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Climate

Shared risk. Shared response.

+ Climate's hidden connections to pandemics

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This Quarter

These are trying times. At the time of writing, the specter of coronavirus is everywhere, and the world is reeling under the pandemic's staggering human and economic costs. Such is the degree of focus, collaboration, and sustained global effort required to address COVID-19 that other challenges seem remote.

Nothing has changed, though, about the urgency of another looming, global challenge—namely, climate change. Indeed, as the authors of "Addressing climate change in a post-pandemic world" note, the question isn't whether we can afford to pay attention to climate change right now, but whether we can afford not to. A valuable prize, of accelerated economic recovery from the pandemic and greater longer-term economic and environmental resilience, is attainable—if we are successful at integrating climate action with our efforts to plan for the recovery ahead, and at applying lessons from this new fight against the virus.

But are we as familiar with climate change as we think? To better understand the challenge, the authors of "Confronting climate risk" catalog an array of physical, economic, and social risks we could face over the next three decades—from lethal heat waves in India to flooding in coastal cities such as Bristol, England, and Vietnam's Ho Chi Minh City—framing the challenges ahead in terms of risk management. The research, part of a landmark study from the McKinsey Global Institute, makes clear that some adverse effects of climate change are now "locked in" over the next decade, and, while companies should assess and plan for them, the management task will be adaptation and resilience, not avoidance.

Other detrimental effects of climate change, meanwhile, could be mitigated—if we act quickly. In "Climate math: What a 1.5-degree pathway would take," the authors present a sweeping, first-of-its-kind analysis of what would be required in each sector of the global economy to limit warming to the 1.5 degrees Celsius that scientists estimate would prevent climate change's most dangerous, irreversible effects. The upshot? It is still possible, but time is short, and the math is daunting.

The findings raise a host of provocative questions for business leaders, some of whom are already grappling with them. BlackRock CEO Larry Fink, for example, suggests in an accompanying interview that climate risk may lead to a significant, and perhaps rapid, reallocation of capital. Further lessons can be gleaned from the CEO stories collected by University of Pittsburgh professor CB Bhattacharya, whose work highlights the importance of collective action in pursuit of sustainability.

Three special packages in this issue highlight the challenges and opportunities of climate change as they appear at the coalface of business (figuratively and literally). Taken together, they portray a series of important shifts that would help the world decarbonize sustainably. The first, “Feeding the world sustainably,” explores ways that green technologies, biotech advances, and artificial intelligence could curb emissions and safeguard ocean resources. “Reimagining industrial operations” looks at the role of innovation, analytics, electrification, and process efficiencies across oil and gas, mining (yes, including coal), cement, consumer goods, and apparel. And “Powering up sustainable energy” explores the decarbonization potential for utilities and battery makers to keep the lights on, sustainably, while an interview with Sunrun CEO Lynn Jurich lays out that company’s aspiration to make residential solar power a viable contributor to a decarbonized grid.

Finally, we close the issue with a look at corporate purpose. If crises like climate change and COVID-19 have taught us anything, it’s to remember to look beyond the short term and see what truly matters. This holds for leaders as well as institutions, as they increasingly struggle with deceptively simple, hard-to-answer questions such as, “What is our company’s reason for being?” And, “How can we have a unique, positive impact on the world?” The authors’ answer, an emerging playbook for corporate leaders, represents a string of first, hopeful steps in what will surely prove a long but worthwhile trip. Let’s take it together.

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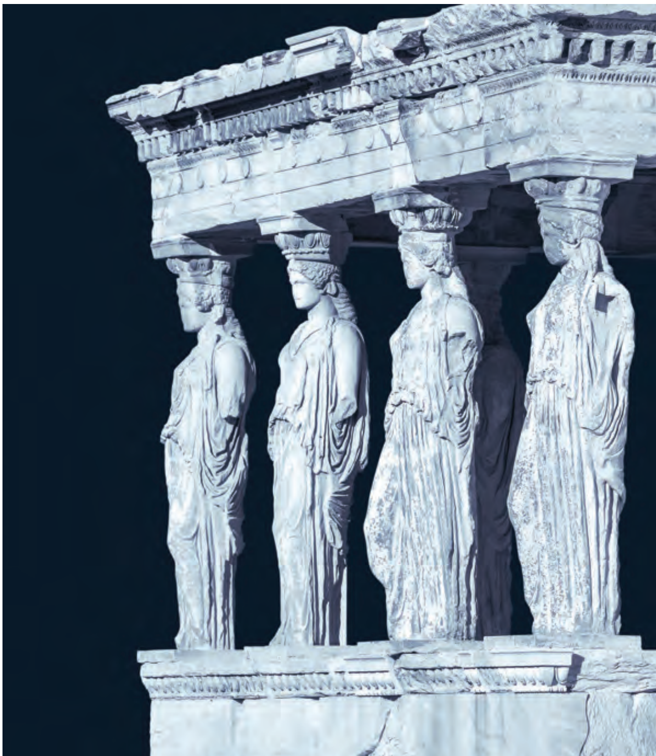
The climate challenge

The top-management response

Feeding the world sustainably

Reimagining industrial operations

Powering up sustainable energy



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The climate challenge

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Confronting climate risk

The changing climate is poised to create a wide array of economic, business, and social risks over the next three decades. Leaders should start integrating climate risk into their decision making now.

