McKinsey & Company

GLOBAL INFRASTRUCTURE INITIATIVE

Reimagining engineering and project development to meet net-zero targets

Voices on Infrastructure – April 2022

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Introduction

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The focus on net-zero engineering and project development is fully under way, and the picture for today's energy, industrial, and transportation assets and underlying infrastructure remains uncertain.

For the industrial economy to meet net-zero emissions by 2050, capital spending over the next three decades would need to increase from the $5.7 trillion spent annually today to $9.2 trillion spent annually—an estimated increase of $105 trillion overall.[1] Such a massive reallocation of capital would likely trigger a period of rapid innovation and growth, reshaping entire industries and revolutionizing the ways businesses create value across industries. High-emitting industries such as oil and gas, power, and manufacturing will need to leverage emerging technologies to create new energy and infrastructure systems at scale while reducing project life cycles.

Looking to the future, success will depend on how quickly today's industries transition to green energy by phasing out carbon-intensive operations. The International Energy Agency and McKinsey have separately estimated that more than 50 percent of the volume of carbon that needs to be cut over the next decade will come from decarbonizing industrial and energy systems. Implementing strategies to move to green energy will require companies to deploy technologies to help decarbonize industrial processes. As an example, a rapid increase in government and industry pledges for clean-fuel production has resulted in a market for biofuels that can replace jet fuel.

Many opportunities in the shift to green energy involve electricity. Thus, the greatest risks and opportunities today may lie in the industries that remain difficult to electrify, such as air transport, heavy mining, oil refining, and the production of steel and cement. Some of the most interesting opportunities in these sectors involve carbon capture, utilization, and storage (CCUS) technologies, as well as technologies for shifting from fossil fuels to hydrogen.

The risks from these new technologies, combined with capital requirements and the sheer scale of engineering and construction needed, will require new operating models and sets of engineering capabilities for the entire industry. Our April 2022 edition explores how companies on the cutting edge of engineering and project development are navigating the transition. We talked with Shaun Kenny, president of the infrastructure at Bechtel's infrastructure global business unit, and Aleida Rios, senior vice president of engineering at BP, about how to increase the pace of developing energy and infrastructure projects.

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

News from the Global Infrastructure Initiative

Tony Hansen

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Welcome to the April 2022 edition of *Voices on Infrastructure*, which tackles how we need to reimagine engineering and project development to meet net-zero targets.

Delivering the capital spending needed to transition to net-zero emissions will require a pace and scale far exceeding the status quo. To accomplish this, the infrastructure industry will need to rethink project engineering and development and explore ways to reduce project life cycles. In this edition, we look at how leaders are evolving to meet the needs of the net-zero transition, creating new competitive advantages, changing processes, and financing capital requirements at pace and scale.

We are hosting a series of GII Roundtables around the world in the second quarter of 2022, starting on April 12 in Washington, DC. The series kicks off on April 12 in Washington, DC. Topics include decarbonizing construction, scaling electric-vehicle infrastructure, preparing grids for the energy transition, creating a 2050 water strategy, delivering contracting excellence, and more. We have also scheduled our first GII Innovation Site Visit to the Riyadh Transit Network, one of the world's largest public transport projects, in November 2022. You can read insights from previous events and see our forthcoming roundtables here.

Preparations are well under way for our eighth GII Summit, which will take place in Tokyo from October 19 to 21, 2022. Our theme for the summit is *creating the pathway to sustainable infrastructure*, and we have just released our preliminary agenda. For more details on our summit, roundtables, site visits, and Voices publications, please visit our GII website.

We hope you enjoy this issue, and we welcome your thoughts on how GII can continue to be a catalyst for driving change toward sustainable infrastructure. If you have comments or would like to subscribe a colleague to *Voices*, please contact us at info@giiconnect.com.

Engineering the energy transition: An interview with Aleida Rios of BP

Aleida Rios, senior vice president of engineering at BP, sheds light on how oil and gas companies can innovate and transform to enable a net-zero future.

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Senior vice president, engineering
BP

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Oil and gas companies are in a race to develop and scale energy solutions that will pave the way for a greener world. To enable the net-zero transition, companies are reimagining nearly every aspect of their businesses, from partnerships to talent and innovation. Doing so requires creating the right conditions to foster innovation, as well as investing in the right resources.

McKinsey's Dara Olufon and Kassia Yanosek spoke with Aleida Rios, senior vice president of engineering at BP, to discuss how engineering can deliver new breakthroughs in the transition to clean energy.

McKinsey: What industry-wide changes will be required to enable the energy transition needed to meet net-zero targets, and how is BP responding?

Aleida Rios: If the world is going to meet the goals of the Paris Agreement, we need everyone to play a role. I think it's brilliant that companies like Ørsted and Tesla are pure play and renewable, but I think it's even more important that companies—like BP—which are not yet fully green but are "greening," have credible plans to transition to lower carbon.

In 2020, BP called for reimagining energy for people and our planet, and we launched a new strategy that will help BP pivot from an international oil company focused on producing resources to an integrated energy company focused on delivering solutions for customers. Across the industry, companies like ours need to put together plans to get to net zero to help meet the Paris climate goals. In our case, we set an ambition to be net zero by 2050 or sooner and to help the world get to net zero, supported by ten aims.

We are no longer going to be predominantly a hydrocarbon company. Instead, we are going to have a balanced portfolio with resilient hydrocarbons, convenience and mobility, and low carbon. I spend most of my time helping to ensure we have a resilient hydrocarbon offer to many parts of the world alongside our work to scale low-carbon energy with offshore wind. As a recent example, we now have an offshore wind pipeline of 5.2 gigawatts [GW]. We've essentially gone from nothing to 5.2 GW—and we've just announced that we have 24.5 GW in the development portfolio for our renewables. We will have that balanced portfolio and those capabilities to enable an integrated-energy system, which is necessary to enable the world to transition.

McKinsey: How will the engineering discipline need to evolve to deliver new energy solutions as the oil and gas industry transitions?

Aleida Rios: Our industry needs entirely new ways of working. We need to take new ideas and incubate and scale them much faster than we've ever done before. Engineers play that critical role of making an idea into something that can be scaled. I think we need to put a greater emphasis on being able to transfer skills that we had in the hydrocarbon business over to the new energy areas very quickly.

Part of the scale problem is that solutions need to be packaged in a way that brings down costs significantly from where they are today. That's why competition is important. It can help bring down costs so that businesses will have the incentive to develop the infrastructure needed for achieving net zero.

Finally, we need talent to actually develop these new technologies. We see such talent in solar and wind—so we know it's possible. There needs to be a system that allows people to work on technology but also incentivizes the green premium to keep coming down. Hydrogen is a perfect example. The technology is readily available, but the premium is too high, and therefore, we need to create the demand.

McKinsey: What breakthroughs in engineering have you seen that inspire you about the future?

Aleida Rios: Engineering is built on breakthroughs. I became an engineer because

I was inspired by breakthroughs. I grew up in Houston, Texas, the energy capital of the world and where NASA was putting people on the moon.

In *How to Avoid a Climate Disaster*, Bill Gates says, “My basic assumption about climate change comes from a belief in innovation. The conditions have never been more clear for backing energy breakthroughs. It’s the power to innovate that makes me hopeful.”

I am hopeful as well. Significant engineering challenges have been overcome in the past ten years. I remember talking about the challenges of solar and wind, and the solutions seemed like they were decades away. Now we have commercially viable solutions, driven by that innovation approach and putting engineering at the heart of those solutions.

Deploying this innovation is about creating the right conditions to back these technologies and decarbonization—and investing in the right resources. If you look at the cost of onshore wind and solar, we’ve lowered the costs by almost 50 percent on wind and almost 90 percent on solar since 2005. And I think most of the breakthroughs came in the past ten years rather than the initial ten years.

McKinsey: What new partnerships and contracting approaches could improve outcomes?

Aleida Rios: I think we need to move much faster on partnerships in areas that require more innovation. As an example, in 2021, we formed a partnership with CEMEX to work to enable full abatement in the cement sector. And we’re leading the Net Zero Teesside Power and Northern Endurance Partnership projects, which we hope will enable the first net-zero industrial cluster in the United Kingdom.

Another example of faster-moving experimentation is BP Launchpad, which enables us to partner with and apply our capabilities to new areas, as well as to identify key capabilities that we need in our own assets. Launchpad is obviously an innovation engine and entrepreneurship, but it’s early-stage innovation, and getting those early-stage innovations, that R&D, across the finish line is important for getting to net zero.

