GLOBAL INFRASTRUCTURE INITIATIVE
By McKinsey & Company

Voices on Infrastructure

Preparing for energy transition in infrastructure

July 2021

Table of contents

Introduction

Tip Huizenga
Senior partner, Sydney
McKinsey & Company

Koen Vermeltfoort
Partner, Amsterdam
McKinsey & Company

Kassia Yanosek
Partner, Houston
McKinsey & Company

Welcome to the July 2021 issue of *Voices on Infrastructure*, a collection of insights on **preparing for the energy transition**.

This issue explores sustainability in infrastructure, particularly as it relates to the construction, engineering, and operation of our electric grids; oil and gas and hydrogen infrastructure; and buildings. Over the past 18 months, we have seen an acceleration of societal, policy, and investor pressures on industry to shift away from fossil fuel–based energy and toward a zero-carbon economy. As an example, while few oil and gas companies at the start of 2020 had announced 2050 net-zero emissions targets, today dozens have, including several with stated targets of or before 2040.

The bar continues to rise, especially as shareholder groups continue demanding broader and faster emissions reductions from the sectors with the highest emissions. The resulting capital challenges are massive. We and others estimate that at least $50 trillion will need to be deployed to reduce fossil-fuel and other greenhouse gas (GHG) emissions by 2050 to meet the goals of the Paris Agreement. Given that the assets and infrastructure that support the economy today are the result of decades of deployed capital, investment decisions by capital providers and industry players in the next few years will be critical. Furthermore, the implications are significant, requiring “brown-to-green” asset transformations (such as replacing diesel generators on offshore oil platforms with renewable power), new infrastructure (for the electrification of transport), and scaling new technologies (such as green hydrogen and carbon-capture technology).

As a result, much uncertainty remains around how best to navigate the energy transition. Which assets could be upgraded to adapt to evolving emissions standards? Which should be decommissioned and dismantled? What new infrastructure needs to be built from the ground up? Further complicating matters, the transition to new sources of energy to meet emissions goals entails stabilizing capacity to withstand fluctuations in demand and supply, weatherizing assets to contend with increasingly common extreme events, and building new supply chains for novel technologies.

Investors, corporate players, and policy makers will need to collaborate to scale emerging technologies, many of which not only require large sums of upfront capital but also have high technical risks and uncertain cash flows. All of these challenges also come with the pressures of delivering projects on aggressive timelines, as required by regulators and individual company commitments.

We hope the following four themes in this issue of *Voices* help inspire leaders globally to reimagine the production and use of energy in infrastructure:

- **Building a more resilient electric grid.** The physical effects of climate change, such as extreme temperatures, forest fires, and floods, are taking a toll on electric grids. Owners and operators can build resilience to face such events and maintain stability when transitioning to and integrating renewable sources of energy. Furthermore, both electrification and new supply sources will likely require an unprecedented commitment of resources to upgrade and build infrastructure.

- **Increasing sustainability in engineering and construction.** The construction industry is directly or indirectly responsible for almost 40 percent of global CO_2 emissions from fuel consumption and 25 percent of GHG emissions overall. Our assessment shows that it is possible to reach net-zero emissions for operating buildings at an average cost of €5 per ton of CO_2, contributing substantially to the overall net-zero pathway that can be achieved at net-zero cost by 2050 in Europe. A combination of several measures can help, including design and process optimization, alternative materials and equipment, and reducing emissions through increased production efficiencies.

- **Accelerating the adoption of novel technologies.** Carbon capture, electrolysis, and the integration of wind and solar energy will likely prove critical to increasing sustainability in engineering. Digital technologies are also playing important roles in infrastructure, especially in supporting electrification and renewable energy sources. New partnerships with tech-minded companies and start-ups, as well as with needed capital partners to scale these projects, can help incumbents focus on their strengths and pursue promising pathways.

- **Assessing the opportunities in decarbonizing oil and gas and chemicals.** The transition from “brown” to “green” infrastructure and deep decarbonization of the oil and gas sector is under way as multiple companies commit to blue and green hydrogen projects and carbon-capture technologies. It’s only a matter of time before blue hydrogen is scalable from a technology perspective. Pursuing sustainability in process engineering can help lead the way.

How industry players respond to climate change in the years to come will have long-lasting effects on the buildings we live in, the power we use, and the safety of our communities—yet much work remains to hit net-zero goals. As an industry that encompasses so many fundamental aspects of our lives, infrastructure can play a key role in the pursuit of a cleaner, greener future.

News from the Global Infrastructure Initiative

Tony Hansen

Director of the Global Infrastructure Initiative, McKinsey & Company

Welcome to the July edition of *Voices on Infrastructure*, addressing the pivotal issue of **preparing for energy transition in infrastructure**.

Achieving net-zero carbon emissions goals will require a deep commitment and a collaborative approach from both the private and public sectors. A successful decarbonization and energy-transition strategy will need to accommodate new policies and regulations, account for new investments and related risks, and adopt an unprecedented sense of urgency. This edition of *Voices* shares perspectives on some of the tangible actions that regions, countries, sectors, and organizations can take to dramatically reduce carbon emissions and accelerate the energy transition.

We have officially begun our next 18-month cycle of GII programming, which will culminate with our eighth GII Summit, to be held in Tokyo in 2022. Creating a pathway to sustainable infrastructure will be our broad theme for this cycle, and this will be reflected in our roundtables, site visits, Summit, and publications. Details of these activities will appear on the GII website over the coming months.