After more than 10,000 years of relative stability—the full span of human civilization—the Earth's climate is changing. Since the 1880s, the average global temperature has risen by about 1.1 degrees Celsius, driving substantial physical impact in regions around the world. As average temperatures rise, acute hazards such as heat waves and floods grow in frequency and severity, and chronic hazards such as drought and rising sea levels intensify. These physical risks from climate change will translate into increased socioeconomic risk, presenting policy makers and business leaders with a range of questions that may challenge existing assumptions about supply-chain resilience, risk models, and more.

To help inform decision makers around the world so that they can better assess, adapt to, and mitigate the physical risks of climate change, the McKinsey Global Institute (MGI) recently released a report, *Climate risk and response: Physical hazards and socioeconomic impact*. (For more on the methodology behind the report, see sidebar, "About the research.") Its focus is on understanding the nature and extent of physical risk from a changing climate over the next three decades, absent possible adaptation measures.

This article provides an overview of the report. We explain why a certain level of global warming is locked

About the research

This article is based on the McKinsey Global Institute (MGI) report *Climate risk and response: Physical hazards and socioeconomic impacts*.[1] Its authors are **Jonathan Woetzel** (a director of MGI and a senior partner in McKinsey's Shanghai office), **Dickon Pinner** (senior partner in the San Francisco office), **Hamid Samandari** (senior partner in the New York office), **Hauke Engel** (partner in the Frankfurt office), **Mekala Krishnan** (senior fellow at MGI), **Brodie Boland** (associate partner in the Washington, DC, office), and **Carter Powis** (consultant in the Toronto office).

The 131-page MGI report, released in January 2020, measures the impact of climate change based on the extent to which it could affect human beings, human-made physical assets, and the natural world. Most of the climatological analysis performed for the report was completed by the Woods Hole Research Center. There are a range of estimates for the pace of global warming; we have chosen the Representative Concentration Pathway (RCP) 8.5 scenario because it enables us to assess physical risk in the absence of further decarbonization. Action to reduce emissions could delay projected outcomes. Download the full report on McKinsey.com.

[1] See "Climate risk and response: Physical hazards and socioeconomic impacts," McKinsey Global Institute, January 2020, McKinsey.com.

in and illustrate the kinds of physical changes that we can expect as a result. We examine closely four of the report's nine case studies, showing how physical change might create significant socioeconomic risk at a local level. Finally, we look at some of the choices most business leaders will have to confront sooner than later.

Our hope is that this work helps leaders assess the risk and manage it appropriately for their company. The socioeconomic effects of a changing climate will be large and often unpredictable. Governments, businesses, and other organizations will have to address the crisis in different and often collaborative ways. This shared crisis demands a shared response. Leaders and their organizations will have to try to mitigate the effects of climate change even as they adapt to the new reality it imposes on our physical world. To do so, leaders must understand the new climate reality and its potential impact on their organizations in different locales around the world.

The new climate reality

Some climate change is locked in.

The primary driver of temperature increase over the past two centuries is the human-caused rise in atmospheric levels of carbon dioxide (CO_2) and other greenhouse gases, including methane and nitrous oxide. Since the beginning of the Industrial Revolution in the mid-18th century, humans have released nearly 2.5 trillion metric tons of CO_2 into the atmosphere, raising atmospheric CO_2 concentrations by 67 percent. Carbon dioxide lingers in the atmosphere for hundreds of years. As a result, nearly all of the warming that occurs is permanent, barring large-scale human action to remove CO_2 from the atmosphere. Furthermore, the planet will continue to warm until we reach net-zero emissions.

If we don't make significant changes, scientists predict that the global average temperature may increase by 2.3 degrees Celsius by 2050, relative to the preindustrial average. Multiple lines of evidence suggest that this could trigger physical feedback loops (such as the thawing of permafrost leading to the release of significant amounts of methane) that might cause the planet to warm for hundreds or thousands of years. Restricting warming to below 1.5 or 2.0 degrees would reduce the risk of the earth entering such a "hothouse" state.

The nature of climate-change risk

Stakeholders can address the risk posed by climate change only if they understand it clearly and see the nuances that make it so complicated to confront. We find that physical climate risk has seven characteristics:

- *Increasing.* Physical climate risks are generally increasing across the globe, even though some countries may find some benefits (such as increased agricultural yields in Canada, Russia, and parts of northern Europe). The increased physical risk would also increase socioeconomic risk.

- *Spatial.* Climate hazards manifest locally. There are significant variations between countries and even within countries. The direct effects of physical climate risk must be understood in the context of a geographically defined area.

- *Nonstationary.* For centuries, financial markets, companies, governments, and individuals have made decisions against the backdrop of a stable climate. But the coming physical climate risk is ever-changing and nonstationary. Replacing a stable environment with one of constant change means that decision making based on experience may prove unreliable. For example, long-accepted engineering parameters for infrastructure design may need to be rethought; homeowners and banks may need to adjust assumptions about long-term mortgages.

- *Nonlinear.* Physiological, human-made, and ecological systems have evolved or been optimized over time to withstand certain thresholds. Those thresholds are now being threatened. If or when they are breached, the impact won't be incremental—the systems may falter, break down, or stop working altogether. Buildings designed to withstand floods of a certain depth won't withstand floods of greater depths; crops grown for a mild climate will wither at higher temperatures. Some adaptation can be carried out fairly quickly (for example, better preparing a factory for a flood). But natural systems such as crops may not be able to keep pace with the current rate of temperature increase. The challenge becomes even greater when multiple risk factors are present in a single region.

- *Systemic.* Climate change can have knock-on effects across regions and sectors, through interconnected socioeconomic and financial systems. For example, flooding in Florida might not only damage housing but also raise insurance costs, lower property values, and reduce property-tax revenues. Supply chains are particularly vulnerable systems, since they prize efficiency over resilience. They might quickly grind to a halt if critical production hubs are affected by intensifying hazards.

