaders to make tackling embodied emissions a priority. The long-term impact of what we're building today creates a huge opportunity for construction companies—whether they are currently leaders in reducing operational emissions or not—to set the standard for the design choices, materials selection, and construction practices that reduce a project's embodied-carbon footprint.

New construction: $7.2 trillion in annual spending

According to McKinsey analysis of the NGFS Net Zero 2050 scenario,[2] $9.2 trillion per year will need to be spent on capital assets to meet global net-zero targets set forth in the Paris Agreement by 2050.[3] Of that $9.2 trillion, $2.0 trillion will need to be applied toward retrofits, equipment upgrades, and improvements to existing assets. The other $7.2 trillion—more than three-quarters of the total—needs to be spent on new construction. This massive building effort will have a significant impact on global carbon emissions, and that's why it is crucial for companies throughout the infrastructure value chain to prioritize embodied emissions as they build their project plans.

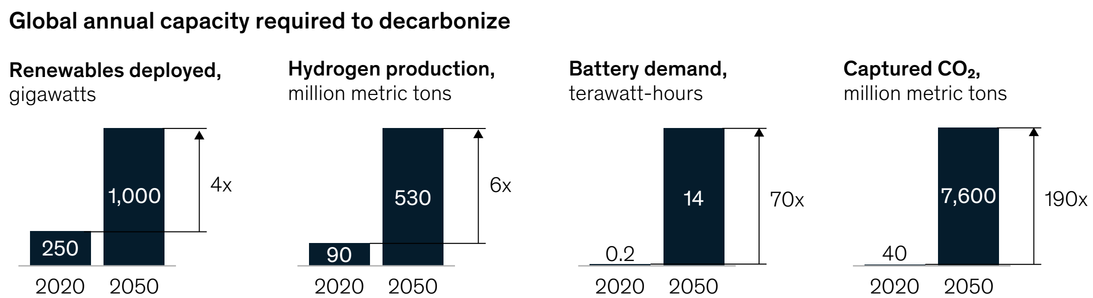
Those project plans will proliferate in the coming years as thousands of new assets come online around the world. The IEA estimates that to decarbonize in line with Paris Agreement targets, renewables deployed must increase fourfold, hydrogen production must increase sixfold, and battery demand must increase a staggering 70-fold (Exhibit 2). This will all be crucial to facilitate the 190-fold increase in CO_2 captured per year—and scaling construction is quickly becoming the bottleneck that could prevent us from reaching net-zero goals.

New capital spending on assets considered to have low operational-carbon emissions, such

[2] "Scenarios portal," Network for Greening the Financial System, 2022.
[3] "The economic transformation: What would change in the net-zero transition," McKinsey, January 25, 2022.

Exhibit 2

Facilitating unprecedented CO_2 capture by 2050 will require thousands of new infrastructure assets.



Note: Figures from source rounded for clarity.
Source: *Net zero by 2050: A roadmap for the global energy sector*, International Energy Agency, October 2021.

as renewable energy sources, will account for roughly 70 percent of capital expenditures through 2050, according to McKinsey analysis of data from the Network for Greening the Financial System (Exhibit 3)—which is good news for the future of operational emissions.[4]

However, many assets with low operational emissions use the same construction materials and processes that are used for high-operational-emissions projects—meaning the up-front embodied-carbon footprint may be the same. Meanwhile, the urgency of reducing carbon emissions has never been higher: experts say we need to cut total emissions in half by 2030 to stay on track for Paris Agreement objectives.[5] Embodied emissions could—and will have to—play a leading role in those reductions.

The path forward

Fortunately, a significant amount of embodied emissions can be reduced by using alternative or unconventional construction processes and materials. Adoption of three practices can help those seeking to be at the forefront of tackling embodied carbon to take advantage of practical opportunities.

Expand adaptive reuse

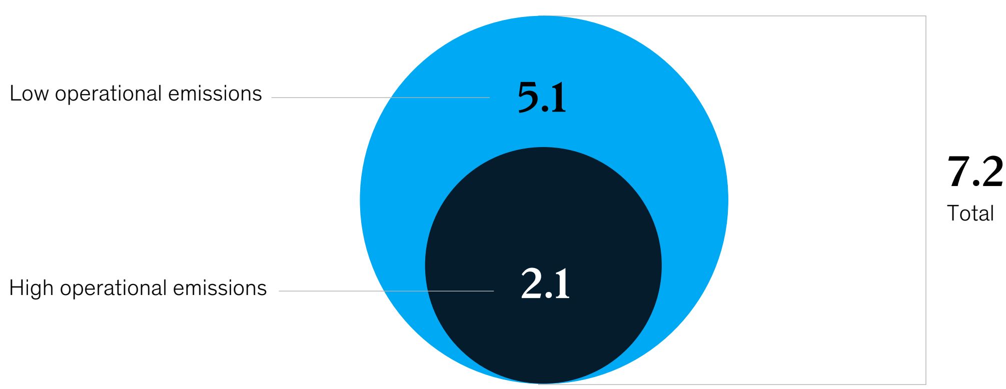
Repurposing an existing building, or adaptive reuse, can be a low-carbon way to expand a company's physical footprint without producing as much embodied carbon. Adaptive reuse usually requires less materials to build out, resulting in lower quantities of building materials and potentially increasing the incentive to use sustainable materials. Developers and engineers can specifically incorporate more sustainable designs with a focus on reducing embodied carbon through lowering material quantities. Sustainable designs that repurpose an existing building or asset have flourished as trendy options for restaurants, breweries, retail stores, and other consumer-facing businesses. Adaptive reuse can also revitalize underused areas of cities, which can further reduce the need for new infrastructure to support new development. Adaptive reuse projects can also provide opportunities for time and cost savings compared with their new-build-project counterparts.

[4] For more, see "The economic transformation," January 25, 2022.
[5] *The net-zero transition: What it would cost, what it could bring,* McKinsey, January 2022.

Exhibit 3

New construction will account for about $7.2 trillion in capital spending, with a clear shift toward assets with low operational emissions.

Average capital spend per year, 2021–50, $ trillions



Source: Network for Greening the Financial System; McKinsey analysis

Shift to lower-carbon building materials

The market for low-embodied-carbon building materials needs targeted support to mature. For example, Kingspan and Peab are partnering with H2 Green Steel and SSAB, respectively, to utilize low-CO_2 steel in their construction materials. As more steelmakers see the benefit of producing low-CO_2 steel, they can hasten the transition away from the traditional carbon-intensive steel production process. Further, this same mentality can be applied to material fabrication processes such as solar panels to provide more low-embodied-carbon material choices for both high- and low-operational-emission capital projects.

Without an incentive for cleaner, more efficient manufacturing and fabrication processes or the development of less-carbon-intensive construction materials, industry and government leaders will struggle to align and could potentially delay the ecosystem's large-scale shift to lower-carbon materials.[6] Clarifying funding options, incentives, and sustainability requirements will help push material suppliers to prioritize meeting targets for reducing the carbon footprint of their portfolio of construction materials.

Embrace greener construction equipment

Traditional diesel-powered construction equipment used in construction operations contributes roughly 3 percent of embodied carbon for new-build construction projects, according to our analysis. The available options for low-emission, electric construction equipment require a substantial investment by a contractor and often deliver lower performance compared with a traditional diesel-powered piece of equipment. However, some equipment manufacturers are at the forefront of developing zero-emission construction equipment. Liebherr, for example, developed an electric crane that the company says performs on par with diesel-powered comparators. Such innovations will be important to fostering scale in green-construction equipment and practices.

Three actions—repurposing existing assets or materials, using lower-emission materials, and using electric construction equipment—can each lower embodied carbon on most construction projects, regardless of what is being built. The industry remains nascent in its efforts to address embodied carbon, but companies at the forefront could quickly demonstrate what it looks like to be a leader in fighting change by reducing embodied carbon.

Zak Cutler is a partner in McKinsey's Toronto office; **Taylor Dayton** and **Matthew Grant** are consultants in the Houston office; **Shu'aib Mahomed** is an associate partner in the Dubai office; and **Jemilat Ojetayo** is a consultant in the Miami office.

[6] For more on the importance of collaboration throughout the construction ecosystem, see "Call for action: Seizing the decarbonization opportunity in construction," McKinsey, July 14, 2021.

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The art of the possible: An interview with leaders from Scottish Water

Many organizations have made decarbonization commitments, but meeting those goals is a different story. Gordon Reid and Mark Williams from Scottish Water share their insights.