If we only focus on continuous improvement and easy wins, we won’t achieve net zero. It’s going to require doubling down on the harder areas, the right projects, and the right relationships. I’m not afraid that the technology won’t be there. It’s the other pieces—the mindset, the ways of working, the partnerships—that we need to enable net zero.

McKinsey: What competitive-advantage opportunities exist for first-mover engineering-driven companies?

Aleida Rios: I’ve talked a lot about behaviors and partnerships and mindsets, but at the end of the day, it’s a physical problem, and these technologies will provide a huge economic opportunity for first movers.

Being a first mover allows you to build capability by doing. We need to make sure that what we’re doing isn’t just partnering with others to provide resources in terms of investment and capital. It’s also a learning opportunity. We’ve got to make sure that we’re providing the know-how.

We’re an incumbent in the energy sector, and we have significant capabilities that we’re going to be able to leverage. For example, our deepwater know-how is a first-mover advantage on offshore wind. It gives me a lot of hope because we now have the capability and technologies to enable it.

McKinsey: How does an organization attract, develop, and retain the talent required to meet net-zero targets?

Aleida Rios: We need to diversify and create transferable skills. A good example of that is our effort to diversify the career road maps for engineers so that they can apply their skills in a different way. In fact, we just transitioned 50 percent of our subsea-riser engineers to becoming CCUS [carbon capture, utilization, and storage] technology managers in Net Zero Teesside.

The opportunities to retain and attract talent are huge—every engineer I've talked to wants to help resolve the climate challenge and sees engineering as core to doing so. We need to be able to create a vision for how they can transfer their skills to these new areas.

It's also important to offer a diverse and inclusive environment for people to do their best. We do this through our actions, not just our strategy. We do it through what we enable and our purpose. On this point, we recently announced our ambition to reach gender parity in our top team (the top 120 roles) by 2025. By 2030, we aim to have women in at least 40 percent of all roles at every level of our company.

McKinsey: Why is gender equity good for business in engineering?

Aleida Rios: It's no secret that I'm passionate about diversity. Diverse teams create more value and innovation. I'm especially inspired by our young engineers because they want to be part of solving the problem. A lot of times they don't see a traditional oil and gas company as part of that, and I think the more we work to represent everyone, the more innovation we'll get.

Just last year, I helped create the One BP Early Careers Engineering Program, and our initial Early Careers Engineers cadre is hugely diverse—it's 44 percent women. That's our future. I deeply believe in our purpose to reimagine energy for people and our planet, and that needs to include everyone. My leadership team of direct reports, the chief engineers, is 40 percent female. I want to see that percolate all the way down.

I was recently inspired to see that over 50 percent—six out of 11 people of our executive team—are women, which is almost unheard of, not just for an oil and gas company but for any company. It was a proud moment, and it was a strategy in action.

Aleida Rios is senior vice president of engineering at BP. **Dara Olufon** is an associate partner in McKinsey's London office, and **Kassia Yanosek** is a partner in the Houston office.

Comments and opinions expressed by interviewees are their own and do not represent or reflect the opinions, policies, or positions of McKinsey & Company or have its endorsement.

Capturing the net-zero opportunity with portfolio synergies

Planning for the net-zero project portfolio presents a long-awaited opportunity to update conventional thinking, transform work processes, and dramatically improve performance.

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Achieving net-zero carbon emissions is already seen as a "moon shot," a highly ambitious undertaking through which an impossible goal is reached. The reality is even more challenging: if this goal is realized, it will be, in part, because permanent changes are made in the way capital projects are framed, financed, and delivered.

The difficulty is partly attributable to the many differences between net-zero projects and conventional ones. Most important is the much broader set of stakeholders involved—in effect, everyone on the planet. There is also increased urgency, given the potential damage inaction could cause to health and the economy. Yet, at the same time, the cost (or "green premium") for consumers and taxpayers must be minimized. And then there is the goal: decarbonization, a dramatic reduction of the carbon footprint of construction—particularly the emissions associated with steel and concrete.

Overall, the global construction industry must deliver $9.2 trillion of clean-energy projects every year from 2022 to 2050, an increase of $3.5 trillion from current levels.[1] This means the net-zero portfolio presents a dramatic shift in the allocation of capital to project types. For example, under a 1.5° pathway, the number of solar panels installed globally per week would be approximately eight times more than what occurs today, while the rate of wind-turbine installations would increase fivefold.

Simply conforming to past practices will not get the job done. A recent study of 3,022 infrastructure projects revealed that only 2.8 percent were completed on time and on budget.[2] Performance on power projects was no better; McKinsey data indicate that the average capital-expenditure overrun was 50 percent higher than the original estimates, with final schedules 62 percent longer than originally planned.[3] And although construction is the largest global industry sector, its productivity improvement has been less than a third of total economy averages.[4]

Meeting these challenges requires moving from established best practices that focus on optimizing individual projects to a top-down, portfolio-synergistic strategy that focuses on standardization, resource capacity, economies of scale, and predictable outcomes.

From project-centric to portfolio-synergistic

Project leaders have long relied on an accepted set of practices for project development and delivery. With costs ranging from hundreds of millions to tens of billions of dollars and durations often spanning a decade or more, large energy and infrastructure projects must be planned and executed with great care. Current best practices for project-centric strategies focus on processes and tools to manage the extensive time and effort invested in evaluating alternative strategies, fully defining the scope and developing detailed plans and estimates.

Projects in the net-zero portfolio are significantly different. Most green-energy projects comprise many identical or similar components whose installation involves relatively straightforward tasks repeated tens of thousands of times. For example, a solar photovoltaic (PV) facility can consist of more than 100,000 panels installed in identical fashion. Similarly, onshore wind farms can include more than 100 turbines. In both cases, many miles of transmission lines must be installed.

[1] For more, see "The net-zero transition: What it would cost, what it could bring," McKinsey Global Institute in collaboration with McKinsey Sustainability and McKinsey's Global Energy & Materials and Advanced Industries Practices, January 2022.
[2] Bent Flyvbjerg, "Why megaprojects systematically fail - and what can be done about it?," Oxford Answers, November 20, 2019.
[3] Based on McKinsey analysis and the McKinsey Overruns Predictive Capability Database.
[4] "The next normal in construction: How disruption is reshaping the world's largest ecosystem," McKinsey, June 4, 2020.

Another difference between green and conventional energy projects is the reversed priorities of capital cost (capex) versus operating cost (opex). In effect, capex is the new opex (Exhibit 1). Green energy's zero cost of fuel and operational simplicity can shift the economic priority toward minimizing and controlling capital cost, which is further heightened by the imperative of minimizing additional costs to the consumer.

When considering the differences between a $10 billion investment in a net-zero portfolio of wind farms and solar parks and the same level of investment in a single large project, such as a new liquefied natural gas (LNG) plant, there are two primary advantages that the former has over the latter:

— *Synergies:* the combination of numerous similar projects to enable each to be designed and installed more efficiently

— *Economies of scale:* reductions in unit cost that occur through repetition. In commercial terms, this effect is commonly seen as discounts for large orders.

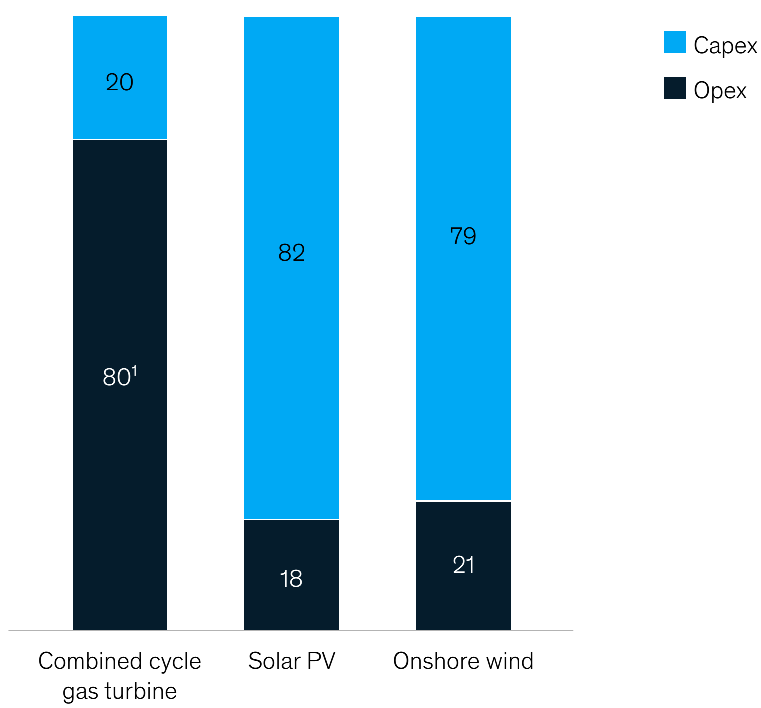
A portfolio-synergistic strategy enables both advantages to be captured (see sidebar, "Elements of a portfolio-synergistic strategy"). This strategy can be further leveraged by the experience accrued when groups of similar projects are delivered repeatedly over long periods of time.