- *Regressive.* The poorest communities and populations of the world are the most vulnerable. Emerging economies face the biggest increase in potential impact on workability and livability. The poorest countries often rely on outdoor work and natural capital, and they lack the financial means to adapt quickly.

- *Unprepared.* Our society hasn't confronted a threat like climate change, and we are unprepared. While companies and communities are already adapting, the pace and scale of adaptation must accelerate. This acceleration may well entail rising costs and tough choices, as well as coordinated action across multiple stakeholders.

How climate risk plays out on a local level

There is already plenty of evidence of the extensive damage that climate risk can inflict. Since 2000, there have been at least 13 climate events that have resulted in significant negative socioeconomic impact, as measured by the extent to which it disrupted or destroyed "stocks" of capital—people, physical, and natural. The events include lethal heat waves, drought, hurricanes, fires, flooding, and depletion of water supply.

More frequent and more intense climate hazards will have large consequences. They are likely to threaten systems that form the backbone of human productivity by breaching historical thresholds for resilience. Climate hazards can undermine livability and workability, food systems, physical assets, infrastructure services, and natural capital. Some events strike at multiple systems at once. For example, extreme heat can curtail outdoor work, shift food systems, disrupt infrastructure services, and endanger natural capital such as glaciers. Extreme precipitation and flooding can destroy physical assets and infrastructure while endangering coastal and river communities. Hurricanes can damage global supply chains, and biome shifts can affect ecosystem services.

The best way to see how this will play out is to look at specific cases. MGI looked at nine distinct cases of physical climate risk in a range of geographies and sectors. Each considers the direct impact and knock-on effects of a specific climate hazard in a specific location, as well as adaptation costs and strategies that might avert the worst outcomes. Let's look at four of those cases (see also following spread, "Global problem, local impact").

Will it get too hot to work in India?

The human body provides one example of the nonlinear effect of breaching physical thresholds. The body must maintain a relatively stable core temperature of approximately 37 degrees Celsius to function properly. An increase of just 0.9 of a degree compromises neuromuscular coordination; 3 degrees can induce heatstroke; and 5 degrees can cause death. In India, rising heat and humidity could lead to more frequent breaches of these thresholds, making outdoor work far more challenging and threatening the lives of millions of people.

As of 2017, some 380 million of India's heat-exposed outdoor workers (75 percent of the labor force) produced about 50 percent of the country's GDP. By 2030, 160 million to 200 million people could live in urban areas with a nonzero probability of such heat waves occurring. By 2050, the number could rise to between 310 million and 480 million.

The average person living in these regions has a roughly 40 percent chance of experiencing a lethal heat wave in the decade centered on 2030. In the decade centered on 2050, that probability could rise to roughly 80 percent.

India's productivity could suffer. Outdoor workers will need to take breaks to avoid heatstroke. Their bodies will protectively fatigue, in a so-called self-limiting process, to avoid overheating. By 2030, diminished labor productivity could reduce GDP by between 2.5 and 4.5 percent.

India does have ways to adapt. Increased access to air-conditioning, early-warning systems, and cooling shelters can help combat deadly heat. Working hours for outdoor personnel could be shifted, and cities could implement heat-management efforts. At the extreme, coordinated movement of people and capital from high-risk areas could be organized. These would be costly shifts, of course. Adaptation to climate change will be truly challenging if it changes how people conduct their daily lives or requires them to move to areas that are less at risk.

Will mortgages and markets stay afloat in Florida?

Florida's expansive coastline, low elevation, and porous limestone foundation make it vulnerable to flooding. The changing climate is likely to bring more severe storm surge from hurricanes and more tidal flooding. Rising sea levels could push salt water into the freshwater supply, damaging water-management systems. A once-in-100-years hurricane (that is, a hurricane of 1 percent likelihood per year) would damage about $35 billion in real estate today. By 2050, the damage from such an event could be $50 billion—but that's just the beginning. The accompanying financial effects may be even greater.

Real estate is both a physical and a financial store of value for most economies. Damage, and the expectation of future damage, to homes and infrastructure could drive down the prices of exposed homes. The devaluation could be even more significant if climate hazards also affect public-infrastructure assets such as water, sewage, and transportation systems, or if homeowners increasingly factor climate risk into buying decisions.

Lower real-estate prices could have significant knock-on effects in a state whose assets, people, and economic activity are largely concentrated in coastal areas. Property-tax revenue in affected counties could drop 15 to 30 percent, which could lower municipal-bond ratings and the spending power of local governments. Among other things, that would make it harder for cities and towns to invest in the infrastructure they need to combat climate change.

The impact on insurance and mortgage financing in high-risk areas could also be significant. There's a duration mismatch between mortgages, which can be 30 years long, and insurance, which is repriced every year. This mismatch means that current risk signals from insurance premiums might not build in the expected risk over an asset's lifetime, which could lead to insufficiently informed decisions. However, if insurance premiums do rise to account for future climate-change risk, lending activity for new homes could slow, and the wealth of existing homeowners could diminish.

Global problem, local impact

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Will it get too hot to work in India?