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Anna Orthofer

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Gordon Reid

General manager of zero emissions
Scottish Water

Mark Williams

Sustainability and climate change manager
Scottish Water

The future of the construction industry is a decarbonized one—and it's approaching fast. Scottish Water, Scotland's national public water and wastewater service, has set the ambitious deadline of achieving net-zero construction by 2040. As construction companies around the world set their own decarbonization targets, industry leaders are looking for strategies to help them meet these goals—or just get started. Perhaps most surprising, however, is how achievable net-zero emissions goals are and how effective high-level strategy can be when it's communicated properly.

In an effort to better understand these strategies, McKinsey's Focko Imhorst and Anna Orthofer spoke with Scottish Water's Gordon Reid, general manager of zero emissions, and Mark Williams, sustainability and climate change manager, about financing the costs of decarbonization, sourcing low-carbon materials, and attracting and retaining talent.

McKinsey: Scottish Water's targets of achieving a net-zero capital program by 2040 are higher than the announced goals of the UK construction industry. What motivated you to make this commitment, and how does it sit within the broader mission of Scottish Water?

Gordon Reid: Like most organizations, we previously focused on addressing our operational emissions. But as we built our intelligence, it became quite clear that our capital-program emissions were not only significant but also poised to become the largest single contributor to our overall emissions. We knew we needed to act on both and to look at the wider picture.

Mark Williams: Our focus on capital-investment emissions differentiates us. We first started to think about this back in the late 2000s. The water sector has a large incumbent asset base, and operational emissions are just one dimension of that. The continued year-on-year investment in the asset base is essentially an ongoing cost, and it results in emissions that we have to take responsibility for.

It's not just Scottish Water. Other parts of the UK water industry have recognized aspects of this and then helped define the rules. Since then, we and one or two others have gone further. We see these ongoing investments as something we must make every year to maintain the asset base and also to improve it and address the resulting emissions.

McKinsey: What are the biggest opportunities for progress, and where do you foresee the greatest challenges and risks?

Gordon Reid: I think the biggest opportunities are linked to reducing capital-program emissions. The approach we take is threefold: we challenge our teams to develop the lowest-carbon solution to a problem, build it with the lowest-carbon materials, and use the lowest-carbon construction techniques.

The biggest challenge is addressing behavior, both for people and organizations. If an engineer has spent years designing conventional reinforced concrete, you've got to take them on a journey to look at the problem differently. Although I see an alternative material as an opportunity to reduce emissions, our supply chain partners look at that as a potential risk and liability. So you need to have a conversation with them that explores the commercial aspects of the transition, which can be challenging. The good news is that once you actually start conversations, they build momentum on their own.

Mark Williams: Building a coalition of infrastructure providers in Scotland is also a big opportunity. If we can start doing that by building demand for the right materials, then together with the supply chain we can start moving forward.

Gordon Reid: A longer-term question is how the cement, steel, and plastics sectors will fully decarbonize their products. There are some pathways available now, but we're a long way from where we would like to be. These sectors will need to make significant investments across their asset base, which is going to take time. But ultimately, we're not going to be able to deliver net-zero construction without those key investments. And it's difficult to influence them because we're so far removed from the primary production facilities.

McKinsey: What have been the biggest insights or surprises since you embarked on your decarbonization journey?

Gordon Reid: The more you understand the different decarbonization pathways for different materials, the more you see that net-zero construction is achievable. The challenge is one of time: When will green steel and green cement be readily available? The surprise is seeing what our project teams can do now to decarbonize construction. They're thinking outside the box, rising to the challenge, and coming up with lots of ways to reduce carbon, and often significantly.

McKinsey: How are you thinking about the costs of decarbonization? And how will you finance those costs?

Gordon Reid: Decarbonizing construction has been a bit of an open-ended question and an area of uncertainty when it comes to the cost of delivering it. The World Economic Forum forecasts it will take a 3 percent premium on construction, and the UK's Climate Change Committee says to get to net zero, it will take 1 to 2 percent of GDP.

Based on these forecasts and the intelligence we have, we think decarbonization will cost about 1 percent of our capital program over the next 20 years. Now, when you put that into the context of the time scale of our investment program, it's not frightening. We can reframe that cost premium as "It's just the way we do business," because the time will come when the only steel you buy will be green steel. The market will shift, and as it matures, it will become stable.

McKinsey: As a local buyer, how are you working with your supply chain to source low-carbon materials and equipment?

Gordon Reid: We've made reducing carbon one of the key incentives for our contractor partners. And we have also asked our 400 framework suppliers to develop carbon-reduction plans, which will hopefully accelerate the development of lower-carbon alternatives that our construction partners can use.

On the supply side, we look to work with other clients to stimulate the market. If we can signal to the market that we all want to buy a low-carbon version of a specific material, then that will incentivize that part of the supply chain to think about making their materials available in our part of the world.

Engagement with our delivery partners is very much at an executive level, sharing our longer-term strategy and goals with them and looking for alignment. Many of these construction organizations have decarbonization targets of their own, so there is an immediate connection. That said, sometimes the grassroots within these organizations don't want to push a low-carbon initiative because they think their executives won't buy into it—but in reality it's exactly what their executives want.

Behavior is a massive challenge here. The safe thing is to do what is conventional. The more difficult thing is to do something different. But if your leadership is saying, "Please, this is what we want you to do," and a client is saying, "This is what we want you to do," it's easier for people to step out of their comfort zones.

Mark Williams: When there's genuine enthusiasm and interest among people at the executive level to have these conversations on a regular basis and to make it a point in every meeting, other people will come forward with ideas. It's not just focusing on those that are doing well; it's giving guidance so all of the supply chain can participate in the journey, including those that genuinely don't know where to start.

McKinsey: A lot of what we hear from executives has to do with attracting talent to construction and capital projects by illustrating the impact they can have on decarbonization and net-zero goals. How has this affected the people you work with?

Gordon Reid: It's given them headroom to do things they previously felt they weren't allowed to do. The younger cohort are much more environmentally aware, and what we are able to do is give the signal that says, "We want you to do this. We want to deliver for 2040, and we need you to rise to the challenge."

Don't just expect your people to deliver. You've got to constantly challenge them. In every construction meeting, there is a health and safety moment where you discuss milestones, progress, and risks. We need to do the same thing for carbon. We need to continually ask, "What have you done this week in your projects to take carbon out?"

Mark Williams: You can have a challenging target in 2040, and people think that's a long way away and they don't have to worry about it. But there are things that need to happen today, tomorrow, next week, and next month to help us on that journey.

McKinsey: How are you planning to scale innovation to accelerate your decarbonization journey?

Gordon Reid: To begin, you need to segment your construction portfolio. If you're dealing with a huge construction project, your carbon-reduction pathway will be very complex. Know the carbon in your project and know what levers you can pull to make a difference—there's a huge amount of innovation that will be driven by that. And engage your supply chain. There may be a thousand components in your project, but when you break it down into the discrete components, you'd be amazed at what you can do. The art of the possible is growing every day.

McKinsey: What is your advice for other capital leaders pursuing complex decarbonization ambitions?

Mark Williams: Gather the information, but don't worry about the precision. Get something down and allow yourself to always focus on the top issues. As you get those under control, you can move on to the next one. The data journey is long and will never be perfect. The important thing is to start.

Gordon Reid: Nothing succeeds like success. Once people can see that something works, they'll follow it through. Similarly, once a project team sees how simple it can be to take carbon out just by looking at things a bit differently, they will do it again on the next project.

Once we started talking about safety, we improved safety. So let's talk about carbon.

Gordon Reid is general manager of zero emissions at Scottish Water, where **Mark Williams** is sustainability and climate change manager. **Focko Imhorst** is a partner in McKinsey's London office, where **Anna Orthofer** is an associate partner.

On the path to net-zero steel in building and construction

Rising demand for greener approaches creates an imperative for the industry to seize the moment, adopt new mindsets, and set standards for the transition to a greener future.

In April 2022, McKinsey published the report Net-zero steel in construction: The way forward, *a collaborative effort by Pedro Assunção, Brodie Boland, Trevor Burns, Emanuele D'Avolio, Alasdair Graham, Focko Imhorst, Ingrid Koester, Carl Kühl, Rory Sullivan, and Alex Ulanov, representing views from McKinsey's Metals & Mining and Sustainability Practices and the Energy Transitions Commission.*

The following article is an edited overview of the report's key findings. To download the full report, please visit McKinsey.com.