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

The shifting energy landscape: An interview with Maria Pope

As the energy industry transitions to cleaner fuel sources and responds to climate change, leaders must also accommodate the evolving needs of the communities they serve.

Maria Pope

President and CEO
Portland General Electric

In some ways, the Pacific Northwest serves as an example of the future of power generation. Late last year, Portland General Electric (PGE) announced it was shuttering the Boardman Coal Plant, a 550-megawatt coal-fueled electric-generating power plant built in the late 1970s. Soon after, the Wheatridge Generating Station, one of the country's first large-scale energy facilities to combine wind power, solar power, and battery storage, came online. In addition, PGE has had to contend with combating hugely destructive forest fires; increasing diversity, equity, and inclusion (DE&I) efforts; and building new tech partnerships.

The following lightly edited interview with PGE President and CEO Maria Pope was conducted by McKinsey's Adrian Booth in June 2021.

McKinsey: To begin, several trends in the energy industry seem to be picking up speed, including increased electrification, wildfires due to climate change, and the continued evolution of technology. Do you think this is an unusual time for the industry?

Maria Pope: The energy landscape has shifted dramatically over the past decade, and even more so in the past several years. Customer expectations of utilities—especially around technology, climate change, and ensuring equity for all communities—have evolved. Severe weather events due to climate change have put energy and system resiliency at the forefront of local, state, and national infrastructure conversations. Underpinning all this is how our societal systems, including the energy system, serve historically disadvantaged communities, such as communities of color, rural communities, and low-income customers.

Each of these trends will impact our industry, in both the short and long term. As a company, PGE is leading by partnering with customers to achieve a clean energy future. This partnership approach has created opportunities to accelerate the deployment of renewable energy resources and the integration of storage technologies. Improved reliability and resiliency of the grid is critically important to a clean energy future.

McKinsey: Regarding the recent wildfires, how does PGE manage public safety and grid stability?

Maria Pope: We take natural disasters very seriously, and we prepare for them on blue-sky days. We've partnered closely with our utility peers in surrounding states and work very closely with the US Forest Service and other agencies to detect early warning signs and to mitigate any risk of damage to our system and, importantly, the areas in which we serve.

In September 2020, more than two million acres burned in the state of Oregon, and about ten million acres burned throughout the West. Approximately 20 percent of our employees were either evacuated from their homes or were ready to be evacuated at a moment's notice. It goes without saying: this was a significant event for everyone, including our company. In the interest of mitigating risk to our customers, their property, and our system, we proactively shut off power and de-energized our transmission and distribution lines. In fact, we know of no instance in which our equipment contributed to any wildfire.

McKinsey: Switching gears a bit, President Biden's proposed infrastructure plan includes a commitment to achieving 100 percent carbon-free electricity by 2035. What is PGE's high-level strategy in this context?

Maria Pope: Our goals are ambitious and reflect both our customers' expectations and the values of the communities we serve. Specifically, we aim to reduce greenhouse gas (GHG) emissions by at least 80 percent by 2030, with an aspirational goal of zero GHG emissions by 2040. Doing so will require major investments in technology and clean energy infrastructure, as well as cost-effective sources of clean and renewable power generation.

A major driver of these goals will be fiscal and tax policy reform. The current tax code contains more than 40 confusing and sometimes obsolete provisions around various energy sources and technologies. Most of the incentives for renewable energy are temporary, while the tax breaks for oil and gas companies are permanent. As a result, the American taxpayer is essentially subsidizing fossil fuel-driven climate change. We believe this must change.

McKinsey: PGE recently closed its largest generation asset, the Boardman Coal Plant, and announced the start of commercial power generation at the new Wheatridge facility. What lessons can you share from this chapter?

Maria Pope: The closure of the Boardman plant is a great example of not only how to sustainably transition legacy coal generation but also how to ensure a smooth transition for employees while keeping customer prices low. Planning took place over many years and resulted in a thoughtful and cost-effective approach to eliminating one of the largest sources of GHG emissions in the state of Oregon.

Concurrent with the Boardman plant's closing, the Wheatridge Generating Station came online—a major milestone in both PGE and Oregon's transition to clean energy. Wheatridge is the first facility of its scale in the country to combine wind power, solar power, and on-site battery storage in an integrated, clean-energy facility. Furthermore, the facility is located adjacent to the Boardman site and serves as a great example of supporting rural communities and the value of partnerships with local governments, stakeholders, and other industry players.

McKinsey: What should the industry be doing to better promote DE&I?

Maria Pope: I'm proud of the work we've done at PGE to improve and focus on DE&I, yet I also appreciate that much work still needs to be done.

We publish our pay equity and key DE&I statistics annually. Internally, we focus on hiring, developing, promoting, and retaining diverse talent. For example, we have two leadership-development programs going simultaneously. One is designed to grow women in leadership and the other to help develop our high-potential Black, indigenous, and people-of-color employees. Externally, we're diversifying our supplier base and are partnering with local and state leaders to ensure equity in our service delivery and outage restoration.

DE&I has been core to our company's values for more than two decades. Our guiding behaviors are foundational to the fabric of our company and how we do business. I am proud that every year since we started measuring results, we have increased the number of women and racially diverse people at our company and in leadership.

McKinsey: Broadly speaking, if you think of PGE as an institution, what do you hope to be true in 2030 if all of your plans come to fruition?