Increasing risk: in India, the probability of anyone experiencing a lethal heat wave is effectively 0 today, but by 2030, 160 million to 200 million people could be at risk

Degree of exposure: as of 2017, heat-exposed work in India produced ~50% of GDP, drove ~30% of GDP growth, and employed ~75% of the labor force

Effect on labor productivity: by 2050, some parts of India may be under such intense heat and humidity duress that working outside would be unsafe for ~30% of annual daylight hours

Adaptation: adaptation measures for India could include providing early-warning systems, building cooling shelters, shifting work hours for outdoor laborers, and accelerating the shift to service-sector employment

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Will mortgages and markets stay afloat in Florida?

Increasing risk: rising sea levels, increased tidal flooding, and more severe storm surges from hurricanes are likely to threaten Florida's vulnerable coastline

Physical damage to real estate: in 2050, a once-in-100-years hurricane might cause $75 billion worth of damage to Florida real estate, up from $35 billion today

Knock-on effects: in Florida, prices of exposed homes could drop, mortgage rates could rise, more homeowners may strategically choose to default, and property-tax revenue could drop 15–30% in directly affected countries

Adaptation: adaptation measures in Florida could include improving the resilience of existing structures, installing new green infrastructure, and building seawalls

Case studies based on the Representative Concentration Pathway (RCP) 8.5 scenario

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Can supply chains weather climate change?

Increasing risk: a once-in-100-years hurricane in the western Pacific, which will be 4x more likely by 2040, could shut down the semiconductor supply chain

Potential damage: supply chains are optimized for efficiency, not resilience, so production could halt for months; unprepared downstream players could see revenue dip 35% in 1 year

Upstream mitigation: protecting semi-conductor plants against hazards could add 2% to building costs

Downstream mitigation: increasing inventory to provide a meaningful buffer could be cost-effective

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Can coastal cities turn the tide on rising flood risk?

Increasing risk: increased flooding and severe storm surges threaten to cause physical damage to coastal cities, while knock-on effects would hamper economic activity even more

Infrastructure threats: ports, low-lying train stations, and underground metros could be at risk, as could factories close to the coast

Total damage: in Bristol, England, a once-in-200-years flood in 2065 could cause ≤$3 billion in damage; in Ho Chi Minh City, Vietnam, a once-in-100-years flood in 2050 could wreak ~$10 billion in damage

Adaptation: it would take up to $500 million for Bristol to protect itself now from that scenario; Ho Chi Minh City might need seawalls, which could be very costly

When home values fall steeply with little prospect of recovery, even homeowners who are not financially distressed may choose to strategically default. One comparison point is Texas: during the first months after Hurricane Harvey hit Houston, in 2017, the mortgage-delinquency rate almost doubled, from about 7 to 14 percent. Now, as mortgage lenders start to recognize these risks, they could raise lending rates for risky properties. In some cases, they might even stop providing 30-year mortgages.

To adapt, Florida will have to make hard choices. For example, the state could increase hurricane and flooding protection, or it could curtail—and perhaps even abandon—development in risk-prone areas. The Center for Climate Integrity estimates that 9,200 miles of seawalls would be necessary to protect Florida by 2040, at a cost of $76 billion. Other strategies, such as improving the resilience of existing infrastructure and installing new green infrastructure, come with their own hefty price tags.

Can supply chains weather climate change?

Supply chains are typically optimized for efficiency over resilience, which may make them vulnerable to extreme climate hazards. Any interruption of global supply chains can create serious ancillary effects. Let's focus on two such supply chains: semiconductors, a specialty supply chain, and heavy rare earths, a commodity.

The risk to each is slightly different. Key parts of semiconductor supply chains are located in the Western Pacific, where the probability of a once-in-100-years hurricane occurring in any given year might double or even quadruple by 2040. Such hurricanes could potentially lead to months of lost production for the directly affected companies. Unprepared downstream players—for example, chipmakers without buffer inventories, insurance, or the ability to find alternative suppliers—could see revenue in a disaster year drop by as much as 35 percent.

Mining heavy rare earths in southeastern China could be challenged by the increasing likelihood of extreme rainfall. The probability of downpours so severe that they could trigger mine and road closures is projected to rise from about 2.5 percent per year today to about 4.0 percent per year in 2030 and 6.0 percent in 2050. Given the commoditized nature of this supply chain, the resulting production slowdowns could result in increased prices for all downstream players.

Mitigation is relatively straightforward for both upstream and downstream players. Securing semiconductor plants in southeast Asia against hazards, for example, might add a mere 2 percent to building costs. Downstream players in both the rare-earth and semiconductor pipelines could mitigate impacts by holding higher inventory levels and by sourcing from different suppliers across multiple regions. This can be done efficiently. For buyers of semiconductors, for example, raising inventory to provide a meaningful buffer could be cost effective, with estimated costs for warehousing and working capital increasing input costs by less than 1 percent. Nonetheless, the price of climate prudence will almost always be some decrease in production efficiency—for example, by creating limitations on lean or just-in-time inventory.

For centuries, we have made decisions based on a world of relative climate stability—we are not accustomed to planning for a world with changing climate.

Can coastal cities turn the tide on rising flood risk?
Many coastal cities are economic centers that have already confronted flood risk. But the potential direct and knock-on effects of flooding are likely to surge dangerously.

Bristol is a port city in the west of England that has not experienced major flooding for decades. But without major investment in adaptation, extreme flood risk there could grow from a problem potentially costing millions of dollars today to a crisis costing billions by 2065. During very high tides, the Avon River becomes “tide locked” and limits land drainage in the lower reaches of the river-catchment area. As a result, Bristol is vulnerable to combined tidal and pluvial floods, which are sensitive to both sea-level rise and precipitation increase. The likelihood of both are expected to climb with climate change.