As the world transitions to lower greenhouse gas (GHG) emissions, construction companies have a major role to play. In making the green buildings of the future, they have a chance to tap into demand that spans geographies and architectures. Indeed, greener business models are potential magnets for trillions of dollars earmarked for sustainable investment.

The decisions made by construction executives now will determine how they are positioned for this transition over the coming decade. Those who prepare astutely are likely to seek out emerging pockets of innovation and increase their investment in sustainable technologies and capabilities. New materials such as green steel are more expensive, and will therefore demand a new pricing model. However, they can significantly reduce embodied carbon in commercial buildings by up to 70 percent by 2030.

Amid tight industry margins, a priority for decision makers will be to ensure there is a solid business case for change. The key will be to establish a market position while adjusting to a new cost base. Decision makers must also ensure that greener business models are aligned with demand that will rise at an uncertain pace over time.

Construction industry emissions

From houses to bridges, hospitals, and skyscrapers, the construction industry is responsible for approximately 25 percent of global GHG emissions. A third of emissions are associated with materials and the construction process—"embodied carbon."[1] One reason for the industry's high emissions is that it is a voracious consumer of steel, accounting for more than 50 percent of global demand.[2] Due to the energy required for its production, steel is a carbon megaproducer, responsible for about a quarter of emissions in the construction process.[3]

Given these metrics, decision makers in both steel and construction need to plot a realistic path toward a lower climate goal. Massive changes are required to align with pathways established under the Paris Agreement, but by shifting from high-emissions steel to near-zero-emissions steel, the industry could take a significant step forward.

Decarbonizing steel

Partial steel decarbonization is possible through wider use of modern furnace technologies in steel production. The most efficient furnaces are powered by natural gas and use energy-efficient direct reduced iron or hot briquetted iron (DRI/HBI). These emit much less GHG than traditional coke-fueled blast furnaces or basic oxygen furnaces (BF/BOFs), which account for approximately 73 percent of global production and are dominant in Europe and China.[4]

Another route to lower-CO_2 steel would be to retrofit BF/BOFs for carbon capture and storage (CCS) or carbon capture and utilization (CCU). If these approaches scale successfully, they could theoretically enable sequestration of about 85 percent of CO_2 emissions from coke feedstock.[5] Ideally, producers would be able to scale hydrogen-reduced DRI/HBI electric-arc furnaces (EAFs) powered with renewable energy. With this combination, producers could make steel with a carbon intensity of less than 0.2 tCO_2 per metric ton of steel, compared with a global average of 1.8 tCO_2 with today's cleanest technologies. High costs would require steel to command a "green premium" of 20 to 25 percent over 20 years to fund the construction of new facilities, not including capital expenditure for hydrogen production, transport, and storage (Exhibit 1).

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1 "Metals & mining insights," McKinsey, accessed September 2021; "Real estate insights," McKinsey, accessed September 2021; based on 2017 emissions.
2 "Steel facts," World Steel Association, accessed January 26, 2022.
3 A significant portion of steel consumption in building and construction is from "long" products, which in the United States are most commonly produced through electric-arc furnaces (EAFs) that have a lower CO_2 emissions intensity per metric ton of steel.
4 International Energy Agency, October 2020.
5 Zhiyuan Fan and Julio Friedmann, "Low-carbon production of iron and steel: Technology options, economic assessment, and policy," Joule, April 2021, Volume 5, Number 4.

Exhibit 1

The required green premium for a new-build hydrogen DRI/HBI+EAF mill would be 20 to 25 percent over 20 years.

Preliminary, illustrative North America example

	Capital expenditure (capex) included[1]								
Route	EAF[2]	DRI[3]	CSP[4]	Hot mill	Cold mill	Galvanized line	CCS[5]	**Included capex,** $ billions	**Needed green premium[6] for breakeven vs ongoing BF/BOF[7]**
Ongoing BF/BOF route[8]									
Hydrogen DRI/ HBI+EAF route with EAF capex[9]	●	*Assumes DRI will be purchased in the market*						0.8	5–10%
Hydrogen DRI/ HBI+EAF route with EAF and DRI capex	●	●						1.2	20–25%
Hydrogen DRI/ HBI+EAF route with integrated facility capex	●	●	●	●	●	●		2.2	40–45%
Ongoing BF/BOF route with CCS capex							●	0.6	40–45%

Note: Cash flows are aggregated from 20 years and terminal value with a discount factor of 8%. Cash flow includes revenues from steel, operating expenditure, and capital expenditure (when applicable). Price of steel assumed to be 2019 average price of hot-rolled coil ($598.74) and adjusted for a constant inflation over time (2% a year). Mills with included capital expenditure have a building time of 2 years (ie, operating expenditure is not included for first two years). All mills have an average 1.2 metric megatons of capacity and 85% utilization rate. Mills including EAF have a distribution of 40% direct reduced iron and 60% scrap.
[1]Mills with included capital expenditure divide capex over first two years. [2]Electric-arc furnace. [3]Direct reduced iron. [4]Continuous strip production. [5]Carbon capture and storage. [6]Green premium is assumed to last for 20 years; does not account for selling, general, and administrative expenses (SG&A). [7]Blast furnaces or basic oxygen furnaces. [8]Capital expenditure not included for BF/BOF mills due to existing operations and small likelihood of new mills being constructed. BF/BOF operating expenditure is the average of both sinter and pellet mills. [9]DRI/HBI+EAF is direct reduced iron and hot briquetted iron plus electric-arc furnaces. Assumes green-hydrogen price steadily decreases from $4.89 per kg in 2021 to $1.62 per kg in 2041. Lower end of price range used due to North American power pricing.

Navigating hurdles

Beyond technical challenges, companies face significant commercial and structural barriers. The sector's generally low margins could certainly dampen producers' appetites for green technologies.[6] Established approaches produce steel for approximately $400 to $500 per metric ton at the slab level. Near-zero-emissions steel is more expensive, albeit with significant variations based on technology, location, and project.

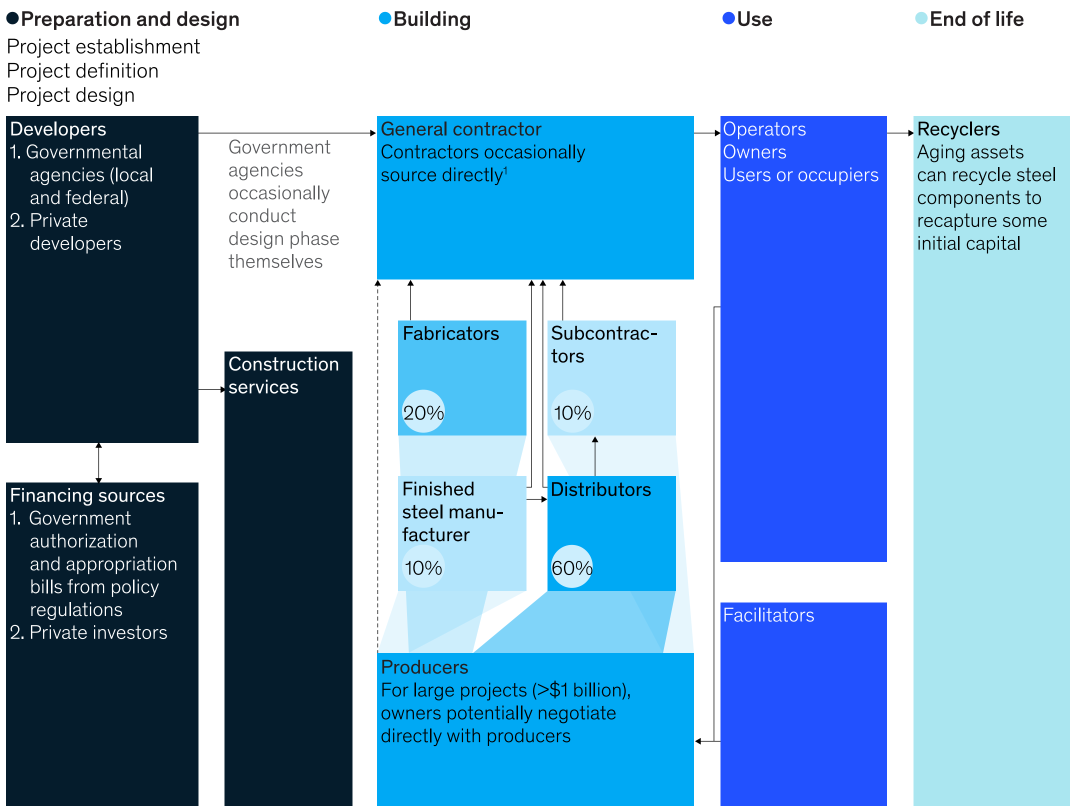
Another barrier to adoption is that individual developers do not routinely count emissions from the steel they consume,[7] and no certification or grading system has been widely adopted to date.[8] Furthermore, the steel industry services a highly fragmented construction landscape, making effective change at scale more difficult to achieve (Exhibit 2).