In addition to wind and solar, the net-zero portfolio will include large green-energy projects, such as nuclear power plants. Because owners or operators typically focus on building one large project at a time, past practice has been to design each on a bespoke basis. Even in such cases, a portfolio-synergistic strategy can provide many benefits. For example, there is growing interest in small modular reactors,

Exhibit 1

For green energy projects, capex is the new opex.

Levelized cost, %



[1]Including fuel
Source: McKinsey analysis

Elements of a portfolio-synergistic strategy

Top-down planning can help develop and deliver each project so the results of the overall capex portfolio are optimized.

Standardization of designs, work processes, and practices across the portfolio can accelerate definition and simplify decision making.

Portfolio size and standardization can be used to increase resource capacity via efficient training while enabling investments in supplier facilities and decarbonization.

Portfolio synergies can be harnessed to enable economies of scale that reduce cost, improve efficiency, and drive continuous improvement.

Managing performance at the portfolio level can enable consistent metrics and shift focus to the efficacy and risks of the portfolio. Ideally, this will make both project and portfolio outcomes more predictable.

which can be factory-built and installed relatively quickly, greatly reducing financing costs.[5] Other benefits of the portfolio-synergistic strategy include more effective quality control (in the shop versus in the field) and reduced design changes as the fleet expands.

Capturing the net-zero opportunity

In its report at the UN Climate Change Conference in Glasgow (COP26), the Glasgow Financial Alliance for Net Zero (GFANZ), a global coalition of leading financial institutions, provided an example of an investment road map for a group of 17 high-priority net-zero portfolios.[6] Among these high-priority portfolios is Solar PV in Africa, which has some of the globe's greatest potential for solar power generation. Although currently deployed in only a few African countries, solar PV is now the continent's fastest-growing renewable energy source.[7]

The cost of the Solar PV in Africa portfolio is estimated at $488 billion over the next 20 years, an average of $24 billion per year. And while this is only a small fraction of the total net-zero investment, it is a massive undertaking that will likely involve all 54 African countries, the combined population of which totals 1.3 billion people. This would be a challenge under the best of circumstances, and the urgency of achieving net-zero emissions creates added pressure. A top-down, portfolio-synergistic strategy can improve past performance and enable these projects to be delivered efficiently (Exhibit 2).

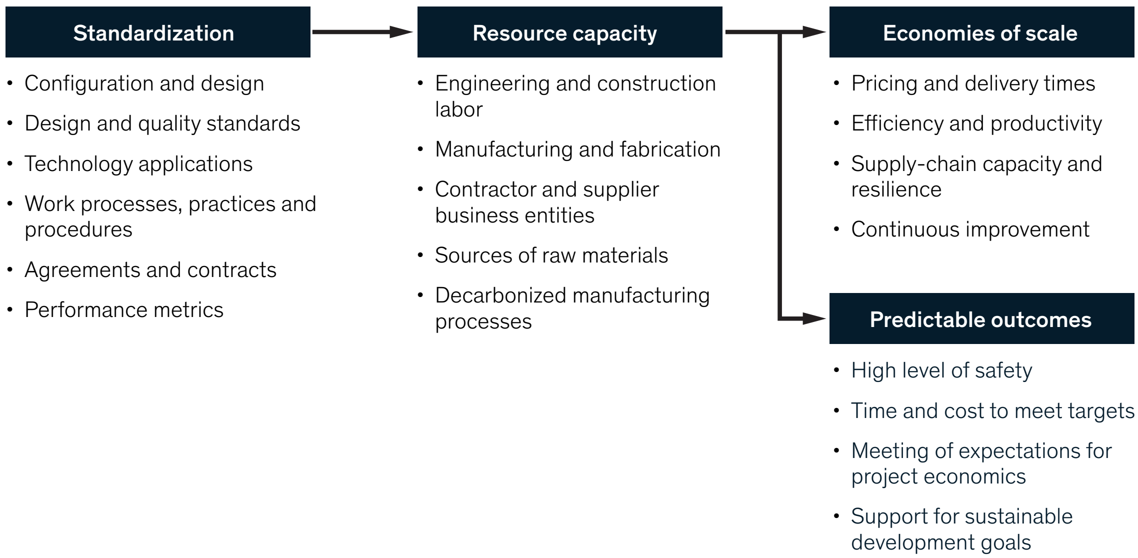
Standardization

The portfolio-synergistic strategy begins with standardization. When done correctly, standardization can be highly effective. In fact, a recent research report from the Construction Industry Institute identified potential savings of 10 percent in capital cost, 15 percent of schedule duration, and 25 percent in life cycle cost.[8]

[5] For more on small modular reactors, see *Benefits and challenges of small modular fast reactors: Proceedings of a technical meeting*, International Atomic Energy Agency, 2021.
[6] "Race to zero: Financing roadmaps," Glasgow Financial Alliance for Net Zero (GFANZ), October 2021.
[7] *Renewable energy market analysis: Africa and its regions*, International Renewable Energy Agency (IRENA), January 2022.
[8] "Webinar: Facility standardization for program success," Construction Industry Institute, October 2020.

Exhibit 2

A top-down strategy can enable green projects to be delivered efficiently.



A large part of the Solar PV in Africa portfolio is likely to be commercial-scale installations that can use standard designs. While location factors will inevitably cause some design variations, standardization can be applied to solar PV in the following ways:

— Standard configurations and designs can be developed for key elements, such as panels, mounting structures and tracking systems, converters and transformers, and switchgear and cables.

— Design and quality standards for structural, mechanical, and electrical elements can be put in place and applied consistently across regions.

— Standard work processes, contract forms, and performance metrics can be used on solar PV projects throughout the region, enhancing efficiency and ensuring effective governance.

— Standard applications of technologies such as digital, drone, and new manufacturing applications can be implemented.

— Standardized manufacturing processes to enable new technologies to decarbonize the production of high-emission construction materials such as concrete and steel can be introduced and quickly matured.

Resource capacity

Standardization provides the basis for developing and sustaining the resource capacity required to provide the products and services to deliver the Solar PV in Africa portfolio. To begin, the combination of standardization with high confidence in the future workload enables the development of skilled resources, with associated opportunities becoming available for underemployed people in the region. Investments can be made in local manufacturing capacity for engineered products, raw and bulk materials, and prefabricated modules. Finally, opportunities are likely to arise for the formation of new businesses to supply goods and services within the region.

Economies of scale

The combination of standardized designs, requirements, and practices, with the associated expansion in regional resource capacity, provides the basis for economies of scale resulting from the following:

— cost savings associated with purchasing goods and services on a large scale over a sustained period

— reduced delivery times associated with efficiency gains as the volume of repetitive tasks and operations increases

— resilience built into the supply of critical materials and services, enabled by investor confidence in building local capacity

— a stable foundation for tracking efficiency, quality, and safety outcomes to identify gaps and continuously improve performance across the region

Predictable outcomes

Finally, standardization and scale enable comprehensive safety training, processes, and equipment in regional resource development programs, which can create confidence in achieving the highest levels of construction and operational safety. Such efficiencies can also help assure achievable estimates of cost, time, economics, regional benefits, and progress to net-zero emissions. Finally, the incorporation of decarbonization initiatives into standardized designs and practices, as well as into regional design and quality standards, can ensure measurable progress in reducing the carbon footprint.

With governments and the financial sector visibly focused on transformations to enable net-zero emissions, attention now swings to the construction sector, in which the urgency of climate change is matched only by the urgency of its own transformation. This requires answering two questions: first, how will the industry change current practices that have inhibited good performance; and second, how can the scale, long duration, and characteristics of the portfolio be leveraged? Failure is not an option. Transitioning from a conventional project-centric approach to one that is portfolio-synergistic will enable the synergies and economies of scale necessary for success.

This article is the second in a series of five covering the challenges of delivering the net-zero portfolio and exploring the transformational opportunities it presents. The first, "Transforming capital projects to deliver net-zero emissions," appeared in February. The next one, in June, will discuss ways to mobilize a step change in global resource availability.