While Bristol is generally hilly and most of the urban area is far from the river, the most economically valuable areas of the city center and port regions are on comparatively low-lying land. More than 200 hectares (494 acres) of automotive storage near the port (often harboring up to 600,000 vehicles) could be vulnerable to even low levels of floodwater, and the main train station could become inaccessible. Bristol has flood defenses that would prevent the vast majority of damage from an extreme flood event today. By 2065, however, more extreme floods could overwhelm the defenses, in which case water would reach infrastructure that was previously safe.

We estimate that a 200-year flood today (that is, a flood of 0.5 percent likelihood per year) in Bristol would cause infrastructure-asset damage totaling between $10 million and $25 million. This may rise to $180 million to $390 million by 2065. The costs of knock-on effects would rise even more, from $20 million to $150 million today to as much as $2.8 billion by 2065, when an extreme flood might shut down businesses, destroy industrial stores, and halt transportation.

We estimate that protecting the city from this 2065 scenario would cost $250 million to $500 million today. However, the actual costs will largely depend on the specific adaptation approach.

Vietnam's Ho Chi Minh City is prone to monsoonal and storm-surge flooding. Today, the direct infrastructure-asset damage from a 100-year flood could be on the order of $200 million to $300 million, rising to $500 million to $1 billion in 2050. Here, too, the knock-on costs in disrupted economic activity are expected to be more substantial, rising from between $100 million and $400 million today to $2 billion to $8.5 billion in 2050.

Many new infrastructure assets in the city, particularly the local metro system, were designed to tolerate an increase in flooding. Yet the hazards to which these assets may be subjected could be greater than even the higher thresholds. In a worst-case scenario, of 180 centimeters of sea-level rise, these thresholds could be breached in many locations, and some assets might be damaged beyond repair.

Compared with Bristol, Ho Chi Minh City has many more adaptation options, as less than half of the city's major infrastructure needed for 2050 exists today. But adaptation may carry a hefty price tag. One potential comparison is Jakarta's major coastal-defense plans, which have a potential cost of roughly $40 billion. That is comparable to Ho Chi Minh City's current GDP.

An effective response

Local climate threats are increasing in most of the world. The changing environment is steadily altering the very nature of regions around the world. At the same time, the likelihood of "long tail" climate events that create cascading systemic risk is growing. Physical climate risk will affect everyone, directly or indirectly.

We think there are three steps that stakeholders could consider as they seek an effective response to the socioeconomic impacts of physical climate risk: integrating climate risk into decision making, accelerating the pace and scale of adaptation, and decarbonizing at scale to prevent a further buildup of risk.

Integrate climate risk into decision making

Climate change needs to become a major feature in corporate and public-sector decision making. As we have noted, physical climate risk is simultaneously spatial and systemic, nonstationary, and nonlinear in its effect. Potential impacts are regressive and rising over time, and stakeholders today may be underprepared to manage them. Decision making will need to reflect these characteristics.

For companies, this will mean taking climate considerations into account when looking at capital allocation, development of products or services, and supply-chain management, for example. Large capital projects would be evaluated in a way that reflects the increased probability of climate hazards at their location: How will that probability change over time? What are the possible changes in cost of capital for exposed assets? How will climate risk affect the broader market context and other implicit assumptions in the investment case? Cities will have to ask similar questions for urban-planning decisions. Moreover, while the MGI report focuses on physical risk, a comprehensive risk-management strategy will also need to include an assessment of transition and liability risk, as well as the interplay between these forms of risk.

Changes in mindset, operating model, and tools and processes will be needed to integrate climate risk into decision making. For centuries, we have made decisions based on a world of relative climate stability. We are not accustomed to planning for a world with a changing climate. For example, statistical risk management is often not part of ordinary processes in industrial companies. With the changing climate, it will be important to understand and embrace the probabilistic nature of climate risk and be mindful of possible biases and outdated mental models; experiences and heuristics of the past may no longer be a reliable guide to the future. The systemic nature of climate risk requires a holistic approach to understand and identify the full range of possible direct and indirect impacts.

One of the biggest challenges from climate risk will be rethinking the current models we use to quantify risk. These range from financial models used to make capital-allocation decisions to engineering models used to design structures. There is some uncertainty associated with a methodology that leverages global and regional climate models, makes underlying assumptions on emission paths, and seeks to translate climate hazards to potential physical and financial damage. But exploring new ways to quantify climate risk is not the highest "model risk." Continued reliance on current models based on stable historical climate and economic data may be even riskier.

Indeed, current models have at least three potential flaws. First, they lack geographic granularity, at a time when companies need to know how their key locations—and those of their suppliers—are exposed to different forms of climate threat. Second, they don't consider that the climate is constantly changing, a critical factor in determining such things as how resilient to make new factories, what tolerance levels to employ in new infrastructure, and how to design urban areas. And third, they are subject to potential sample bias, since decision makers are accustomed to trusting their own experience as they make decisions about the future.

Accelerate the pace and scale of adaptation

The pace and scale of adaptation will likely need to increase significantly. But adaptation is challenging. With hazard intensity projected to increase, the economics of adaptation could worsen over time. Technical limits may crop up. Difficult trade-offs may need to be assessed, including who and what to protect and who and what to relocate. Many instances may require coordinated action by multiple stakeholders.

Despite all that, many stakeholders will have to figure out ways to adapt. Key measures include protecting people and assets, building resilience, reducing exposure, and ensuring that appropriate insurance and financing are in place.