6 Leadership in energy and environmental design (LEED) certified buildings typically command a higher rent than non-LEED-certified buildings, but this is generally insufficient to offset the additional costs of using green steel.
7 Denmark, France, and the Netherlands have rules regarding embodied carbon, and Finland and Sweden plan to follow suit in 2025 and 2027. US cities such as Santa Monica, California, have similar legislation in place. "Buy Clean Colorado" and "Buy Clean California" are state legislative acts focused on steel. A shift may be supported by further legislation such as the US Bipartisan Infrastructure and Jobs Act, CLEAN Future Act, and SUPER Act of 2021.
8 For example, the Partnership for Carbon Accounting Financials (PCAF) has not yet included embodied-carbon emissions in required reporting of financed construction emissions due to feasibility constraints.
9 To demonstrate the potential for the construction industry to adopt greener steel, McKinsey analyzed an illustrative marginal abatement cost curve for materials and construction associated with an eight-story commercial office building (for illustrative purposes only). Regional differences and differences in the construction type of the building (for example, cast-in-place, hybrid, or structural steel) have a significant impact on both overall emissions and on abatement potential of different levers.

Exhibit 2

A fragmented value chain is a barrier to the construction industry's adoption of greener steel.

Construction value chain phases



Note: Percentages are the share of steel produced.
[1]Generally, finished steel, rebar, rods, rolls, and sheet metal.

Opportunities for the commercial sector

Despite many challenges, economically feasible progress is possible.[9] Analysis shows it would be possible to reduce an office building's embodied carbon by about 1,250 metric tons (or 70 percent) through alternative technologies, materials, and steel production methods that we expect to be widely commercially available by 2030.[10]

To achieve these reductions, producers should prioritize efficiency in construction materials and design, as well as migrating to lower-CO2 steel, concrete, flooring, and tiling and replacing structural steel and concrete with glulam beams, cross-laminated timber (CLT), and timber.[11] Companies could also embrace electrification of on-site equipment such as generators and machines.

[10] "Building decarbonization: How electric heat pumps could help reduce emissions today and going forward," McKinsey, July 25, 2022. The CO2 abatement curve is an illustrative example. Regional differences (for instance, in steel production, technology, or materials availability) can significantly change the levers. The mentioned costs are aggregated for the eventual lever.

[11] This assumes no regulatory constraints on the use of cross-laminated timber (CLT) or timber (for example, limited to five-story buildings) and no recent price increase—for example, CLT or timber could be applied on site for concrete slabs, load-bearing walls, or facades.

To meet abatement goals, the construction sector should start moving toward greener technologies, planning for realistic economic scenarios, and standardizing measurements, labeling systems, and methodologies to track levels of embodied carbon. This would enable decision makers to set targets more confidently and plot decarbonization pathways.

To unlock demand, developers, operators, owners, and large occupiers could form buyer's clubs to aggregate purchase commitments. In addition, they could commit to offtake agreements with near-zero-emissions mills and seek out dedicated green funding. Financers could facilitate that process by setting up systems to track and report on funding and by leveraging environmental product declarations and life cycle assessments to support quantification.

Through this range of efforts, greener technologies could enable a significant reduction in steel industry emissions, and therefore create a more sustainable construction industry. In the context of a fast-warming planet, the imperatives for decision makers should be to seize the moment, adopt a radical mindset, and take concrete steps to transition to a greener future.

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Investing in pathways to decarbonize infrastructure

The net-zero transition requires a deep understanding of emissions drivers by asset class, opportunities specific to each asset, and the development and rigid execution of decarbonization options.

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Previous McKinsey research has estimated that about 50 percent of capital expenditures required to meet net-zero emissions are related to infrastructure assets.[1] This accounts for some of our highest-emitting industries, including power, transportation, and buildings. Thus, the owners, operators, and investors of these assets are in a unique position to facilitate a net-zero transition.

Doing so is not without its challenges. Infrastructure owners will need to protect and future-proof past and current investments and find new environmentally friendly investment opportunities—without compromising returns. Furthermore, they will need to do this while navigating technological uncertainty as well as evolving regulations and policies, which is particularly challenging for those with geographically distributed portfolios. On this point, many infrastructure owners—namely corporate operators and investors—have committed to emissions reduction targets or are considering new targets.

The Global Infrastructure Investor Association (GIIA) and McKinsey are collaborating to develop a perspective on the decarbonization opportunities and challenges for infrastructure investors (see sidebar "About the GIIA and McKinsey collaboration"). We initially focused our efforts on five infrastructure asset classes—airports, container ports, electricity transmission and distribution (T&D) grids, data centers, and waste-to-energy (WtE) plants[2]—to establish the emissions baseline, determine viable decarbonization pathways, and synthesize implications for infrastructure investors.

Our analysis shows that investors who develop a deep understanding of what is increasing emissions in their portfolios, and subsequently create a plan with bankable decarbonization levers, can make real progress on their decarbonization ambitions in a financially sustainable way.

[1] Hauke Engel, Eliav Pollack, Anders Rasmussen, and August Runge, "Infrastructure investing to build a net-zero-carbon world," McKinsey, December 2, 2021.
[2] Incineration plants for municipal solid waste.

Sidebar

About the GIIA and McKinsey collaboration

Since the beginning of 2021, the Global Infrastructure Investor Association (GIIA) and McKinsey have closely collaborated to provide a perspective on the role of infrastructure investors in decarbonizing infrastructure assets.

Our efforts are focused around three objectives:

First, developing a carbon baseline for selected infrastructure sectors based on a sample of companies across transportation, electricity, digital, and waste, with a focus on Scopes 1 and 2 emissions.

Second, developing carbon-reduction pathways until 2030, in line with the Science Based Targets initiative,[1] and including an estimate of associated costs to asset owners.

And third, deriving decarbonization implications for selected infrastructure sectors. These implications were based on several factors, including differences in baselines and decarbonization options across asset classes, pathway costs and key trade-offs, and key unlocks required by companies, investors, and regulators.

[1] For more on science-based targets, visit sciencebasedtargets.org.

Establishing the baseline for CO_2 emissions

Successfully formulating a decarbonization strategy depends on understanding the major sources of emissions, specifically Scopes 1, 2, and 3 emissions:

— Scope 1 emissions are direct emissions from company-owned and -operated facilities or vehicles, such as emissions from combustion of natural gas in a boiler for building heating.

— Scope 2 emissions come from third-party facilities that supply energy for company-owned and -operated facilities; emissions from the generation of purchased electricity are one example.

— Scope 3 emissions are indirect emissions from sources not owned or controlled by the company, such as through the manufacturing of purchased materials or use of sold products.

Given these different types of emissions and the challenges in measuring them, understanding the major sources of emissions in infrastructure requires clarification about its archetype and asset-specific variations.

Asset archetypes

Infrastructure asset classes differ by emissions profiles and public perception but may be broadly grouped into three main asset archetypes: direct enablers, associated emitters, and hidden emitters. Although addressing each archetype is important, the targets set by corporate owners and investors today typically concern direct enablers and associated emitters.

Direct emitters, such as WtE plants, typically have high emissions from their core operations (more than 90 percent in our data sample), such as the combustion of plastics and other non-bio-based materials, and thus rely on technological advances to reduce the carbon intensity of their operations. By contrast, the emissions for associated emitters, such as airports and container ports, are primarily driven by Scope 3 emissions (more than 90 percent), which are not directly controlled by asset owners. For example, airports see emissions from airplanes taxiing between the runway and gates. As a result, reducing emissions relies primarily on supporting the low-carbon-intensity operations of airlines and ocean carriers. Finally, emissions from hidden emitters, such as data centers and T&D grids, arise from high electricity consumption for their operations (Scope 2, more than 90 percent in our data sample). For instance, data centers consume large amounts of electricity for computing and for cooling equipment. Overall, renewable power sourcing and higher efficiency measures can significantly reduce emissions for these assets.