Maria Pope: Customers are at the center of all that we do, and that won't change. We believe that advances in technology will go a long way toward achieving net-zero emissions and real-time integration of energy sources. In our vision, energy generation and customer use will be seamlessly integrated and go hand in hand with dynamic pricing. We'll widely use AI and machine learning to anticipate customers' preferences, ensure overall grid stability, and deliver a truly interconnected, clean-energy future.

Technology is core to how we look at things. We are partnering with several tech companies, ranging from the largest global players to small local start-ups. And through these partnerships, as well as with some of the innovative leaders who have joined our company from tech and other sectors, we are accelerating our pace of technology deployment and seeing impressive results.

We also know that broader economy-wide leadership is expected of us. For example, we invested in partnering to address the transportation sector's emissions because at about 40 percent, transportation is the largest source of GHG emissions in our economy. And just a couple of weeks ago, we announced, along with Daimler Trucks North America, a first-of-its-kind energy island charging station for large all-electric trucks.

Maria Pope is the president and CEO of Portland General Electric.

Seizing the decarbonization opportunity in construction

As decarbonization initiatives gain momentum, construction players can benefit—but only if they view ESG as a strategic opportunity.

Jose Luis Blanco
Partner, Philadelphia
McKinsey & Company

Hauke Engel
Partner, Frankfurt
McKinsey & Company

Focko Imhorst
Associate partner, London
McKinsey & Company

Maria João Ribeirinho
Partner, Lisbon, Madrid
McKinsey & Company

Erik Sjödin
Partner, Stockholm
McKinsey & Company

As one of the world's biggest economic ecosystems, the construction industry has a major part to play in achieving global sustainability goals. Following the COVID-19 outbreak, we asked 100 senior construction executives what industry trends they expected to accelerate after the pandemic—and 53 percent cited sustainability. Furthermore, 10 percent of respondents said they had already increased investments in sustainability measures since the start of the crisis.[1]

Today's decisions will have a significant effect on the buildings segment in particular. With investors and capital markets increasingly prioritizing environmental, social, and governance (ESG) measures, more and cheaper capital is available for sustainable players—which we expect to be one driver of a rapid increase in demand for ESG-friendly buildings. In fact, the smart-buildings segment is expected to grow at a CAGR of 10 to 13 percent by 2025. Meanwhile, regulators in more than 50 countries have already established or are planning a form of carbon taxation.

This article explores construction's impact on greenhouse gas (GHG) emissions in the context of buildings, examining how the industry can decarbonize both existing projects and new builds.[2] It also illustrates how companies in the sector can benefit from approaching ESG as a strategic opportunity versus the traditional view that it is simply a cost that is hard to pass on to other players in the value chain (for example, tenants or developers).

Construction's impact on the environment

ESG factors are the key measures of sustainability and societal impact in construction. The environmental component addresses aspects ranging from air quality and energy management to a project's impact on biodiversity, waste, and water management. On this point, construction is directly or indirectly responsible for almost 40 percent of global CO_2 emissions from fuel consumption and 25 percent of GHG emissions overall.

GHG emissions from the construction ecosystem are mainly driven by two components: raw-materials processing for buildings and infrastructure (about 30 percent of total construction emissions per year, largely cement and steel) and buildings operations (about 70 percent). Given the lengthy life cycle of the average building, pre-2020 construction will account for 80 percent of the world's building stock by 2050. Therefore, it will be crucial over the coming years not only to decarbonize new buildings but also to retrofit existing stock to be more sustainable.

Specific retrofit decarbonization initiatives can be cost-effective

Taking a closer look at emissions from the operation of existing buildings, two factors are important: the energy efficiency of the building (thermal insulation and heating-control systems) and the energy source used for heating (such as using renewable electricity to drive heat pumps versus gas boilers). The latter is the priority for emission reduction; in the European Union, it's estimated that switching to renewable technologies in heating will account for 72 percent of emission reductions, supporting the pathway to net-zero emissions.[3]

This assessment shows that it is possible to reach net-zero emissions for operating buildings at an average cost of €5 per ton of CO_2, contributing substantially to the overall net-zero pathway that can be achieved at net-zero cost by 2050 in Europe. Given that the average building emits two tons of CO_2 per year, the average annual cost increase would be only €10 per dwelling per building per year—an increase to the average energy bill of approximately 1 percent.

Meanwhile, increased levels of insulation could still contribute around 20 percent of overall emissions

[1] See Timmy Andersson, Jonas Biörck, Jose Luis Blanco, Jan Mischke, Rob Palter, Maria João Ribeirinho, David Rockhill, Erik Sjödin, and Gernot Strube, "The next normal in construction: How disruption is reshaping the world's largest ecosystem," June 4, 2020, McKinsey.com.
[2] For more on future-proofing infrastructure, see our recent "2021 GII Summit: Project of the future." Of particular relevance are the sections on "Best ideas from the summit" and our "Sector roundtables," specifically around engineering, construction, and building materials, globalinfrastructureinitiative.com.
[3] For more, see Paolo D'Aprile, Hauke Engel, Godart van Gendt, Stefan Helmcke, Solveigh Hieronimus, Tomas Nauclér, Dickon Pinner, Daan Walter, and Maaike Witteveen, *How the European Union could achieve net-zero emissions at net-zero cost*, December 3, 2020, McKinsey.com.

reductions by improving energy efficiency and thus reducing demand—as well as compounding the positive effects of renewable heating sources. Thus, the most significant shifts in EU heating systems include moving 40 percent of residential and commercial buildings to heat pumps by 2050 (versus 2 percent now), 33 percent to district heating (versus 12 percent now), 15 percent to biogas or hydrogen boilers (versus 0 percent now), and 10 percent to solar thermal as an add-on technology (versus 2 percent now).