Protecting people and assets. In response to the record-breaking 2010 heat wave in India that killed 300 people in a single day, the Ahmedabad Municipal Corporation developed the country's first heat-action plan. Its measures included establishing a seven-day probabilistic heat-wave early-warning system, developing a citywide cool-roof program, and setting up teams to distribute cool water and rehydration pills to vulnerable populations during heat waves. Steps such as these are crucial for protecting people. Stakeholders must also be prepared to prioritize emergency response and preparedness, erect cooling shelters, and adjust working hours for outdoor workers who are exposed to heat.

Measures to make existing infrastructure and assets more resilient can help limit risk. Some of this would address “gray” infrastructure—for example, raising the elevation level of buildings in flood-prone areas—while other moves would protect “green” infrastructure. The Dutch program Room for the River, for example, gives rivers more room to manage higher water levels.

On the other hand, it will sometimes be more cost effective to erect new buildings than to retrofit old ones. Some $30 trillion to $50 trillion will be spent on infrastructure in the next ten years, much of it in developing countries. These infrastructure systems and factories could be designed to withstand the withering storms of the future, rather than what passes for a once-in-200-years event now.

Building resilience. Decisions about strengthening assets will need to go hand in hand with measures to drive operational resilience in systems. An important aspect of this is understanding the impact thresholds for systems and how and when they could be breached. Examples of resilience planning for a world of rising climate hazards include building global inventories to mitigate the risk of food or raw-material shortages, building inventory levels in supply chains to protect against interrupted production, establishing the means to source from alternate locations or suppliers, and securing backup power sources.

Reducing exposure. Adaptation strategies for many physical assets will have to reflect their full life cycle. For example, it may make sense not only to invest in addressing asset vulnerabilities for the next decade but also to shorten asset life cycles. In subsequent decades, as climate hazards intensify, the cost–benefit equation of physical resilience measures may no longer be attractive. At that point, it may become necessary to redesign asset footprints altogether by relocating employees and assets. We have already seen some examples of this, such as the buyout programs in Canada for residents in flood-prone areas. Quebec prohibits both the building of new homes and the rebuilding of damaged homes in its floodplain.

Decisions will need to be made about when to focus on protecting people and assets versus when to find ways to reduce their exposure to hazards, which regions and assets to spend on, how much to spend on adaptation, and what to do now as opposed to in the future. Companies need to develop a long-term perspective on how risk and adaptation costs will probably evolve, and they will need to integrate voices of affected communities into their decision making.

Rethinking insurance and finance. People are reluctant to carry insurance for unlikely events, even if they can cause significant damage. Today, only about 50 percent of losses are insured. That percentage is likely to decrease as the changing climate brings more—and more extreme—climate events. Without insurance, recovery after disaster becomes harder, and secondary effects become more probable. Underinsurance reduces resilience.

To adjust to constantly changing physical risk, insurers will have to reconsider current data and models, current levels of insurance premiums, and their own levels of capitalization. Indeed, the entire risk-transfer process (from insured to insurer to reinsurer to governments as insurers of last resort) may need examination, looking at whether each constituent is still able to fulfill its role. Without changes in risk reduction, risk transfer, and premium financing or subsidies, some risk classes in certain areas may become harder to insure, widening the insurance gap that already exists in some parts of the world. New questions will have to be asked, and innovative approaches will be needed.

Finance will also have to adjust if it is to play a significant role in funding adaptation measures, especially in developing countries. Public–private partnerships or participation by multilateral institutions is needed to prevent capital flight from risky areas. Innovative products and ventures have already been developed to broaden the reach and effectiveness of such measures. They include "wrapping" a municipal bond into a catastrophe bond, to allow investors to hold municipal debt without worrying about hard-to-assess climate risk.

Decarbonizing at scale

There is one critical part of addressing climate change that the MGI report does not examine: decarbonization. While adaptation is urgent, climate science tells us that further warming and risk increase can only be stopped by achieving net-zero greenhouse-gas emissions. In "Climate math: What a 1.5-degree pathway would take," on page 26, the authors take a closer look at decarbonization, which is a daunting challenge that leaders will need to address in parallel with adaptation during the years ahead.

To prepare for the climate of tomorrow, stakeholders will have to learn, mitigate, and adapt. Individuals, businesses, communities, and countries will need to recognize physical climate risk and integrate it into decision making. The next decade will be critical, as decision makers rethink the infrastructure, assets, and systems of the future, and the world collectively sets a path to manage the risk from climate change. Q

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Reckoning with the overlooked business risks of climate change

Experts from the Woods Hole Research Center discuss how companies are missing the scope of mounting physical risks from climate change.

How should organizations cope with climate change? As president and executive director of the Woods Hole Research Center, Dr. Philip Duffy has spent much of his career translating climate science for business leaders and policy makers and fostering awareness of how climate change affects society. His colleague, former investment manager Spencer Glendon, joined Woods Hole to explore the pressure that climate change places on the financial system. In these edited excerpts from two interviews, Duffy and Glendon discuss the unforeseen challenges our increasingly unstable climate creates for businesses and governments. "Folks don't grasp the immediacy, the scope, and the scale of physical climate risk," says Duffy.

What was unusual is now more normal

Spencer Glendon: What's happened with the changing climate is that what's usual is moving. The range of possible outcomes is extending. What was unusual before is now more normal. What was normal before happens less often. And what was unheard of happens some of the time. In statistical terms, the climate had a normal distribution that's now shifting and flattening.

In lay terms, it means that what was a nice day happens less often, and what was an uncomfortable day happens more often, and what was a truly bizarre day happens somewhat frequently when it almost never happened before. In the last five years in Houston, they've had a couple of one-in-500-year events and a couple of one-in-100-year events. They haven't had a period of time that didn't have an unusual event.