Tom Brinded is a partner in McKinsey's London office; **Justin Dahl** is a partner in the Houston office, where **Erikhans Kok** is a partner and **Richard Westney** is a senior adviser.

The innovation function: An interview with Shaun Kenny of Bechtel

Infrastructure companies can help meet the needs of future generations by focusing on innovation today. Shaun Kenny discusses how teamwork, training, and technology can help companies get it right.

Shaun Kenny

President, Infrastructure
Bechtel

Tony Hansen

Managing director
Global Infrastructure Initiative
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Meeting global net-zero targets will require an unprecedented amount of energy. Consequently, an unprecedented number of major projects are required to help facilitate the energy transition. These projects include generating and transmitting more renewable energy, decarbonizing existing facilities, and significantly increasing use of lower-carbon transportation. Although delivering these projects at scale and pace involves significant challenges, doing so will also create a number of exciting opportunities, such as building stronger partnerships with customers; improving the science of construction; deploying integrated engineering, procurement, and construction (EPC); and helping manage risk across and along the supply chain.

To learn more about how infrastructure companies can lead in the transition to net zero, McKinsey's Tony Hansen spoke with Shaun Kenny, president of Bechtel's infrastructure global business unit.

Tony Hansen: What industry-wide changes will be required to enable the delivery of the unprecedented number of projects needed to meet net-zero targets, and how is Bechtel responding to these changes?

Shaun Kenny: We're seeing the G-7 and G-20 commit to a COVID-19 recovery that's environmentally sustainable and socially inclusive, and this commitment is accelerating secular changes that were already under way. For our industry, the key questions are "what" and "how"—that is, "What types of major projects are being delivered and developed?" and "How will we deliver them?"

If you consider the "what," we're seeing many more renewable-generation and transmission projects, more interest in decarbonizing existing facilities, and more low-carbon transport. We're also seeing more work in digital connectivity and control. It's one thing to provide more energy, but with better sensor technology and connectivity, energy providers and users can collaborate to save energy. There's also a great deal of interest in "how" projects are being performed, including an emphasis on designs to reduce materials and improve energy efficiency.

In terms of how Bechtel is responding to the challenge of choosing the right projects and delivering them in the best possible way, there are four key areas we're focusing on. First, we're building stronger partnerships with our customers. Second, we're focusing on the science of construction. Third, we're looking for opportunities to deploy our EPC mindset and model. Last, we're helping our supply chain partners manage risk and, in turn, offer more to project teams.

Tony Hansen: Can you give a few highlights where these focus areas are playing out?

Shaun Kenny: On building stronger partnerships with customers, we were the delivery management partner for the tunnels and stations excavation package on the Sydney Metro City & Southwest project. We were able to transfer around 70 percent of that team onto the subsequent Metro West project. In this way, the customer has benefited because we retained the core knowledge, and the distinct working culture and alignment built up a very successful project.

When it comes to the science of construction across the renewables and clean-power sector, our approach to construction focuses on cycle time improvement for the installation of commodities. As an example, we are working on a solar project in Texas with tens of thousands of repetitive installation tasks. The construction schedule is six months, and therefore minutes can easily scale to millions of dollars, so we have implemented our Minutes Matter program, which amplifies incremental improvements to increase productivity and improve repeatability.

Moving on to integrated EPC, we're now self-performing the civil and marine construction work for our LNG [liquefied natural gas] projects, which we've historically used subcontractors for. Today, with the build-out on the US Gulf Coast, we're vertically integrating these work streams, which delivers much more flexibility and certainty of outcome and has led us to provide continuity of employment for our apprentices and construction professionals through the different project phases.

Finally, when it comes to enabling supply chain partners, we've been working on an integrated team with CityFibre, which is investing in schemes across the United Kingdom to train its contractors. We're bringing our experience to bear in recruitment and training but also helping trade contractors improve their organizational capabilities. In other words, we're ensuring the team match can operate in this type of environment.

Tony Hansen: How will project engineering and project development need to evolve to deliver at the projected scale and pace? Where have you seen breakthrough improvements in project development and engineering that inspire you?

Shaun Kenny: In my experience, when owners are faced with challenges of scale and pace of development, they're best served by working with EPC contractors from the outset to simplify what is to be built and then eliminating the interfaces that cost money and slow down delivery.

If we look at this through the lens of the natural-gas value chain, upstream, we've built more than a third of global LNG production, completing 17 large-scale LNG trains in just five years. The scale of the energy transition is a similar type of challenge to the LNG build-out. It requires close collaboration through project development and the implementation of a fully integrated EPC model that eliminates and optimizes interfaces and is focused on making our construction professionals productive and safe.

Downstream, we've installed around eight gigawatts of clean gas power in the United States over the past decade, and we've been successful by working with a few customers and select original-equipment manufacturers to develop standard designs and execution plans. This has also allowed us to better understand the talents of the respective teams and, as a result, bring out the best in one another.

Tony Hansen: What needs to change in talent development and retention to mitigate the skill and labor constraints across the value chain?

Shaun Kenny: The highest-performing teams come from inclusive, bias-free, and respectful workplaces where everyone can expect to be treated fairly and have opportunities to progress.

Bechtel is focused on diversity and inclusion. As an example, we're putting in place programs that are focused on building workplaces that work for women because we still do not see enough women in the industry. We've also got our #WeAreBechtel campaign, which is focused on identifying, discussing, and aligning on the behaviors we can expect to see in our workplaces.

Construction jobsites are usually complex environments, so technology that makes it simpler for our construction professionals to stay safe and be more productive is always our goal. For example, our mobile workstations and base camps in the field provide model information to our craft professionals and supervisors to help them visualize what they're building.

Wherever we've been successful, wherever we've worked with customers closely and developed successful programs, you'll see ongoing training and apprenticeship programs and community engagement programs focused on explaining what's being built and maybe attracting the community into the industry.

Tony Hansen: How will the approaches differ for developing and developed countries?

Shaun Kenny: EPC challenges are universal, but emerging markets offer a greater opportunity to improve the local skills base and to support the long-term growth of the supply chain. Our approach adheres to three dimensions: strong teamwork, continuous training, and smart technology to serve the construction professional.

For example, in the teamwork space, the market in Saudi Arabia today is very strong and talent demand is high, so it's great to see more women enter the workforce. Changes are happening in the kingdom. It also presents us with an untapped resource we can lean on and reinforces the need to build inclusive workspaces fit for everyone.

One of the things we always focus on is upskilling local communities and providing sustainable skills. Previously, when working in the Middle East on large aluminum projects, we've been able to help the project owners develop the supply chain to the emerging downstream industries as well as provide better local options for plant operations and maintenance.

And finally, on the technology side, we use technology to make it simpler for our construction professionals to be safe and more productive. Just as a simple example, we're using a geographic-information system [GIS] to improve work planning and optimize haul routes on our motorway projects and "as built" utilities to help guide machines to locate and drive piles on our renewables projects.

Tony Hansen: What new partnerships and contracting approaches could improve outcomes?

Shaun Kenny: It's encouraging to see several transport agencies in the United States engaging private-sector players upstream, earlier, in project planning. We're seeing these predevelopment agreements [PDAs] trending in passenger rail, as well as with airport authorities and airlines to develop new terminal infrastructure.

The way PDAs work is that the public-sector agencies engage the team that will ultimately implement the project. The team then works with the owner to consider all the technical, commercial, and financial options for the project to arrive at the best solution. This allows the agency to collaborate with the industry practitioners early and come up with a technical solution that not only works but also is financially feasible.

Tony Hansen: What are the competitive-advantage opportunities for first-mover engineering and construction [E&C] companies?

Shaun Kenny: I was at an event recently where Hannah Jones, the CEO of Earthshot Prize, said something that really stuck with me. She made the point that with the challenges the world faces, we should be thinking of the sustainability function as the innovation function.

Until then, I'd always thought of sustainability in the traditional sense, which is more about meeting our needs without compromising the needs of future generations. But I think when you look at it through an innovation lens, it gives sustainability much more urgency. Sustainability is about bringing innovation to the ways we work today to enable the needs of future generations.

Finally, I think that COVID-19 has taught us that we can't take our frontline workers for granted. For those of us in the integrated EPC world, that means being relentless about safety, building workplaces with a sense of belonging, and serving our frontline construction professionals better. Companies that get this right are going to do the best in the transition to net zero.

Shaun Kenny is president of infrastructure at Bechtel. **Tony Hansen**, based in McKinsey's Seattle office, is the managing director of the Global Infrastructure Initiative (GII).