Reducing the emissions impact of new builds

New building construction is responsible for more than 2.5 gigatons of CO_2e globally (5 percent of total GHG emissions). Concrete and steel processing represents the largest share (60 percent) of embodied carbon because of the large quantities of each material incorporated in a typical structure and their energy-intensive production processes.[4]

Reducing emissions for new builds requires a different approach than that of decarbonizing building operations. Regulations for new builds are currently tightening, requiring higher levels of insulation: for example, new buildings in the European Union are now subject to the Energy Performance of Buildings Directive. With this in mind, the decarbonization of materials can be achieved through a combination of several measures:

— lowering demand for primary resources through design and process optimization (including reduced waste, improved building footprints, and limited overspecifications), and by increasing closed-loop circularity for materials and components (including increased usage of scrap material and reduced recycling-yield losses)

— shifting commonly used materials and equipment to alternatives that are more energy efficient, including substitution with low-carbon materials, higher-performing materials, and electrification of heavy equipment

— reducing emissions during production of required materials, including increased production efficiencies, electrification of processing equipment, and technology advancements

— using generative design to create outcome-based designs that help frame and clarify how different materials and design choices can lower GHG emissions

— pushing toward productization of projects, modularization, and off-site construction to reduce the overall footprint of the construction process

We modeled a potential abatement pathway for materials and construction processes, taking as an example a European residential building (five stories, 500-square-meter footprint), to assess the optimal combination of the principal measures (exhibit). This model was based on input from our global pool of sector experts and the latest scientific literature.

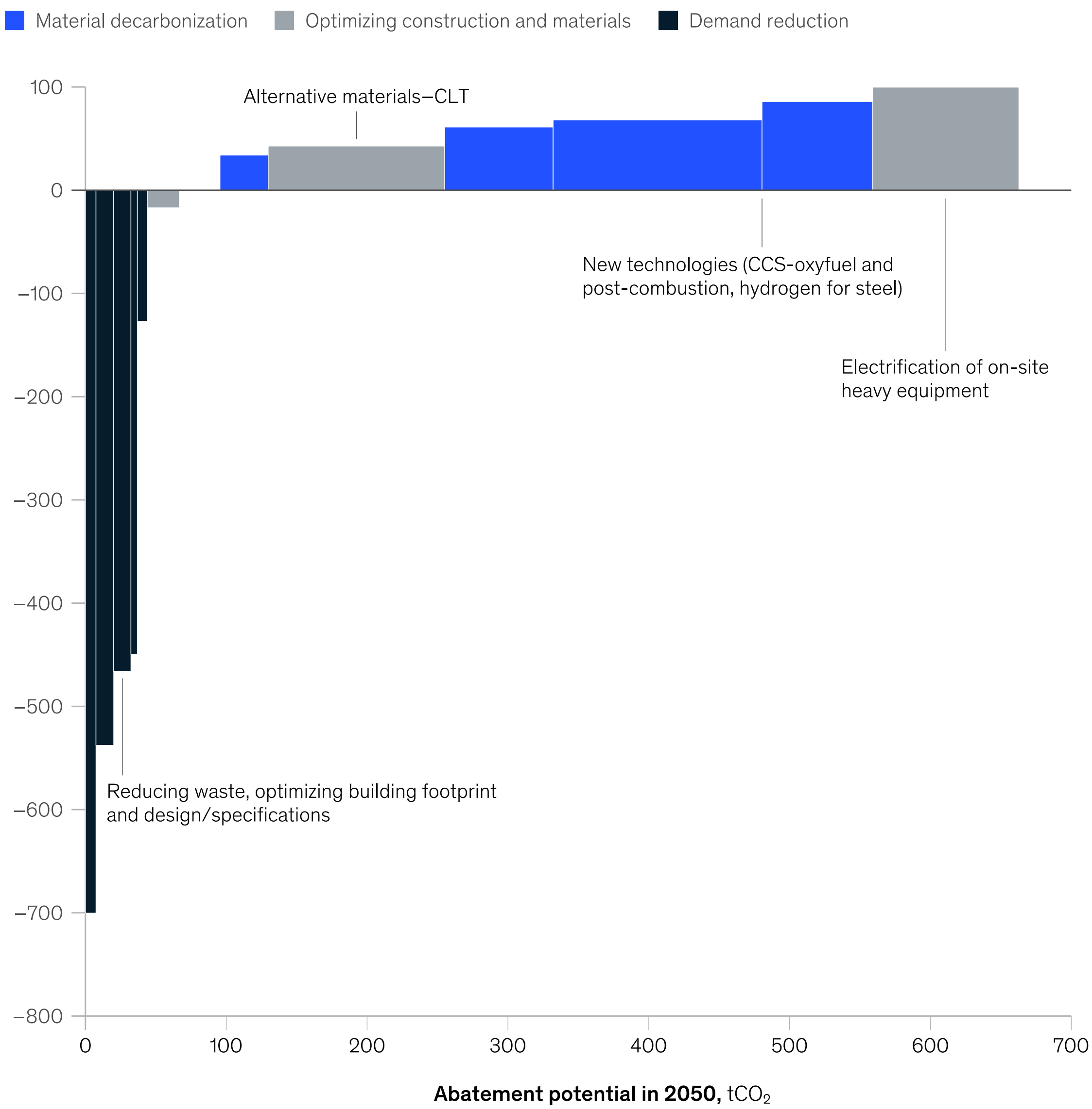
The pathway toward zero-carbon buildings at zero cost increase may require rethinking basic principles and combining existing and alternative materials. The optimal mix of these will vary for different buildings and locations. Analysis for the building referenced in the exhibit (mainly based around well-known and more established levers) suggests that most abatement potential comes from reducing upstream emissions in the material-production process (45 percent) and shifting to alternative materials and equipment (40 percent). A relatively small abatement potential comes from lowering demand, including primary resources (a

[4] For more on embodied carbon, see Lynelle Cameron, “Data to the rescue: Embodied carbon in buildings and the urgency of now,” *Voices on Infrastructure: The project of the future*, September 2020, globalinfrastructureinitiative.com.