Philip Duffy: Even on time horizons of 20 or 30 years, which isn't very long, we see dramatic changes in risk. We see, for example, significant portions of the world becoming difficult to inhabit because of perpetual extreme heat and humidity and because of near-perpetual drought.

The whole region around the Mediterranean, in 20 or 30 years, could be headed toward near-perpetual drought. The Iberian Peninsula stands out as a hot spot. If you look at a map of Australia, the strips around the edge, which are the main parts of the continent that are inhabited, will also likely be in near-perpetual drought.

Planning horizons will shorten

Philip Duffy: Ten or 20 or 30 years may seem like long time horizons from a business perspective, but they're not. Most people alive today will still be alive ten or 20 or 30 years from now. There are financial instruments that have 30-year time horizons—municipal bonds, home mortgages.

Spencer Glendon: Having an unstable climate means that planning horizons shorten. And when planning horizons shorten, the financial markets will shorten as well. You extend 30-year credit only if you believe you know a lot about the next 30 years. What I find amazing is the people who say that "we don't know anything about the future" and then borrow for 30 years. Actually, they're making an enormous number of assumptions about stability.

What I think will happen is that credit of all kinds will shorten in duration—and duration is going to go away in the marketplace. Now, that probably means that existing forms of long-duration credit are mispriced in a way that will cause their rates to rise because they include so much uncertainty.

Assessing physical climate risk

Philip Duffy: At the Woods Hole Research Center, we've initiated some relationships with corporations, and we're showing them things that, from a scientific point of view, are quite rudimentary—maps of future risk, of different forms of extreme weather. Mainly, physical climate risk isn't on their radar screen. To the extent that folks are focused on climate risk, they're thinking of regulatory risk and transition risk. Those are issues, and they're closely tied to physical risk. But I think that folks don't grasp the immediacy and the scope and the scale of physical climate risk.

Spencer Glendon: I think a climate-risk assessment for a corporation is likely to be a very healthy exercise because it takes the business operations out of just the two-dimensional and out of just the finance department and into the practical, physical attributes of whatever the operation is.

Suppose you're running an internet business that seems totally virtual. Well, data servers are in a place, and electricity comes from a system. And, in many cases, those are outside of your control, and they have specific locational risk.

Watch out for 'temporal mismatches'

Spencer Glendon: Look for where you are insured in a way that's got a short time horizon. What assets do you have, or invest in, that someone else is bearing the risk for and that someone else has made no guarantee to you that they will bear it in perpetuity?

What I call temporal mismatches are when someone has made a commitment to 30 years for a mortgage, but it's conditional on getting insurance that's renewed annually. That 30-year mortgage is really a one-year mortgage that's renewed by the insurance company—not by the mortgage company and not by the homeowner. So, you have a third party that can end that contract.

Philip Duffy

is the president and executive director of the Woods Hole Research Center. Before joining the WHRC, Duffy served as a senior policy analyst in the White House Office of Science and Technology Policy and as a senior advisor in the White House National Science and Technology Council.

Spencer Glendon

is a senior fellow of the Woods Hole Research Center. Prior to joining WHRC, Glendon spent 18 years as a macroanalyst, partner, and director of investment research at Wellington Management.

The world is full of those kinds of contracts that I think people in executive positions should be aware of. They rarely are.

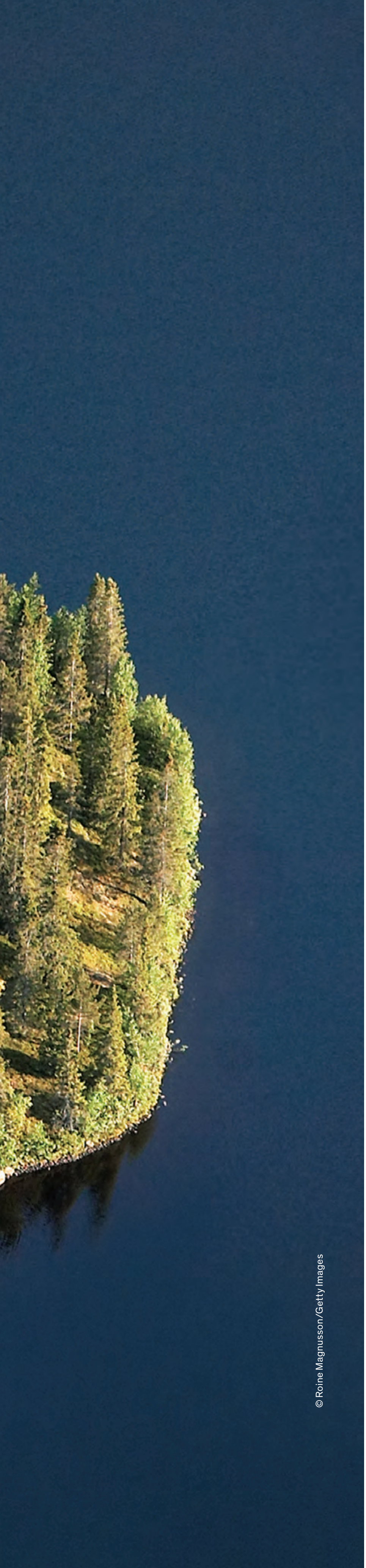
The public sector has an important role

Philip Duffy: We're looking at real estate in Florida. There's academic literature that shows differential price trends for at-risk real estate versus real estate that's not at risk. And where does that go? Those trends are going to increase. The differential is going to increase as the risk increases. That's going to affect insurability. It's going to affect the mortgage banking industry. It's obviously going to affect property values.