Asset-specific variations

Many investors own infrastructure assets across different asset classes and will therefore need to assess emissions across different sectors. In addition, they will need to consider asset location and age, technical and design specifics, customer base, and government regulatory and counterparty objectives, all of which drive differences in emissions starting points and the type of investment opportunities to decarbonize.

Many newer assets tend to have lower emissions because more carbon-efficient technologies were incorporated into their design. Take container ports, for instance: now-standard electric cranes emit up to 100 percent less CO_2 than diesel cranes (which can drive more than 50 percent of Scopes 1 and 2 emissions for container port terminals), assuming electricity can be sourced through renewable energy. Location is another critical exogenous factor affecting energy needs, such as how much heating or cooling is needed; CO_2 intensity of purchased electricity, depending on the power mix in the region; and the availability and price of green power purchase agreements (PPAs).

Identifying decarbonization levers

Scopes 1 and 2 emissions decarbonization levers can be classified in six categories across asset types:

— *Natural electricity grid abatement* can reduce the carbon footprint of the asset's energy consumption (such as shifting to renewable energy sources in the power grid).

— *Operational efficiency initiatives* can minimize unnecessary emissions (such as optimizing routes for on-site vehicles).

— *Energy-efficiency investments* can reduce energy consumption (such as adjusting temperature settings, or improved insulation).

— *Green-power procurement* can support initiatives to switch to a renewable power supply (such as installing solar panels).

— *Electrification investments* to electrify mobile equipment (such as switching on-site vehicles from internal-combustion-engine vehicles to battery electric vehicles).

— *Technology solutions* can be integrated across the previous five categories to reduce carbon intensity (such as carbon capture and storage solutions).

Across these categories, maturity and economic and implementation feasibility differs. A higher number of net present value (NPV)–positive initiatives tend to be available for operational and energy efficiency categories as well as green power.

Although implementation feasibility is high for efficiency levers, green power and electrification show a medium level of financial feasibility, given high variances in regional availability and prices of green power and between individual levers. Finally, with many carbon-reducing technologies still maturing, technology levers tend to have low to medium financial feasibility for immediate carbon reduction.

Determining viable decarbonization pathways

Based on the set of levers each asset class can implement, decarbonization pathways and associated costs vary substantially across infrastructure asset classes (exhibit). Considering the required investment, selecting the right pathway and timing of execution is critical for owners to protect and enhance returns.

Our analysis, which focuses primarily on reducing Scopes 1 and 2 emissions, shows that data centers and container ports can achieve high emissions reduction by 2030 (in line with the targets set by the Paris Agreement[3]), benefiting from the decarbonization of the electricity mix and from implementing NPV-positive initiatives. The decarbonization from society-wide increased use of renewable power sources in the electricity mix can reduce emissions for data centers and container ports by up to 35 percent by 2030 (assuming there's no increase in emissions increase via increased capacity). Energy efficiency, operational efficiency, and (partial) electrification initiatives can then bridge the gap. Other nascent technologies, such as cooling technology for data centers, are expected to continue to mature and can play roles to further accelerate the net-zero transition in the second half of this decade.

Owners of airports and WtE assets are generally expected to face steeper challenges to meet ambitious net-zero emissions targets by 2030. Accounting for natural abatement of electricity grids and NPV-positive levers, the potential emissions reduction by 2030 is estimated at 34 percent for airports but less than 1 percent for WtE assets.[4] Airports could reach a net-zero pathway by 2030 by implementing "out of the money" initiatives, such as installing heat pumps. Likewise, implementing two levers—advanced sorting mechanisms (35 percent emission abatement by 2030) and carbon capture and storage (CCS)—can achieve significant decarbonization for WtE plants and place them on a 2030 net-zero trajectory. However, this will be challenging given the high cost and technology readiness of these solutions.

[3] For more on these targets, see "The Paris Agreement," UN Framework Convention on Climate Change (UNFCCC), accessed September 29, 2022.
[4] Based on the assumption that most WtE plants can supply their own energy for the following machinery.

Exhibit

A net-zero pathway scenario is possible by activating levers to achieve a 50 percent emissions reduction by 2030.

Feasible emission-reduction potential, % of status quo emissions

Decarbonization pathway scenarios

Asset class	Scenario 1: Activate positive NPV[1] levers and account for natural abatement	Scenario 2: Net-zero pathway	Capital expenditure requirement	NPV-negative levers
Data centers	–52	See Scenario 1		X
Ports	–69	See Scenario 1		X
Airports	–34	–50		✓
Waste to energy (WtE)	0	–35		✓
Transmission and distribution (T&D) grids	Scopes 1 and 2 emissions are mainly driven by grid power losses, which are difficult to address in the midterm. For T&D grids, focus on enabling decarbonization through capacity expansion and accommodating renewable energy is key, and accelerating natural electricity grid abatement (through change in electricity mix) by these actions will also benefit T&D grids by reducing own carbon emissions.			✓

[1]Net present value.

Due to the scarcity of practical and cost-effective levers to reduce losses on existing grids, T&D grids can reduce their carbon footprints by executing on one of their core societal roles: enabling the transition to renewable electricity. As asset managers prepare grids for a higher share of renewable electricity, significant emissions reductions—up to 95 percent of Scopes 1 and 2 emissions in our sample—are expected to increase because of the continued electrification of society. However, the carbon intensity of these reductions will continue to fall in line with the overall decarbonization of the electricity mix.

Enabling ecosystem decarbonization

Scope 3 emissions account for more than 90 percent of total emissions for airports and container ports and are distinctly different from Scopes 1 and 2 (see sidebar “Addressing Scope 3 emissions for container ports”). Asset owners often face challenges when measuring these emissions because of the need for transparent and accurate data from third parties. These emissions are also more difficult to reduce because asset owners lack direct control over emissions drivers.

Although asset owners are one step removed from these emissions, there is value in acting on Scope 3 emissions. A growing number of businesses are already experimenting with initiatives, a move that supports their customers' decarbonization efforts while creating a competitive advantage. It's clear that close collaboration and alignment with a broad set of stakeholders across the value chain, including suppliers and customers, is required in the years to come.

Implications for infrastructure investors

For infrastructure investors, the decarbonization challenge is complex. Not only do they need to oversee a diversified portfolio in terms of geographies and asset classes, but they also must execute changes while managing coinvestors, operators, and end users.

To best navigate these challenges, infrastructure investors should take actions to help decarbonize assets, mitigate financial and reputational risk, and capture opportunities within their portfolios:

— *Focus on the details:* Investors should establish a detailed understanding of emissions baselines in their investment porfolios and activities driving them and provide portfolio-wide views that can be beneficial to individual portfolio companies, which often have narrower points of view.

— *Set the path:* Based on their emissions baseline, investors should identify emerging decarbonization themes and build theme-specific capabilities. Capabilities required to successfully decarbonize differ, depending on decarbonization themes within an investors' portfolio. For example, deep technological expertise is required for some assets (such as WtE plants) versus stringent implementation management for others (such as data centers).

— *Capture scale benefits:* Several decarbonization levers, such as green power, electrification, and CCS, will be broadly

Sidebar

Addressing Scope 3 emissions for container ports

Scope 3 emissions for container ports, which make up 70 to 90 percent of total emissions, occur across the maritime value chain on the ocean (shipping) and on land (transport and infrastructure).

There are three core principles critical to supporting Scope 3 abatement for container ports: deploying infrastructure to increase supplies of low-carbon fuels, such as marine ammonia and biofuels; improving operational efficiencies to minimize demurrage and associated excess fuel burning (such as transparency on estimated times of arrival and adjustments for inbound vessels, which can reduce waiting time for trucks); and providing customers with access to renewable energy and electrified equipment for on-site operations.

An increasing number of terminal operators and carriers are taking action, enabled by regulations from port authorities (such as the Port of Rotterdam) and more ambitious shipping regulations (such as International Maritime Organization targets[1] and inclusion in the EU Emissions Trading System[2]).