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Infrastructure for a net-zero economy: Transformation ahead

Eliminating greenhouse-gas emissions would entail major changes to the world's stock of infrastructure assets. New McKinsey analysis measures the shifts that could take place during this transition.

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As the global transition to net-zero emissions gains momentum, the infrastructure sector will experience large changes, ranging from the buildout of renewable-power capacity and electricity grids to the decarbonization of existing assets around the world. Recent McKinsey research shows that, in a scenario where the world achieves net-zero emissions in 2050, organizations would need to pour $3.5 trillion more into low-emissions capital stock annually than they do today.[1] At the same time, some existing high-emissions infrastructure and equipment would need to be decommissioned or would be underutilized. The convergence of these trends would result in a transformation of the world's built environment. Here is a look at what changes might lie ahead and what they could mean for infrastructure investors and owners worldwide.

An economy-wide transformation

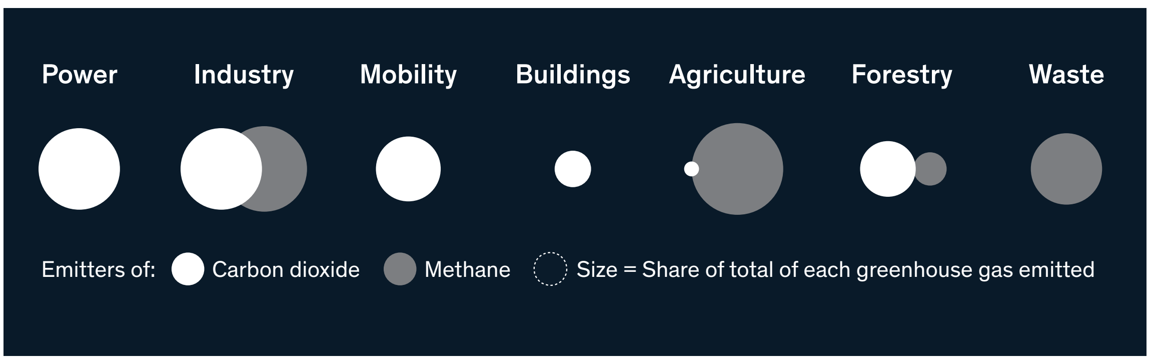
To stabilize the climate and limit rising physical risks from hazards such as extreme heat and more frequent storms, science tells us that it is necessary to stop increasing the concentration of greenhouse gases (GHGs) in the atmosphere—that is, to reduce net GHG emissions to zero. Since substantial GHG emissions now come from each of seven energy and land-use systems, every system would need to greatly reduce its emissions for this net-zero goal to be reached (Exhibit 1). Power and industry, two asset-heavy systems, together generate about 60 percent of global CO_2 emissions. Across all seven systems, the combustion of fossil fuels—coal, gas, and oil—accounts for more than 80 percent of CO_2 emissions, based on current accounting methodologies.

Thus, the transition to net-zero emissions would entail shifts in the production of many goods and services that underpin these energy and land-use systems. For example, under the Net Zero 2050 scenario from the Network for Greening the Financial System (NGFS), our analysis suggests that oil and gas production volumes would be 55 percent and 70 percent lower, respectively, by 2050 than they are today. Low-emissions steel, which makes up about one-quarter of today's output, would account for almost all of the world's steel production by 2050 (Exhibit 2). Production of electric power in 2050

[1] The scenario used in this analysis is the Net Zero 2050 scenario from the Network for Greening the Financial System (NGFS); some variables were downscaled to provide more sector granularity. This is a hypothetical scenario and not meant as a projection or prediction. Our analysis covers the sectors accounting for 85 percent of global GHG emissions. For more information, see "The net-zero transition: What it would cost and what it could bring," McKinsey Global Institute, January 2022.

Exhibit 1

All carbon dioxide and methane emissions today come from seven energy and land-use systems.



Source: *"The net-zero transition, what it would cost, what it could bring,"* McKinsey Global Institute, January 2022; McKinsey EMIT database.

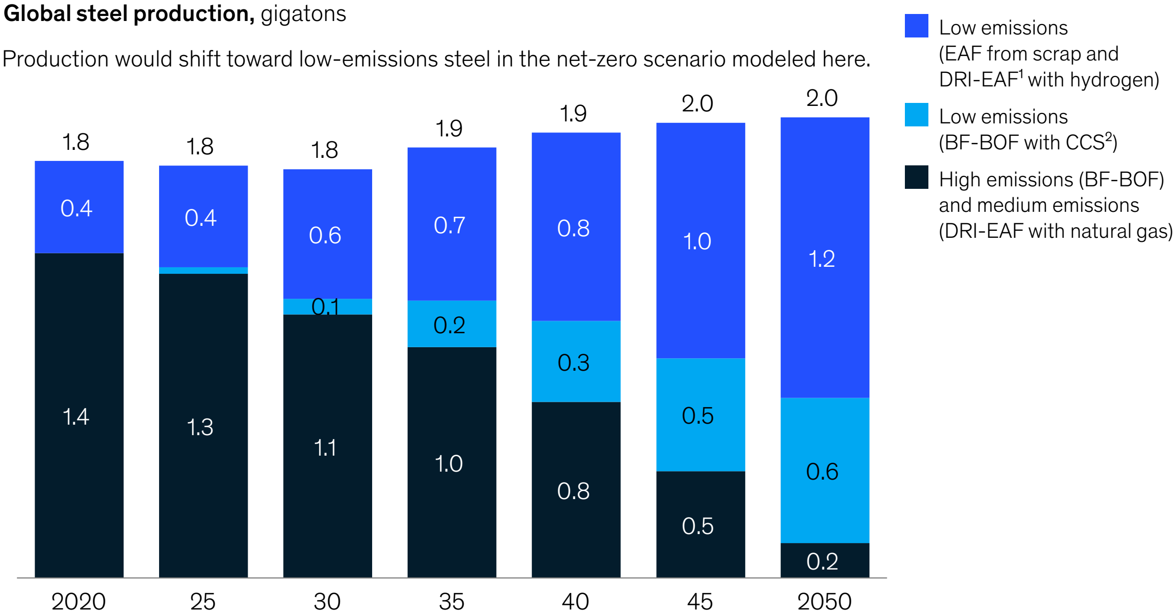
would be more than double what it is today as other sectors use more electricity and developing countries add generation capacity to meet their populations' energy needs (Exhibit 3). Other industries, such as those that manage carbon with carbon capture and storage (CCS) technologies, could also grow.

Exhibit 2

A net-zero transition in the steel sector could result in cost increases and require increased capital spending to decarbonize production.

Global steel production, gigatons

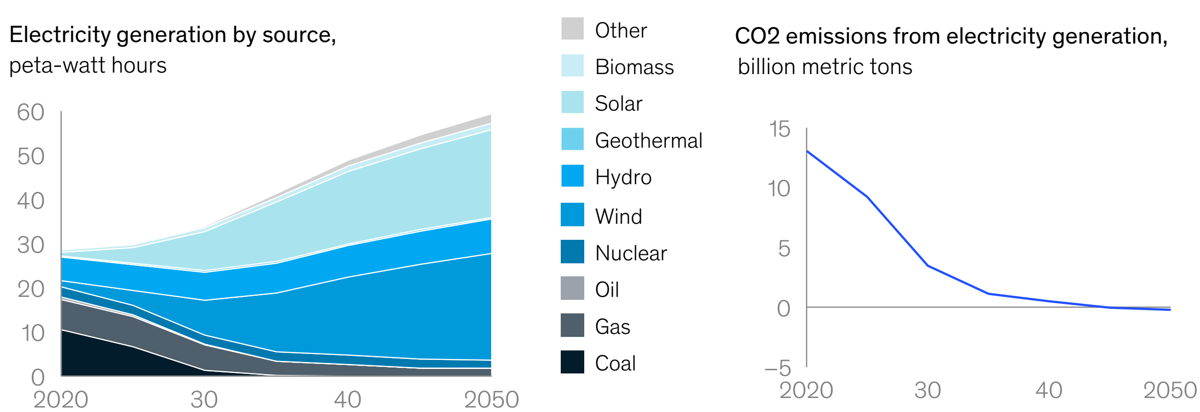
Production would shift toward low-emissions steel in the net-zero scenario modeled here.



[1]Direct-reduced iron, electric-arc furnace.
[2]BF-BOF = blast furnace, basic oxygen furnace, CCS = carbon capture and storage.