Exhibit

The decarbonization pathway may require a rethink of basic principles and a combination of existing and alternative materials.

Average abatement cost to 2050,[1] €/tCO_2



Note: The horizontal axis shows the abatement potential of the technology switches. The vertical axis displays the average abatement cost as €/tCO_2 for each switch.

[1] The mentioned costs are aggregated for the eventual technology; the switches originate from multiple other technologies; relatively low reduction from district heating due to relatively high baseline (compared to heat pumps) and high amount of switches from gas boiler to district heating.

Source: Decarbonization Pathway Optimizer total of 15 percent). Thus, the pathway suggests that a significant share of these measures would bring cost savings to the industry.

No single player in the ecosystem can tackle emissions alone. The construction ecosystem is highly fragmented, with many steps along the building life cycle. Although each player in this highly complex ecosystem can make a difference and capture opportunities, collaborative efforts among various stakeholders are likely to yield the best results. Ultimately, this means that, depending on the asset type, each stakeholder has unique opportunities to make an impact on emissions at multiple stages of the life cycle.

A longer version of this article, "Call for action: Seizing the decarbonization opportunity in construction," can be read on McKinsey.com.

Jose Luis Blanco is a partner in McKinsey's Philadelphia office, **Hauke Engel** is a partner in the Frankfurt office, **Focko Imhorst** is an associate partner in the London office, **Maria João Ribeirinho** is a partner in the Madrid office, and **Erik Sjödin** is a partner in the Stockholm office.

The authors wish to thank Gernot Strube for his contributions to this article.

Engineering bright spots for a green energy future: An interview with Robin Watson

Robin Watson CBE, chief executive of Wood, explains how digital technologies in process engineering can help lower emissions and achieve greater sustainability.

Robin Watson

Chief executive
Wood

In 2017, Wood acquired engineering and project-management company Amec Foster Wheeler, greatly expanding Wood's process engineering capabilities in industries such as oil and gas, chemicals, and mining. The acquisition also expanded Wood's focus on a number of technologies expected to play key roles in the shift away from fossil fuels.

The following lightly edited interview was conducted by McKinsey's Giorgio Bresciani in June 2021.

McKinsey: What is at the top of your agenda and Wood's in terms of a strategy for the energy transition, and why?

Robin Watson: First, we see an unstoppable momentum to the realization that the energy industry does, in fact, need a transition. That's something that we've really been conscious of for the past six or seven years, which culminated in our acquisition of Amec Foster Wheeler. The breadth of end markets they offered helped us reposition Wood to respond to changing attitudes in energy and future market opportunities.

The conventional energy business has a role to play on two fronts. One is as a primary fuel source. There are few alternatives as reliable as fossil fuels are today. That is changing, of course, but the transition to renewables needs to be secure. Similarly, the exploration and production of fossil fuels needs to lower its carbon emissions, whether that be using carbon capture and storage or embracing alternative power sources to provide the energy for extraction and supply.

We put a range of scenarios together from this perspective, and then we pitched the strategy that we felt was a good blend.

McKinsey: On that point, how should we go about decarbonizing the oil and gas industry while maintaining the reliability of the supply needed?

Robin Watson: We can now use digital solutions in a way that gives us a more accurate interpretation of what is happening in real time, and I think that's an important step forward.

We're looking to make the configuration as efficient and effective as possible, with as low a carbon footprint as possible, and technology is part of the solution. We're excited by what carbon capture can do in terms of sustaining a secure energy supply while reducing the impact to the environment. We've been involved in many carbon-capture-and-storage studies over the past 30 years. It's only a matter of time before it becomes a big part of the energy transition story.

Finally, we need to accelerate the focus on integrating renewable electricity from sources such as wind and solar, and ensuring a certain level of reliability, perhaps supplemented by fossil fuels, rather than fossil fuels being supplemented by renewable sources.

McKinsey: When you look at the opportunities presented by deploying these new technologies, what do you see as the bright spots for the future?

Robin Watson: There are a number of bright spots in terms of our work on projects for established energy companies. For example, we are working on an industry-leading project offshore in the North Sea where we put wind-generated electricity into an offshore installation. We've also done work on refineries in Europe where we used solar photovoltaic solutions to provide the primary supply of electricity.

One of the reasons we repositioned ourselves through the Amec Foster Wheeler acquisition was for the process-engineering capabilities it afforded us. Process engineers are some of the brightest, most well-equipped people on the planet to unlock carbon-capture-and-storage challenges, such as the technical considerations around making jet fuel from renewable resources. That's really exciting. You can have a jet flying with essentially no carbon footprint. Only 15 or 20 years ago, that would have been science fiction.