[1] "IMO's work to cut GHG emissions from ships," International Maritime Organization, 2021.
[2] "EU Emissions Trading System (EU ETS)," European Commission, accessed September 29, 2022.

applicable across asset classes and geographies. Scaled investors can increasingly look to establish centers of excellence and central procurement functions to install best-practice solutions (such as PPAs and electric-equipment procurement) across portfolio companies while reducing time and cost of implementation.

— *Invest in partnerships:* Some emerging technologies, such as CCS and clean hydrogen, will become critical to decarbonization, yet they could struggle with access to funding and proving grounds for validating and scaling technology. Thus, investors can partner with emerging players in relevant spaces, benefiting from early access to technologies alongside financial returns while mitigating risk of losing the license to operate in certain sectors or incurring substantial cost from carbon taxes. Beyond this, investors can also explore partnerships with other stakeholder groups, including customers and governments, to jointly accelerate solutions while sharing cost and risks.

Yet some challenges to reaching decarbonization targets remain. More extensive industry collaboration will likely be required to ensure acceleration on broader support across the ecosystem:

— While NPV-positive levers are increasingly available, many asset classes cannot decarbonize fully without negatively affecting economic viability. Regulatory support and clear policy direction will be required to ensure targets for critical infrastructure do not overreach technical feasibility, and that regulated-tariff assets are compensated for investments required to achieve decarbonization targets. In doing so, stakeholders need to be pragmatic in balancing short-term investment requirements with long-term decarbonization targets.

— At the same time, stricter climate targets across sectors will be critical to coordinating incentives across owner and operator partners. Joint commitments are critical to ensuring that all partners in co-ownership structures collaborate on required capital expenditures and that costs will translate to exit multiples as future owners take control of the assets.

Despite the challenges facing infrastructure investors, there is real opportunity to create NPV-positive change while protecting returns and maintaining a license to invest from limited and general partners and society. A deep understanding of what creates emissions, as well as the internal capabilities of each organization, will be critical to making the right decisions at the right times. In turn, industry leaders and investors can help foster the industry-wide alignment required for managing risk and implementing changes while protecting returns and meeting global climate targets.

At the upcoming Global Infrastructure Initiative in Tokyo October 19–21, 2022, McKinsey and GIIA are hosting a workshop that will dig deeper into the work undertaken as part of the collaboration, supported by case studies and interactive panel discussions.

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Preparing for tomorrow: An interview with Tariq Taherbhai

As economies, climate, and technologies change, so does the construction industry. Tariq Taherbhai of Aon explains today's most pressing risks.

Tariq Taherbhai

COO
Global construction and infrastructure
Aon

In an evolving industry, economy, and climate, new risks are coming to the forefront—and infrastructure and construction CEOs need to make sure their companies are prepared. Construction contractors should account for risks—everything from talent and data privacy to the supply chain and the natural environment—sooner rather than later. The question is how to do so effectively.

We spoke with Tariq Taherbhai, COO of global construction and infrastructure at Aon, about what CEOs should have on their horizons as they navigate the years to come, from assessing the risks posed by suppliers and subcontractors to dealing with volatile climatic events in large construction projects.

McKinsey: Let's start with a 50,000-foot view of the factors driving complexity in construction and infrastructure today. What are three things that should be at the top of every CEO's risk agenda?

Tariq Taherbhai: There are so many risks that CEOs rightly spend time worrying about that it's a disservice to all of them to boil down a list to just three. That being said, I'll try. Reflecting on everything going on in the world today, the three risks that are top of mind revolve around talent, macroeconomic conditions, and climate change.

As megaprojects increasingly proliferate, the ability to execute successfully at scale is of paramount importance. On a large project, a small error can have significant consequences. As a result of this heightened risk profile, leaders need personnel who are best suited to the tasks at hand. For example, on a multibillion-dollar project, a company might be responsible for allocating hundreds of millions of dollars every month. The skills and expertise to manage such large amounts of people and capital inflows and outflows are typically found in C-suite executives. Thus, it's imperative that project executives, although not necessarily part of the C-suite, are trained appropriately.[1]

Given that economic growth appears to be slowing because of inflation,[2] another critical item that should be on every CEO's agenda is ensuring that the company has a full understanding of the financial health of key partners and suppliers.[3] As macroeconomic and geopolitical conditions continue to be volatile and uncertain, companies must assess and plan for the risks they face if, for instance, one of their subcontractors or suppliers defaults. Ideally, CEOs can ensure that the company has a plan for how it will react and persevere if a key supplier or subcontractor fails on any one project.

In addition, periods of inflation require leaders to ensure that their risk capital partners have an accurate and up-to-date understanding of their companies' financial situation. The balance sheet protection provided by risk capital partners is effective only if the disclosed valuations are reflective of current pricing. Outdated valuations may leave businesses underinsured and therefore subject to greater financial volatility.

Finally, the risk of a warming climate must influence a CEO's strategic decision making.[4] Societies are demanding commitments from businesses to achieve net-zero greenhouse-gas emissions,[5] and it's incumbent on leaders to define their net-zero strategies before other industry stakeholders—such as customers, governments, communities, lenders, or insurers—demand it from them on terms that are inconsistent with the CEO's strategy.

McKinsey: How is technology helping to mitigate some of these risks and uncertainties? Can you point to one or two specific examples of digital innovation?

[1] Cristina Alonso, Antonio de Gregorio, Prakash Parbhoo, and Mikael Robertson, "Training your own capital-project talent," McKinsey, April 27, 2022.
[2] "How inflation is flipping the economic script, in seven charts," McKinsey, July 6, 2022.
[3] Jan Henrich, Jason Li, Carolina Mazuera, and Fernando Perez, "Future-proofing the supply chain," McKinsey, June 14, 2022.
[4] *Sustainability*, "Climate change hazards intensifying," blog entry by Jonathan Woetzel, McKinsey, January 22, 2020.
[5] For more, see "Insights on the net-zero transition," McKinsey.

Tariq Taherbhai: Some of the most impactful technology is helping to mitigate project risk and also helping to make construction company operations more efficient. An area of digital innovation that has been quickly embraced by the industry is the adoption of Internet of Things [IoT] sensors and other forms of real-time data capturing on project sites. The adoption of such technologies helps create a record of construction data that is now being effectively used to help companies assess the quality of work, protect workers, and even assist with regulatory conversations. In coming years, we expect certain data from construction sites to be shared directly with capital providers and other construction industry partners, thereby improving efficiencies throughout the construction process.

McKinsey: How are construction and infrastructure leaders integrating climate risk assessment and mitigation across their organizations? What are the key challenges in embedding climate-related considerations into a project?

Tariq Taherbhai: There is perhaps no greater and more visible manifestation of climate risk in action than the impact a warming climate has on the built environment. From the heartbreaking damage caused to structures, homes, and entire communities from worsening floods, fires, and droughts to the significant amount of funds spent on rebuilding after damage has occurred, the impact of a warming climate is manifestly visible.

In response, construction and infrastructure leaders are redesigning many aspects of their construction operations. For example, hotter days mean fewer summer outdoor working hours for site workers. Landslides and road closures caused by floods and wildfires mean that companies need to account for contingencies and even potential redundancies in their logistics and inventory planning. And, given that the impacts of climate change are now arguably foreseeable, construction leaders need to consider how to incorporate resiliency and sustainability into their projects. This means considering which materials and construction techniques will allow structures to better adapt to a more volatile climate.

A key challenge for all businesses is the consideration of just how much risk to plan for given the costs associated with such planning. Although companies will decide how much risk to bear based on multiple factors, we encourage firms to access the latest climate risk models when making such decisions, especially for projects being constructed in natural catastrophe–exposed areas of the world.

McKinsey: In your view, is the industry doing enough to prioritize cybersecurity and data privacy when it comes to deploying digital construction and operations solutions?[6] What more could—or should—leaders be doing?

Tariq Taherbhai: The industry has made significant strides in terms of providing solutions for cybersecurity and to safeguard data privacy, yet a key concern is the cyberrisk created by the proliferation of IoT sensors and other connected construction technologies. A large construction project can have hundreds of workers on site at any one time accessing and sharing information, which means leaders need to consider all the ways that their own operations are at risk from malicious actors taking advantage of less-secure connections.

By this time, it's expected that all leaders have put their operations through a complete cyberrisk assessment and have also purchased adequate cyber-insurance limits to ensure that they have access to liquidity in the case of a cyber event. That said, my view is

[6] "Cybersecurity trends: Looking over the horizon," McKinsey, March 10, 2022.

that companies could be doing more to probe the security postures of their counterparties. Since a contractor has potentially dozens of counterparties on any specific project, such as the process a contractor will use to assess the financial health of its subcontractors, we encourage contractors to engage in a similar process to assess the cybersecurity posture of its subcontractors and other counterparties.