Exhibit 3

The NGFS Net Zero 2050 scenario entails a transformation of energy and land-use systems.

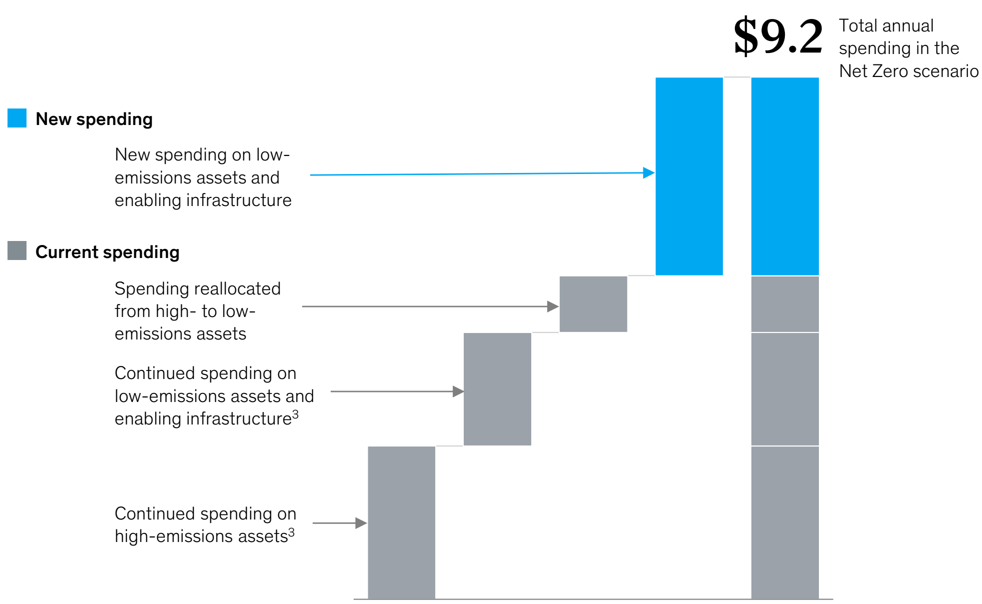


To achieve the production shifts envisioned under the NGFS Net Zero 2050 scenario, organizations would retire or transform some existing physical assets and acquire new ones. McKinsey analysis suggests that about $275 trillion in cumulative spending on physical assets, or approximately $9.2 trillion per year, would be needed between 2021 and 2050 across the sectors that we studied. This total includes $3.5 trillion more spending on physical assets than today, and the additional amount would all go into low-emissions assets (Exhibit 4). Moreover, about $1 trillion of the capital that is now being spent on high-emissions assets, such as coal-fired power plants, would be reallocated to low-emissions assets. (When we account for increases in spending that are expected to take place as incomes and populations grow, as well as for currently legislated transition policies, we find that the required increase in spending would be lower, though still about $1 trillion.)

Exhibit 4

Spending on physical assets for energy and land-use systems in the NGFS Net Zero 2050 scenario would rise to about $9.2 trillion annually, or about $3.5 trillion more than today.

Annual spending on physical assets for energy and land and land-use systems[1] in the Net Zero 2050 scenario,[2] average 2021–50, $ trillion[1]



[1]We have sized the total spending on physical assets in power, mobility, fossil fuels, biofuels, hydrogen, heat, CCS (not including storage), buildings, industry (steel and cement), agriculture, and forestry. Estimation includes spend for physical assets across various forms of energy supply (eg, power systems, hydrogen, and biofuel supply), energy demand (eg, for vehicles, alternate methods of steel and cement production), and various forms of land use (eg, GHG-efficient farming practices).

[2]Based on the NGFS Net Zero 2050 scenario using REMIND-MAgPIE (phase 2). Based on analysis of systems that account for ~85% of overall CO_2 emissions today. Spend estimates are higher than others in the literature because we have included spend on high-carbon technologies, agriculture, and other land use, and taken a more expansive view of the spending required in end-use sectors.

[3]Our analysis divides high-emissions assets from low-emissions assets. High-emissions assets include assets for fossil fuel extraction and refining, as well as fossil fuel power production assets without CCS; fossil fuel heat production, gray-hydrogen production; steel BOF; cement fossil fuel kilns; ICE vehicles; fossil fuel heating and cooking equipment; dairy, monogastric, and ruminant meat production. Low-emissions assets and enabling infrastructure include assets for blue-hydrogen production with CCS; green-hydrogen production using electricity and biomass; biofuel production; generation of wind, solar, hydro-, geothermal, biomass, gas with CCS, and nuclear power along with transmission and distribution and storage infrastructure; heat production from low-emissions sources such as biomass; steel furnaces using EAF, DRI with hydrogen, basic oxygen furnaces with CCS; cement kilns with biomass or fossil fuel kilns with CCS; low-emissions vehicles and supporting infrastructure; heating equipment for buildings run on electricity or biomass, including heat pumps; district heating connections; cooking technology not based on fossil fuels; building insulation; GHG-efficient farming practices; food crops, poultry and egg production; and land restoration.

Source: McKinsey Center for Future Mobility Electrification Model (2020); McKinsey Hydrogen Insights; McKinsey Power Solutions; McKinsey–Mission Possible Partnership collaboration; McKinsey Sustainability Insights; McKinsey Agriculture Practice; McKinsey Nature Analytics; McKinsey Global Institute analysis

Overall, spending would undergo a profound shift: 65 percent of today's spending on physical assets for energy and land-use systems goes toward high-emissions assets, but over the next 30 years, an average of 70 percent of spending would be on low-emissions assets.

The outlook for sectors

Sectors are unevenly exposed in the net-zero transition. The sectors with the highest degree of exposure directly emit large quantities of greenhouse gases (for example, the coal and gas power sector) or sell products that emit greenhouse gases (such as the fossil-fuel sector or the automotive sector). Approximately 20 percent of global GDP is in these sectors (Exhibit 5). Another 10 percent of GDP is in sectors with high-emissions supply chains, such as construction. Here, we focus on three sectors—power, industry, and buildings—in which infrastructure and industrial assets will likely be affected by the net-zero transition, as our analysis of the NGFS Net Zero 2050 scenario suggests.

Exhibit 5

Sectors most exposed to the net-zero transition generate about one-fifth of GDP globally.

Exposed sectors by share of global GDP created

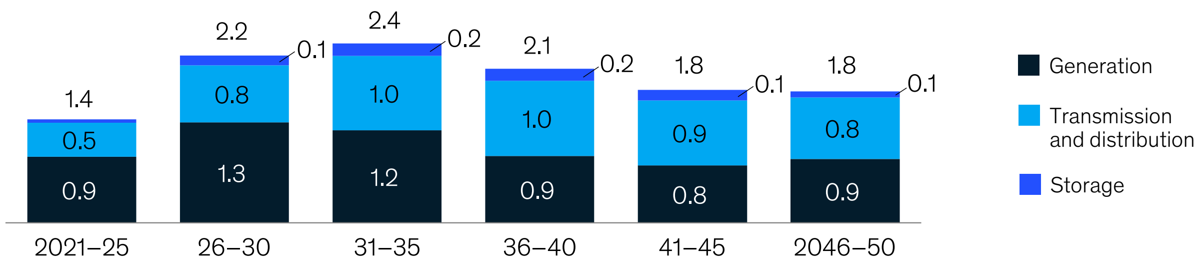
Power

To decarbonize and meet growing demand for electricity, the global power sector would need to phase out fossil fuel–based generation and add capacity for low-emissions power. These changes would require substantial annual capital spending from 2021 to 2050, estimated at an annual average of $1 trillion for power generation, $820 billion for power grids, and $120 billion for energy storage (Exhibit 6). The possibility of asset stranding, which could be significant in the power sector, has prompted concerns about financial-sector risk and the need to build capabilities for quantifying and managing it. Our analysis suggests that about $2.1 trillion of the sector's coal and gas power capital stock could be stranded by 2050 in the NGFS Net Zero 2050 scenario. Eighty percent of this amount is today's capacity.

Exhibit 6

In the power sector, the NGFS Net Zero 2050 scenario would bring investment opportunities and near-term unit cost increases.

Annual capital expenditures, 2021–50,[2] average over 5-year period, $ trillion



Average annual capital spending would rise in the NGFS Net Zero 2050 scenario compared to today, as generation capacity, transmission and distribution networks, and storage infrastructure are built out.