We need to invest the time and energy necessary to unlock these things from a consumption perspective, minimizing the impact to the environment. This will require either fiscal regime or capital allocation—probably both—as well as recognizing that everyone in society needs to contribute. I'm encouraged by some of the moves the big energy companies have taken, such as taking the proceeds from some of the conventional energy businesses and redeploying the capital into alternative carbon-capture solutions.

McKinsey: How do you see design solutions evolving for companies to meet their commitments around Scopes 1, 2, and 3, both on current operations and for new projects?

Robin Watson: It's making sure the current operations are energy efficient and that waste is minimized. It's looking at the embedded supply chain and asking yourself, "Can people work remotely? What logistics are needed to support an industrial cluster?"

These decisions should be made at the front end of a project. The things we do when we assess environmental impact go far beyond simply asking, "Where is the land? What is the access? How do we make sure it's far from the waterways?"

We use our technical knowledge to make things lighter, smaller, even unmanned. We can provide a microgrid to provide circular electrification, or we can use four smaller, electrically powered units rather than two larger gas-powered units. In chemicals, forming an industrial cluster, rather than just having a refinery, can provide the polymers and products needed to substitute carbon-intensive products such as steel and concrete.

McKinsey: What roles will automation, digital technologies, and artificial intelligence play in the energy transition, specifically in how they change the project space?

Robin Watson: In terms of engineering, we often question how we can use technology to be more efficient and more effective. The cloud allows us to distribute our engineering across the globe, which can provide insights from different sectors. For example, an insight from the automotive sector can be replicated in the process industry.

We've provided around 120 steam-methane reforming hydrogen units over the past 60 years, and we see a real pathway to carbon capture and storage of these units. It's only a matter of time before blue hydrogen is scalable from a technology perspective. That's a good example of using broader process-technology skills to make and move hydrogen differently. Shifting the infrastructure of natural gas onto blue hydrogen will enable us to deliver cleaner fuel to homes. From there, we can connect to multiple end markets, such as hydrogen fuel cells and buses and trucks.

Technology can also provide different technical solutions. If someone is looking for a steam-methane reformer unit, for instance, we can suggest going with carbon-capture technology instead. It might be useful to capture the carbon in one site but difficult to store it because of the physical location.

McKinsey: Building on this, how have customer needs evolved over the past three to five years?

Robin Watson: In the past ten years, probably 60 percent of our business has been dictated by fewer than a dozen customers. Ninety percent of what we did was upstream oil and gas. Now, with the repositioning of the business, our top 20 customers account for less than 40 percent of our revenue base. Today, our customers are focused on optimizing the performance of their existing assets, which has developed into optimizing the sustainable performance of existing assets.

We're probably doing more on onshore solar in the United States than most of the large energy companies because there are more utilities than developers. But we see energy companies coming into that space. We've taken some of our international oil company customers into that market because we've got good knowledge. We know the whys and wherefores of successfully completing these projects.

McKinsey: Finally, what do you think Wood will look like in 2030?

Robin Watson: We're going to be working heavily across all aspects of the energy transition. Augmented and virtual reality already let us take clients to the seabed if they're putting in a new subsea system, or piling a wind turbine, or if they want a floating facility for offshore wind.

Environmental, social, and governance goals, worker welfare, and workers' rights are things we're also very proud of at Wood. We've got a million workers in the world who are much better protected through our Building Responsibly program. In addition, we're actively working on inclusivity in terms of not just gender but also representation of different nationalities across our senior management team. Ultimately, I hope to better reflect the 60 countries we operate in.

Robin Watson is chief executive of Wood.

Staying connected: The investment challenge for electric grids

Responding to the short- and long-term needs of electric grids requires integrated and coordinated investment. Yet determining where and how much to invest is complicated by evolving market conditions.

David González

Senior partner, Madrid
McKinsey & Company

Diego Hernandez Diaz

Solution associate partner,
Power Solutions, Geneva
McKinsey & Company

Today, electric grids the world over are impacted by events and trends primarily linked with the move away from fossil fuels. On closer look, the effects of the energy transition typically fit into one of three major scopes: decentralization and decarbonization, long-term resilience, and evolving consumer behaviors.

Further complicating matters, electric grids are largely under cost and margin pressure and suffer from both an aging workforce and aging infrastructure. On this last point, our research shows grid operators working with asset infrastructures that go well beyond the projected life span of 30 to 40 years, and as much as five lifetimes in some extreme cases.

In this context, grid operators, owners, and other players in the broader energy ecosystem must determine where and how much to invest to prepare for the years to come.

The challenges of a changing electric grid

Preparing electric grids to respond to today's challenges requires nuanced approaches. Operators and owners will need to consider the effects of three major scopes.

Flexibility in the face of decarbonization and decentralization

As emissions-reduction targets become increasingly ambitious on the back of landmark initiatives such as the Paris Agreement and the EU Green Deal, fossil fuels will continue to play a major role in the energy system through 2050, with oil demand likely peaking in 2029 and gas in 2037.[1] That said, it is up to individual grid operators to manage the renewable-energy supply profile versus the fossil-fuel load profile.

The call for decarbonization has also driven the rise of new downstream elements such as lithium-ion batteries and electric vehicles, among others. While in principle these elements all serve the greater purpose of decarbonization, they also affect both overall demand- and peak-load profiles, further exacerbating the need for operators to provide flexibility. The demands on tomorrow's grid will shift as more people plug into the system.

Similarly, there has been a shift toward the decentralization of the power system, which refers to the practice of generating energy off-grid and in proximity to where it is distributed, increasing the penetration of energy sources such as rooftop solar rather than more traditional power plants. As the number of nontraditional players increases, including individual consumers who install rooftop solar panels, so does demand for new services. Thus, some grid operators are changing from the traditional unidirectional power flow to an alternating bidirectional power flow.