Given that the contractor will be ultimately held responsible for any incident that might occur on a construction project, folding in counterparty cyberrisk assessments is essential. All the connections between individuals on construction projects represent points of vulnerability, and so we would encourage leaders to focus on understanding and securing those.

McKinsey: Supply chain disruptions were a defining factor of 2021 and 2022. One Aon study found that 84 percent of CFOs identify this as a priority concern for 2022.[7] How do you see this playing out in the years to come? What actions can construction leaders take to get ahead of continued volatility?

Tariq Taherbhai: Supply chain challenges continue to cause slowdowns and outright project delays. Although we expect broad-based demand to moderate because of slowing economies, thereby easing strain on the supply chain, we also expect volatility in the prices of construction inputs, especially as the price of energy fluctuates because of geopolitics.

We are advising leaders to ensure they build in as much lead time as possible into their schedules. In addition, we are seeing certain contractors push back against fixed-price, date-certain contracts, essentially transferring some supply chain risk back to the owner. Our view is that contracting models such as progressive design build and other collaborative contracting models will continue to gain prominence to reflect this movement. Finally, certain risk capital providers are innovating to help their clients manage this risk, and so we would recommend exploring capital solutions, including specific insurance solutions, targeted to help businesses manage their supply chain risk.

Tariq Taherbhai is the COO of global construction and infrastructure at Aon.

[7] “Supply chains: Turning risks into opportunities” Aon, 2022.

Doing good demands doing better: Delivering net-zero capital projects

A net-zero project management framework aligns project performance with current trends in asset valuation and energy transition goals.

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Although the advice to "do well by doing good" (attributed to Benjamin Franklin) has influenced business leaders for generations, it is likely more relevant today than ever.

In an effort to move toward net-zero greenhouse gas (GHG) emissions, asset owners of all types are increasingly recognizing that the goals of business and global sustainability have become inextricably linked. Investors in publicly traded companies now consider climate change to be the most pressing environmental, social, and governance (ESG) issue.[1] Institutional investors are similarly engaged: an international group of 236 asset managers has formed the Net Zero Asset Managers initiative in support of reaching net-zero emissions by 2050.[2] And private-equity general partners are integrating ESG into due diligence and strategy, increasing transparency, and working to improve ESG performance in portfolio companies.

While conventional financial metrics clearly remain important, the value of investments in new assets is also dependent on how well they support ESG goals. For example, internal carbon pricing (ICP)—an internally set, hypothetical cost per metric ton of emitted CO_2—is increasingly used to guide capital investment decisions.[3]

Today, achieving corporate goals depends on achieving climate goals—and vice versa. The most viable path from net-zero goals to results requires developing and delivering $9.2 trillion in projects each year through 2050.

Changing definitions of asset value require a new framework for developing and delivering net-zero projects

Historically, project managers have focused on creating asset value by meeting safety, cost, quality, and schedule objectives. Environmental regulations and permits set the conditions under which the project could proceed, and project organizations, work processes, and best practices evolved in accordance with these priorities.

Today, creating asset value requires expanding project responsibilities to meet net-zero objectives. This in turn affects organizational strategies, which asset owners must use to deliver the net-zero project portfolio as well as the project development and delivery plans for each project.

A new approach, net-zero project management, expands on current best practices to account for the additional responsibilities associated with decarbonization. In doing so, net-zero project management recognizes three sources of carbon emissions associated with a typical capital asset:

— *Emissions from operations* are associated with operating, maintaining, and eventually decommissioning the asset.

— *Emissions from manufacturing* (also known as embodied carbon) are associated with the energy required to produce the materials from which the asset is built.

— *Emissions from construction* are associated with the energy required to perform direct and indirect construction activities.

Net-zero project management recognizes that reducing or eliminating each of these emissions sources requires redefining and broadening conventional engineering, procurement, and construction responsibilities (Exhibit 1).

Broadening the scope of net-zero engineering
Site selection factors into the use of renewable power sources, while transportation methods for feedstock and product are evaluated to reflect GHG emissions. As the project progresses to focus on facilities engineering,

[1] Meggin Thwing Eastman and Linda-Eling Lee, *2022 ESG trends to watch*, MSCI ESG Research LLC, December 2021.
[2] The Net Zero Asset Managers initiative is an international group of asset managers committed to supporting the goal of net-zero GHG emissions.
[3] Jessica Fan, Werner Rehm, and Giulia Siccardo, "The state of internal carbon pricing," McKinsey, February 10, 2021.

Exhibit 1

The net-zero project delivery framework requires broadening the responsibilities of engineering, procurement, and construction.

	Engineering	Procurement	Construction
Emissions from operations	Leads		
Emissions from manufacturing	Supports	Leads	Supports
Emissions from construction	Supports	Supports	Leads

Source: McKinsey Capital Excellence Practice

the design focuses on minimizing GHG emissions from operations and can also include the optimization of product specifications. In some cases, industry consortiums can support the application of new technologies. For example, a coalition of companies is helping Singapore achieve its net-zero emissions pledge by accelerating the development of carbon capture, utilization, and storage (CCUS) technologies to create the country's first end-to-end decarbonization process.[4]

Specifications for engineered equipment and materials now prioritize minimizing GHG emissions associated with manufacturing and power consumption, and new design tools can help engineers reduce operating emissions.[5] For example, to help design buildings for energy efficiency, the US Department of Energy's Building Technology Office, a division of the National Renewable Energy Laboratory, provides EnergyPlus, an open-source program that models energy consumption.[6]

Engineering can also consider emissions in addition to conventional measures of asset value. Value engineering (VE) has long been used as a design optimization process to reduce capital and life cycle costs. A conventional VE workshop results in an A-list of ideas clearly worth implementing, a B-list of those that may or may not add sufficient value, and a C-list of those that are tabled for consideration on later projects (Exhibit 2). These same techniques can be applied to increasing value by reducing GHG and other emissions.

Engineering can also play a role in working with procurement as new approaches to setting supplier expectations for addressing manufacturing emissions are incorporated into supply chain management.

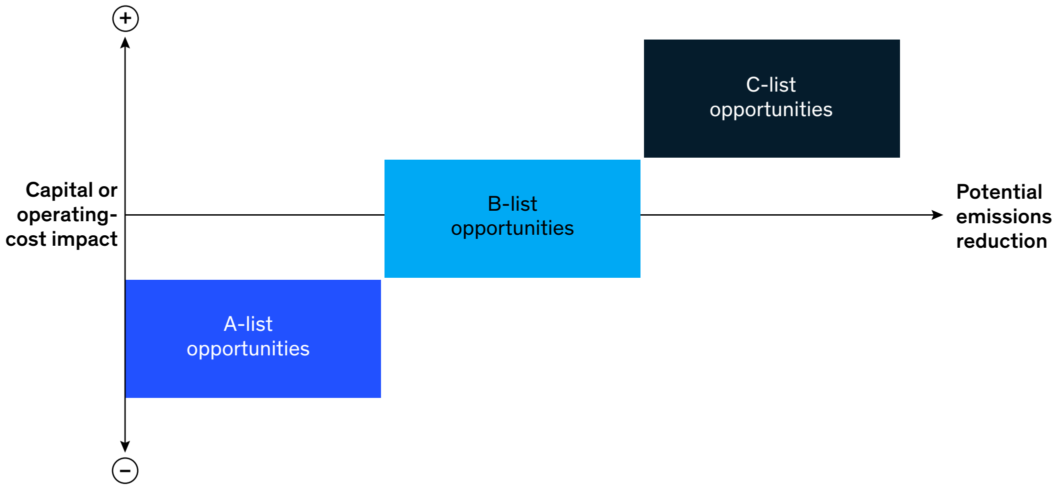
[4] "Industry leaders collaborate to develop Singapore's first end-to-end decarbonisation process to mitigate climate change," National Research Foundation, Prime Minister's Office, Singapore, July 2, 2020.

[5] For more on McKinsey's approach to finding and removing carbon from businesses, see *New at McKinsey*, "McKinsey launches Catalyst Zero to help clients find and remove carbon across their businesses," McKinsey, July 13, 2022.

[6] For more information on EnergyPlus™ software, see the EnergyPlus website.