Industry

Two heavy industrial sectors—steel and cement—together account for approximately 14 percent of global CO_2 emissions and 47 percent of the industry sector's CO_2 emissions. While technologies are still emerging, steel and cement production can broadly be decarbonized in three ways: by installing CCS equipment at existing plants, by shifting to low-emissions fuel and other inputs, or by building new low-emissions production capacity. These approaches would require additional capital spending (Exhibit 7). This capital spending would, in turn, lift unit production costs, which will be a key challenge for steel and cement producers. By 2050, the average cost to produce a metric ton of steel would be 30 percent higher than it is today; for cement, the comparable increase would be 45 percent in the scenario modeled here.

Buildings

In the NGFS Net Zero 2050 scenario, the buildings sector would decarbonize by improving energy efficiency—for example, through the use of insulation—and by replacing fossil fuel–powered heating and cooking equipment with low-emissions systems (Exhibit 8). The average annual spending on physical assets between 2020 and 2050 would be $1.7 trillion per year. The buildings sector's biggest adjustments during this transition would be managing the up-front capital costs for end consumers to retrofit equipment and aligning incentives among various stakeholders (such as building owners who invest capital and tenants who may see the benefits of reduced operating costs).

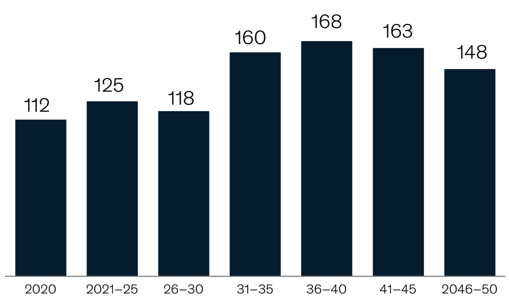
Exhibit 7

A net-zero transition in the steel and cement sectors could result in cost increases and require increased capital spending to decarbonize production.

Steel

Spending would be required in the net-zero 2050 scenario modeled here to build new low emissions production capacity (eg, hydrogen-based DRI-EAF[1]) and install CCS.[2]

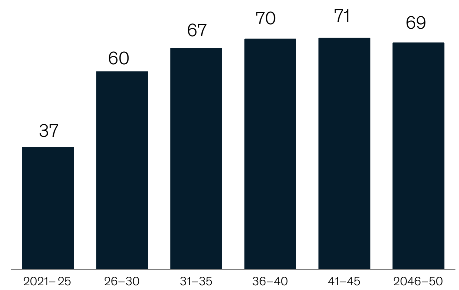
Annual capital expenditures, 2021–50[3]
Average over 5-year period, $ billion



Cement

Capital spending would be required to build low-emissions production capacity and add CCS equipment to existing plants.

Annual capital expenditures, 2021–50[3]
Average over 5-year period, $ billion

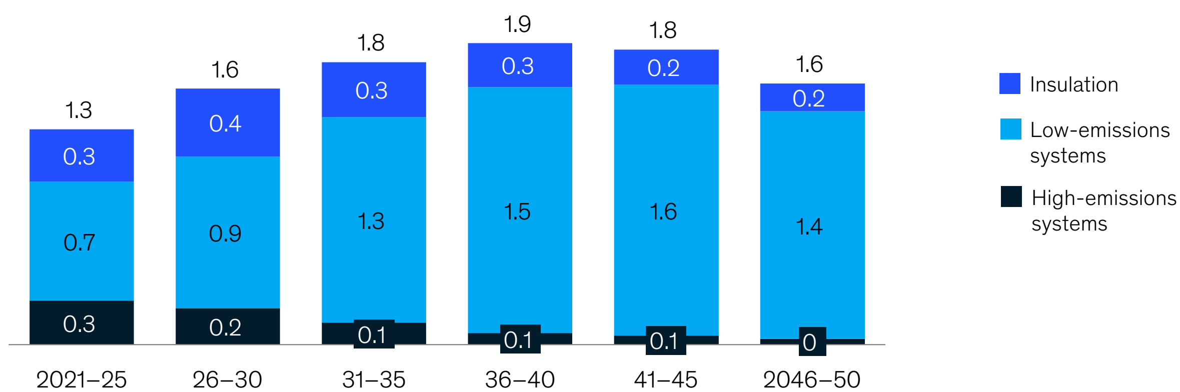


[1]Direct-reduced iron, electric-arc furnace.
[2]Carbon capture and storage; Capital spending includes plant, equipment, and maintenance costs. Assumes global weighted average unit capex cost with weighting toward China, European Union, United Kingdom, United States, Mexico and Canada.
[3]Capital expenditures include the following components: plant, equipment and maintenance costs, CCS capex. CCS capital spending does not include CO_2 transportation, storage and usage. Capital spending associated with increased clinker substitution has not been sized.
Source: Mark Bolinger et al, "Queued up: Characteristics of power plants seeking transmission interconnection as of the end of 2020," Berkeley Lab, May 2021.

Exhibit 8

A net-zero transition in the building sector would entail a shift toward low-emissions equipment.

Average spending on physical assets, 2021–50,[1] average over 5-year period, $ trillion



In the net-zero scenario modeled here, spending would shift toward heating and cooking systems that do not run on fossil fuels and toward building insulation.

[1]Includes spending in both the residential and commercial sectors.

Managing the transition

The transition to net-zero emissions would require economies and societies to make major adjustments.[2] Infrastructure investors and owners can work with governments, businesses, and enabling institutions to support many of these adjustments through coordinated action, undertaken over extended planning and investment horizons. Three categories of action stand out. First, in the financial realm, institutions can catalyze capital reallocation by developing new financing structures, financial instruments, and markets; arranging collaborations across the public and private sectors; and managing risk to stranded assets. Second, organizations in the infrastructure value chain can manage demand shifts and cost increases by building awareness of climate risks and opportunities, lowering technology costs, nurturing industrial ecosystems, collaborating across value chains, and creating incentives for goods producers. Finally, infrastructure organizations in the private sector can help address socioeconomic impacts such as job losses, reskilling, and redeployment programs for affected workers, while governments might consider economic diversification programs, social support schemes, and other compensating mechanisms.

Working toward net-zero emissions will be a far-reaching global endeavor, and the infrastructure sector will have an integral role to play in transforming the world's capital stock. Although capital spending during the transition will be substantial, it is important not to view this spending only as a cost. Much of it could yield operating-cost savings through reduced fuel consumption, improved material and energy efficiency, and lower maintenance expenses. What's more, many investments would position organizations to tap into growing demand for low-emissions goods and services. For infrastructure owners and investors, the time is now to begin pursuing the opportunities that the net-zero transition will bring.

Mekala Krishnan is a partner in McKinsey's Boston office, and **Jonathan Woetzel** is a senior partner in the Shanghai office.

This article is adapted from *The net-zero transition: What it would cost, what it could bring*, a McKinsey Global Institute report by Annabel Farr, Danielle Imperato, Mekala Krishnan, Tomas Nauclér, Daniel Pacthod, Dickon Pinner, Hamid Samandari, Sven Smit, Humayun Tai, Jonathan Woetzel, and Weige Wu. To obtain the report, visit www.mckinsey.com/net-zero.

[2] "Solving the net-zero equation: Nine requirements for a more orderly transition," McKinsey, October 27, 2021.

How big business is taking the lead on climate change

Business leaders have made bold commitments to reducing emissions. The challenge will be fulfilling these pledges across industries.

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In retrospect, the most significant outcome of COP26—the UN Climate Change Conference that convened in Glasgow on October 31, after a yearlong postponement—may not have been the formal agreement hammered out by diplomats in the main plenary hall but the momentum that emerged from the meetings and conversations among global business leaders that took place along the sidelines.

From the outset, the sheer size of the private-sector turnout at COP26 suggested that industry was no longer prepared to stand by and wait for government action. By the time the summit concluded on November 13, many of the world's largest companies and financial institutions had voluntarily announced bold new plans aimed at mitigating global warming. More than 5,200 businesses pledged to meet net-zero carbon targets by 2050, and some 450 banks, insurers, and investors—collectively representing $130 trillion in assets and 40 percent of the world's private capital—committed to making their portfolios climate neutral during the same period. A group of major automakers pledged to stop selling fossil-fuel-powered vehicles by 2035. And the Mission Possible Partnership, an expansive industry-backed group focused on developing decarbonization road maps sector by sector, unveiled plans for three industries that have been among the hardest to transition: steel, shipping, and aviation. More sectors will follow.