Long-term grid resilience

Because of the gradual rise in temperature due to climate change, there has been an increase in the severity and frequency of extreme, or longtail, weather events. In response, regulators have prioritized the future stability of the power supply.

Several recent events have made grid operators increasingly likely to consider mitigation of the risks of climate change when planning their overall investments. Notable examples include Hurricane Harvey in 2017, which took out ten gigawatts of power-generating capacity and several hundred power lines.[2] One year later, the Vaia windstorm in Italy caused more than €2.8 billion in losses. And most recently, the cold-weather power crisis in Texas highlighted the negative implications associated with not fully considering the destructive potential of extreme weather events.[3]

Evolving consumer behaviors

As the energy transition unfolds, the paradigm is shifting. The average consumer's behavior regarding energy consumption has also started to change. Some traditional users of electricity are

[1] For more, see "Global Energy Perspective 2021," January 2021, McKinsey.com.
[2] Tyler Hodge and April Lee, "Hurricane Harvey caused electric system outages and affected wind generation in Texas," US Energy Information Administration, September 13, 2017, eia.gov.
[3] For more on the electric-grid failure in Texas, see *The Power & Gas Blog*, "The Texas power crisis: Shining a light on the generation outages," blog entry by Adam Barth, Jesse Noffsinger, and Humayun Tai, March 11, 2021, McKinsey.com.

becoming so-called prosumers who produce, store, and sometimes sell back their own energy. This trend toward prosumerism implies challenges to the electric grid, especially when prosumers can and want to react to and influence the market.

As consumers increasingly expect reports around consumption with a focus on efficiency, many owners and operators are increasingly focused on quality of service, extending beyond the expectations of the service itself to include value-added services. Our conversations with operators and regulators around the globe reveal an increased focus on average outage duration for consumers, as determined by the System Average Interruption Duration Index (SAIDI), as well as a push to understand the drivers of any differences in reliability. Here, it's worth noting that SAIDI numbers range from one to four digits, which at the very least suggests an opportunity to improve quality of service to consumers.

In the face of all these changes, grid operators will continue to be held accountable for the quality of service.

Determining where and how much to invest

Responding to both short- and long-term electric-grid challenges requires integrated and coordinated investment and execution programs. However, identifying the right level of investment and where to allocate funds remains a problem that individual operators need to tackle, as determined by evolving market conditions.

Generally speaking, investments will fall into one of four key categories:

— expanding the grid's capabilities to handle the increased need for supply- and demand-side flexibility

— renewing and improving the grid's overall quality and resilience

— expanding operators' abilities to respond to down-market needs by leveraging the extensions of the system (the new downstream)

— upskilling operators' capabilities and teams (although this may be outside the scope of a major capital-investment plan)

Power-sector revenues are often dedicated first to covering the needs of existing grids, while investments in operations and reliability are often driven by changing regulations. The bulk of capital-expenditure investments, however, are made with the revenues from services provided. As an example, Europe is essentially leading the way in responding to the needs of electric grids, and the projected revenue pool in Europe could reach more than €150 billion by 2025. This offers some perspective on the potential capital expenditures for grid operators in other regions, which will likely follow similar patterns.

Coping with this increased volume and implied acceleration presents further challenges, many of which can be addressed through mechanisms such as the rise of energy-service companies, a proliferation of specialized start-ups, or even M&A—all aiming to assist grids with financing, solutions, or products.

The respective needs of grids, as well as their investment capacities, have seen the rise of energy-services companies with offerings for both B2B and B2C segments. This market is expected to grow by a CAGR of 10 to 20 percent over the next ten years, and the growth will likely be driven by four key factors, which mainly address the need for decarbonization and decentralization:

— *Disaster resilience:* Rising concerns about energy resilience are expected to increase the number of microgrids, requiring services for asset development, management, and maintenance.

— *Need for backup power:* Critical services, such as hospitals, and companies are willing to pay for extra capacity.

— *Ability to handle complex loads:* Changing energy mixes can sometimes require complex loads, often because of variable generation through renewables.