Exhibit 2

Value engineering uses marginal abatement cost-benefit analysis to classify ideas into three categories.



A-list opportunities

- generate capital expenditure and operational expenditure savings, usually via operational or energy efficiencies
- modest reductions in emissions
- likely to be recommended for implementation

B-list opportunities

- neutral impact on capital expenditure and operational expenditure (eg, renewable energy or methane reduction)
- significant potential reductions in emissions
- may or may not be recommended for implementation

C-list opportunities

- significant capital expenditure and operational expenditure cost (eg, via hydrogen, carbon capture, or other new technologies)
- high potential reduction in emissions
- unlikely to be recommended for implementation on this project; further development may move to A-list

Finally, constructability has long been an important aspect of engineering. Now, in addition to reducing cost, time, and risk, constructability studies can also include means to reduce construction emissions through design decisions that influence productivity.

Expanding the role of net-zero procurement

Previously, supplier and service provider contracts stressed cost, quality, and schedule performance. Net-zero procurement still emphasizes these factors, but it also prioritizes decarbonization as well as new ways to allocate commercial risk. Additionally, each step of the procurement process can now be reviewed to incorporate GHG emission requirements in contractor or supplier prequalification, bidding requirements and evaluation, and contract terms and conditions.

Given that 70 to 80 percent of most organizations' GHG emissions are related to the supply chain, it is no surprise that global organizations are already working closely with suppliers to enable the energy transition.[8] According to a 2022 World Economic Forum paper, supply chain sustainability has shifted from being "niche and public-relations focused … to a core business and global competitiveness concern, notably in the past three to four years." Companies are increasingly setting ESG targets for their supply chains or deploying direct interventions such as supplier capacity building and "preferred-supplier" lists.[9]

[8] Sarah O'Brien, CEO of the Sustainable Purchasing Leadership Council.
[9] "Supply chain sustainability policies: State of play," World Economic Forum, May 10, 2022.

Until now, buyers have found it challenging to assess embodied carbon from alternate suppliers. For example, two identical steel beams may have very different levels of embodied carbon, with one manufactured using energy from coal-fired sources and the other using renewable energy sources. To meet this challenge, a nonprofit consortium has developed the Embodied Carbon in Construction Calculator (EC3), a free, open-source tool that gives design engineers the means to turn their 3-D building model into an interactive carbon heat map. This enables designers and procurement specialists to easily identify low-carbon supply alternatives.[9]

Procurement may also have a similar role in working with construction management, design, and administration contracts, defining expectations for construction emissions along with the means to ensure compliance.

Decarbonizing with net-zero construction management

Net-zero construction management begins with constructability planning that considers GHG emissions as they relate to site layout, commuting to the jobsite, and construction productivity and fuel consumption. Emissions from construction equipment are also being addressed in several innovative ways. Gammon Construction Ltd., a Hong Kong–based contractor, is using a new type of battery energy storage system (BESS) to deliver power only when needed, thereby reducing carbon emissions by 80 to 85 percent when compared with conventional diesel generators.[10]

In addition, the HS2 project—Britain's new high-speed rail line and the largest infrastructure project in Europe—recently announced its first diesel-free construction site. The operation uses a 176-metric-ton electric crawler crane, biofuels to power machinery on-site, and 100 percent renewable energy.[11]

HS2's Innovation Accelerator aims to create opportunities for new technologies focused on productivity and the environment. For example, Nodes & Links is pioneering the use of AI in project management systems to track and control carbon emissions (see sidebar, "An interview with Greg Lawton, cofounder and CEO of Nodes & Links").

[9] "Data to the rescue: Embodied carbon in buildings and the urgency of now," McKinsey, September 15, 2020.
[10] *Advancing Net Zero: Asia Pacific Embodied Carbon Primer*, World Green Building Council, September 2020.
[11] "Major green milestone for HS2 as project announces first diesel-free construction site," HS2, May 12, 2022.

Sidebar

An interview with Greg Lawton, cofounder and CEO of Nodes & Links

McKinsey: Project managers the world over are well equipped to meet safety, cost, time, and quality objectives. Now we have a new one: reducing carbon. What are you and your firm doing along these lines?

Greg Lawton: Decarbonizing construction is not as hard as you might think. We need to do two things: first, expand our existing data and analysis methodologies to include both embodied carbon in construction materials and carbon emissions during construction; and second, create commercial incentives to reduce carbon emissions, just as we do for safety and other performance metrics. We already have everything we need to do both.

McKinsey: It's easy to capture data on safety, quality, expenditures, and time, but how do you capture data on carbon?

Greg Lawton: We're getting better at understanding the carbon associated with construction materials, such as steel and concrete, as well as the emissions from construction equipment. And modern integrated scheduling tools allow us to analyze how those emissions vary with time. So we can now estimate, plan, track, and forecast carbon performance just as we do other variables.

McKinsey: Are any projects using these methods today?

Greg Lawton: Yes, the HS2 project is an example. This project is currently working at 300 construction sites, and teams are now able to use emissions data to translate material and equipment usage into carbon cost, thereby expanding their tracking, forecasting, and control tools to include embodied and emitted carbon.

McKinsey: You mentioned the need for commercial incentives to reduce carbon emissions. Where does that stand?

Greg Lawton: This is already happening, and it is a very important trend. For example, in the United Kingdom, national contracting standards have been updated to include pricing mechanisms for decarbonization, and projects are starting to set prices and liquidated damages around carbon delivery.

Net-zero assurance is essential for stakeholder confidence

The goal of project assurance is to assure financial and nonfinancial stakeholders that a project's objectives will be met. Traditionally associated with cost, schedule, and quality, assurance can expand to include net-zero objectives as well (Exhibit 3).

Risk and uncertainty management now considers environmentally driven business risks, including reputation, investor sentiment, market factors, and regulations. In addition to conventional risk management tools such as Monte Carlo simulation and risk registers, scenario planning can also help assess the resilience of project designs and plans. That said, contingency funding, previously used primarily to cover design changes and estimate uncertainties, may need to be increased to account for the potential impact of decarbonization-related risks and uncertainties.

Decision making now involves decarbonization by redefining how front-end investment decisions are staged. For example, the timing of investment decisions can now be aligned with emissions-driven decisions such as site selection, technology selection, or product specifications. Decision support packages at each gate can be expanded to include fully defined emission-reduction plans that are explicitly tied to the asset's carbon-based value calculations.

Stakeholder alignment now ensures alignment of financial and nonfinancial stakeholders on the net-zero implications of key strategic planning and investment decisions. Net-zero projects tend to have higher visibility than conventional projects, as well as a larger group of nonfinancial stakeholders. Although there is general agreement on the end goal of net-zero actions, agreement on the means is far from universal, and independent parties can be useful in facilitating the necessary alignment.

Transparency is essential for alignment and accountability, and it is the primary focus of net-zero assurance. That said, it requires timely, accurate, and useful information on all sources of carbon, as well as key plans and decisions to reduce emissions and the results achieved.

Independent validation can help assure that sustainability goals are met. Methods for this include instituting independent reviews of emissions calculations, validating evaluations of potential new decarbonization technologies, ensuring conformity to the latest industry standards regarding GHG emissions, and engaging independent third parties as needed for key design and planning reviews.

Accountability is perhaps the most significant potential change to conventional project management because it redefines performance

Exhibit 3

Net-zero assurance encompasses several net-zero objectives.

metrics for project managers and teams. With project objectives now expanded to include sustainability, the conventional performance metrics can also be expanded.

Project and team performance now considers aspects such as capturing real-time emissions data and trends, calibrating internal and external organizational performance, and periodically resetting emissions targets across the project portfolio.

Project managers will likely agree with French statesman Charles Alexandre de Callone, who once said, “The difficult is done at once, the impossible takes a little longer.” Indeed, millennia of amazing infrastructure achievements stand as proof that seemingly insurmountable challenges can eventually be overcome.

The urgency of climate change is no different. Leaders are setting goals, markets are mobilizing, and skilled people worldwide are engineering and building the assets that will drive the transition to net-zero emissions. Strengthened project delivery organizations can help ensure that millions of project managers are able to deliver the infrastructure needed to make net-zero emissions a reality.

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This article is the final article in a series of five covering the challenges of delivering the net-zero portfolio and exploring the transformational opportunities it presents. It follows “Managing capital risk in the race to net zero,” which was published in August.

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