The challenge will be making these plans a reality, not just for a few first movers but for whole industries. A new McKinsey analysis found that capital spending to reach net-zero emissions would need to increase from $5.7 trillion annually today to $9.2 trillion annually over the next three decades.[1] That is an estimated increase of $105 trillion over 30 years. Such a massive reallocation of capital would likely trigger a period of rapid innovation and growth, likely reshaping entire industries and revolutionizing the way businesses create value across industries.

Although this transition will generate new opportunities for many, with great opportunity comes great risk. And because no single firm can bear these risks on its own, managing them will require cooperation across industries and between industry and government. For business leaders, the biggest uncertainties concern whether technology, capital, and policy will come together in ways that allow firms to break away from old production methods and invest in new lines of business and new supply chains.

Boldly pledging to reduce emissions and actually implementing the changes that will make these reductions possible are two very different things. And as industries embark on decarbonization, their ability to make good on their COP26 pledges will largely depend on three factors: technological innovation, the pace at which carbon-intensive "brown" businesses can be converted into greener ones, and the deployment of massive waves of new capital.

Game-changing technologies

At the center of the coming industrial transformation is technology. The International Energy Agency (IEA) estimates that to reach net-zero emissions, half the carbon reductions in 2050 will require technologies that today are in the R&D or demonstration stage and not yet ready for commercial deployment. The innovations needed include "game changer" technologies that will be highly disruptive, especially in industries that have so far proved difficult to decarbonize.

There is no shortage of interesting technical ideas, but the process of turning these innovations into scalable businesses is capital intensive and fraught with risk. Significant investment may be necessary before it can be determined that a seemingly promising technology is even effective, let alone cost competitive. Risk-sharing mechanisms will be critical to developing, proving, and scaling up these first-of-a-kind technologies.

[1] "The net-zero transition: What it would cost, what it could bring," McKinsey, January 2022.

A decade ago, during the first wave of the energy transition, businesses developing commercial-scale solar components, biofuels, and battery-storage systems faced similar challenges. A key lesson from this first wave was that market forces on their own weren't enough to help first movers develop and commercialize these technologies. The initial funding required was often too high for venture capital investors, yet the commercialization risk of new technologies was too high for mainstream debt and equity investors. For most successful technologies, such as solar, the solution turned out to be a combination of policy supports, including tax credits, direct subsidies, and loan products, that backstopped the technology commercialization risks of scale-up projects.[2] The industry learned that when government and businesses worked together, they could help unleash private capital—debt financing, mainly—that allowed rapid scaling and helped drive down costs and improve technical performance.

Looking to the future, deep cuts in emissions from across the industrial system will depend on a cluster of critical technologies. Those likely include electric power plants that have zero emissions but could ramp up and down as needed—keeping the lights on even as wind and solar generators shift their output with the vagaries of the breeze and the sun. Hydrogen-fueled power plants are a leading candidate. Hydrogen could be a game changer in other sectors as well because, once produced, it is easy to store. Hydrogen fuel cells could thus be useful for applications, such as heavy trucks or ships, where batteries aren't a practical way to store the huge volumes of needed energy on board.

Despite their promise, these types of technologies are nascent today—and so are viable business models. Here, lessons from the first wave should be applied. Government support will likely be necessary so that good ideas don't perish before they can be tested by business. Particularly important will be mechanisms such as government-backed loans for early, risky projects. The technologies that will be most crucial to achieving deep cuts in emissions will be capital intensive to scale and will thus benefit from low-cost debt financing.

Brown to green

Decarbonizing the high-emitting industries that today account for nearly 80 percent of global emissions presents another major challenge. The US energy transition that began during the 19th century—a shift from biomass to coal, which was jump-started by technological improvements to the steam engine—took nearly 100 years. If the world is to avoid the worst impacts of climate change, it must transition to net-zero emissions at a much swifter pace over the next few decades.[3]

Many analyses of the coming energy transition focus on the industries of the future. In reality, success will depend for the most part on how quickly the industries of today can transition from brown to green by phasing out carbon-intensive operations. The IEA and McKinsey have separately estimated that decarbonization of the industrial and energy systems comprises over 50 percent of the volume of carbon that must be cut over the next decade. McKinsey's estimates have suggested that decarbonizing industrial and power systems, as well as scaling low-emissions power capacity, would require $60 trillion cumulatively over the next 30 years.

The brown-to-green transition was an important emerging theme at Glasgow, as firms in some of the world's highest-emitting industries, such as steel, cement, oil production, and electric power, made pledges to cut pollution. Implementing brown-to-green strategies will require firms to deploy technologies to help decarbonize industrial processes. Oil companies, for example, are using a suite of technologies—including crop genetics, chemical engineering, and refining—to

[2] Ruth Greenspan Bell, "Change on climate change: Breaking the policy deadlock," *Foreign Affairs*, September 23, 2015.
[3] Charles F. Cooper, "What might man-induced climate change mean?," *Foreign Affairs*, April 1978.

develop biofuels that will help make fuel sales carbon neutral. A rapid uptick in government and industry pledges for clean fuel production has resulted in a market for biofuels that can replace jet fuel, for example. Investors are already rewarding some firms that have successfully executed brown-to-green transformations in this sector. Over the past decade, for example, the Finland-based company Neste has transformed itself from a regional oil refiner to the world's largest producer of renewable fuels. Its valuation has more than doubled.

Many opportunities in the shift from brown to green involve electricity. Thus, the greatest risks and opportunities today may lie in the industries that remain difficult to electrify, such as air transport, heavy mining, oil refining, and the production of steel and cement. Some of the most interesting opportunities in these sectors involve technologies for capturing carbon and storing it safely underground and technologies for shifting away from fossil fuels and using hydrogen as a fuel. Many firms in high-emitting industries are well poised to develop and deploy these technologies at scale given their existing skills in areas such as geology, chemical engineering, and complex project development. When it comes to testing whether the overall effort will be enough to mitigate warming globally, what will be key to watch is how many companies execute brown-to-green transformations on timelines like that of Neste.

A rapid shift toward green will mean accelerating the retirement of high-emitting assets to create space for cleaner alternatives. The transition away from conventional coal is already well under way across the Western world and has begun accelerating globally. About two dozen nations announced commitments to phase out coal power at COP26, and member nations of the Organisation for Economic Co-operation and Development (OECD) made a five-year, $8.5 billion commitment to help South Africa move away from coal, which today fuels 90 percent of the country's electric power demands. In the United States, some state regulators are speeding the retirement of coal by softening the financial blow—for example, by incorporating the cost of shutting coal plants into the rate base of the companies they regulate. Although these are important developments, the global transition away from coal is just getting started, and action on one of the key challenges—helping the workers and communities that will bear the economic brunt of this shift—remains uneven.

Investing in decarbonization

A huge shift in the expectations of the world's bankers and asset allocators is now under way, helping create more urgency around decarbonization. The newly formed Glasgow Financial Alliance for Net Zero (GFANZ) has brought a group of financial institutions together to identify ways to collectively invest in high-emitting sectors that might speed their efforts to develop zero-carbon technologies and to responsibly retire assets such as coal-fired plants.

Many other alliances are emerging—which will prove most important is hard to pin down, but what is clear is that financiers are beginning to shift their capital deployment to make it more consistent with the goal of net zero by midcentury.

Lenders have begun considering the risk that high-emissions industries won't fare well in the future and linking debt issuances to company sustainability objectives, although the mechanisms for doing so are still maturing. Determining the risk profiles of the various opportunities for sustainable investment that currently present themselves, such as green retrofits for oil and gas production or industrial plants, remains a major challenge for lenders. Without better metrics, efforts to invest in decarbonization could bring about many unintended consequences, including locking out the financing that will be critical to decarbonizing high-emitting assets. Industry players and investors are working to address this problem by developing quantitative parameters for assessing risks and returns in order to facilitate the flow of appropriately risked capital into decarbonization investments, but there is still much work to be done.

New momentum

COP26 helped focus the global business community on decarbonization, providing momentum for new investment and spurring the formation of new partnerships in the process. The challenge today lies in helping investors channel capital to brown-to-green transformations in which novel third-party financing and public–private partnerships help unlock financial returns. Although private capital providers are already seeking opportunities to invest in brown-to-green asset transitions, this is most evident in countries where the policy guidance is clear and future financial rewards seem assured.

The larger picture remains sobering. Climate change is a global problem, and the challenges in the developing world are very different from those that are most familiar to industry leaders in developed economies. Two-thirds of emissions are produced in developing countries, and around half come from industries in which the technological and business solutions to reducing emissions remain unclear. The next major global climate conference, COP27, which will take place in Egypt, will be an overdue opportunity to spotlight that next frontier.

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