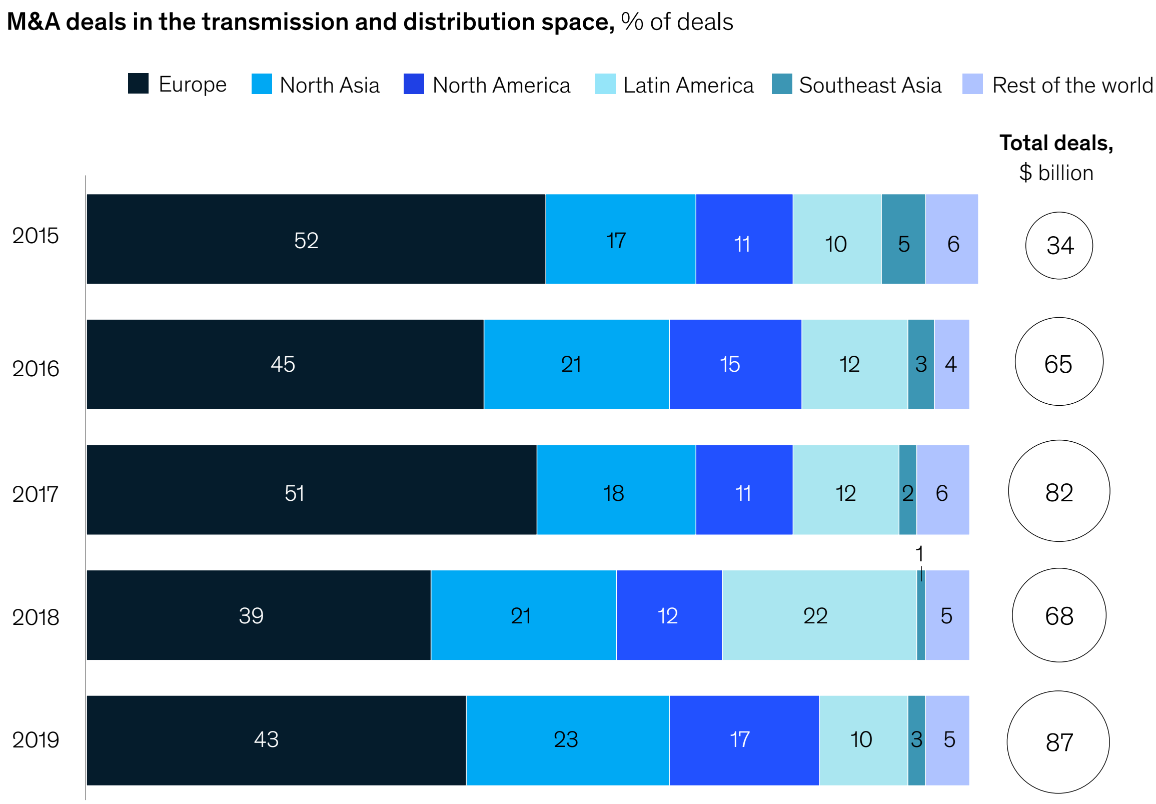
— *Adaptable offerings:* Energy services can easily be customized to a consumer's energy demands, allowing the addressable market to include both large corporations and smaller companies.

Further, a thriving world of start-ups is aiming to target the energy ecosystem, especially in related sectors and technologies, while challenging conventional utility business models. Thinner boundaries in the new downstream sector have enabled these new market entrants to develop and deliver out-of-the-box energy-transition innovations, such as virtual power plants, potentially disrupting industries.

Finally, it is worth highlighting that M&A activity has been taking place in the transmission and distribution space, as financial and infrastructure funds, as well as private-equity investors, have identified the energy transition as a time of opportunity (exhibit). External investors have formulated different strategies (from minority stakes

Exhibit

As energy continues its transition, the total value of M&A deals in transmission and distribution has nearly tripled since 2015.



Note: Figures may not sum to 100%, because of rounding.
Source: Dealogic.com

to full control) and are aided by their strong capital backing: the average investment increased fourfold from $0.4 billion in 2010 to $1.6 billion in 2020.[4]

In a diverse landscape with a variety of customer demands and consumption trends, the solutions to the challenges facing the electric grids of the future will also vary widely. This is the result of not only existing, quantified value propositions but also evolving energy policies and regulations and increased spending on R&D. Grid operators and regulators must clearly define their priorities and plan capital expenditures to align with these priorities.

David González is a senior partner in McKinsey's Madrid office, and **Diego Hernandez Diaz** is an associate partner of McKinsey's Power Solutions in the Geneva office.

[4] Based on analysis from dealogic.com.

McKinsey & Company || Capital Excellence

The world's largest organizations turn to McKinsey & Company to make radical change when it matters most. From more than 130 locations in 65 countries, McKinsey's Capital Excellence Practice, together with our global network of industry and sector experts, helps companies deploy best-in-class thinking across the capital-projects portfolio and project-delivery value chain.

Partnering with organizations and their leaders, we challenge traditional approaches to productivity improvement and environmental sustainability in capital projects, transforming capital strategy, project planning, and delivery practices throughout the project lifecycle. Our integrated approach brings together functional and sector specialists who can be on the ground where and when organizations need them, guiding capital projects for public- and private-sector entities in sectors including real-estate and infrastructure development, transport and logistics, metals and mining, energy and materials, aerospace and defense, and advanced manufacturing.

Working as part of McKinsey's wider Operations Practice, Capital Excellence connects boardroom strategies to the front line, infuses technology where and when it matters, and delivers lasting transformations enabled by capability building—fast. This combination allows capital owners, investors, and project organizations to optimize productivity and deliver new value.

Over the past five years, we have delivered impact in more than 3,000 engagements, including work on 150 megaprojects collectively valued at more than $1 trillion. Our unique ability to partner with enterprises and drive fundamental change is rooted in our independent perspective, alignment with organizations' goals, a deep commitment to innovation and impact, and the depth and breadth of our expertise and experience.

mckinsey.com/industries/capital-projects-and-infrastructure/how-we-help-clients

Global Infrastructure Initiative

Since 2012, McKinsey & Company's Global Infrastructure Initiative (GII) has convened many of the world's most senior leaders in infrastructure and capital projects to identify ways to improve the delivery of new infrastructure and to get more out of existing assets. Our approach has been to stimulate change by building a community of global leaders who can exchange ideas and find practical solutions to improve how we plan, finance, build, and operate infrastructure and large capital projects.

GII consists of a global summit, regional roundtables, innovation site visits, and the Voices on Infrastructure digital publication. The seventh GII Summit took place virtually in Montréal, April 6–8, 2021.

globalinfrastructureinitiative.com

GLOBAL INFRASTRUCTURE INITIATIVE

By McKinsey & Company