The public sector has an important role to play through things like building codes, which make insurance tractable by allowing insurance companies to price policies in ways that reflect the true risk. It can also do things like preventing people from rebuilding for the fifth time in a flood zone. There should be synergies between the public and private sectors in the management of risk. Q

The interviews with Philip Duffy and Spencer Glendon were conducted by **Tom Fleming** and **Simon London,** members of McKinsey Publishing based in McKinsey's Chicago and Silicon Valley offices, respectively.

Climate math: What a 1.5-degree pathway would take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Decarbonizing global business at scale is achievable, but the math is daunting.

by Kimberly Henderson, Matt Rogers, Bram Smeets, and Christer Tryggestad

Amid the coronavirus pandemic, everyone is rightly focused on protecting lives and livelihoods. Can we simultaneously strive to avoid the next crisis? The answer is yes—if we make greater environmental resilience core to our planning for the recovery ahead, by focusing on the economic and employment opportunities associated with investing in both climate-resilient infrastructure and the transition to a lower-carbon future.

Adapting to climate change is critical because, as a recent McKinsey Global Institute report shows, with further warming unavoidable over the next decade, the risk of physical hazards and nonlinear, socioeconomic jolts is rising.[1] *Mitigating* climate change through decarbonization represents the other half of the challenge. Scientists estimate that limiting warming to 1.5 degrees Celsius would reduce the odds of initiating the most dangerous and irreversible effects of climate change.

While a number of analytic perspectives explain how greenhouse-gas (GHG) emissions would need to evolve to achieve a 1.5-degree pathway, few paint a clear and comprehensive picture of the actions global business could take to get there. And little wonder: the range of variables and their complex interaction make any modeling difficult. As part of an ongoing research effort, we sought to cut through the complexity by examining, analytically, the degree of change that would be required in each sector of the global economy to reach a 1.5-degree pathway. What technically feasible carbon-mitigation opportunities—in what combinations and to what degree—could potentially get us there?

We also assessed, with the help of McKinsey experts in multiple industrial sectors, critical stress points—such as the pace of vehicle electrification and the speed

[1] See "Climate risk and response: Physical hazards and socioeconomic impacts," McKinsey Global Institute, January 2020, McKinsey.com.

with which the global power mix shifts to cleaner sources. We then built a set of scenarios intended to show the trade-offs: If one transition (such as the rise of renewables) lags, what compensating shifts (such as increased reforestation) would be necessary to get to a 1.5-degree pathway?

The good news is that a 1.5-degree pathway is technically achievable. The bad news is that the math is daunting. Such a pathway would require dramatic emissions reductions over the next ten years—starting now. This article seeks to translate the output of our analytic investigation into a set of discrete business and economic variables. Our intent is to clarify a series of prominent shifts—encompassing food and forestry, large-scale electrification, industrial adaptation, clean-power generation, and carbon management and markets—that would need to happen for the world to move rapidly onto a 1.5-degree pathway.

None of what follows is a forecast. Getting to 1.5 degrees would require significant economic incentives for companies to invest rapidly and at scale in decarbonization efforts. It also would require individuals to make changes in areas as fundamental as the food they eat and their modes of transport. A markedly different regulatory environment would likely be necessary to support the required capital formation. Our analysis, therefore, presents a picture of a world that could be, a clear-eyed reality check on how far we are from achieving it, and a road map to help business leaders and policy makers better understand, and navigate, the challenges and choices ahead.

Understanding the challenge

While it might seem intuitive, it's worth emphasizing at the outset: every part of the economy would need to decarbonize to achieve a 1.5-degree pathway. Should any source of emissions delay action, others would need to compensate through further GHG reductions to have any shot at meeting a 1.5-degree standard.

No easy answers

And the stark reality is that delay is quite possible. McKinsey's *Global Energy Perspective 2019: Reference Case*, for example, which depicts what the world energy system might look like through 2050 based on current trends, is among the most aggressive such outlooks on the potential for renewable energy and electric-vehicle (EV) adoption. Yet even as the report predicts a peak in global demand for oil in 2033 and substantial declines in CO_2 emissions, it notes that a "1.5-degree or even a 2-degree scenario remains far away" (Exhibit 1). Similarly, the McKinsey Center for Future Mobility (MCFM)—which foresees a dramatic inflection point for transportation[2]—does not envision EV penetration hitting the levels that our analysis finds would be needed by 2030 to achieve a 1.5-degree pathway. MCFM analysis also underscores a related challenge: the need to take a "well to wheel" perspective that accounts for not only the power source of the vehicles but also how sustainably that power is generated or produced.

Given such uncertainties and interdependencies, we created three potential 1.5-degree-pathway scenarios. This allowed us to account for flexibility in the pace of decarbonization

[2] See Rajat Dhawan, Russell Hensley, Asutosh Padhi, and Andreas Tschiesner, "Mobility's second great inflection point," *McKinsey Quarterly*, February 2019, McKinsey.com.

among some of the largest sources of GHGs (for example, power generation and transportation) without being predictive (see sidebar "About the research"). All the scenarios, we found, would imply the need for immediate, all-hands-on-deck efforts to dramatically reduce GHG emissions. The first scenario frames deep, sweeping emission reductions across all sectors; the second assumes oil and other fossil fuels remain predominant in transport for longer, with aggressive reforestation absorbing the surplus emissions; and the third scenario assumes that coal and gas continue to generate power for longer, with even more vigorous reforestation making up the deficit (see "Three paths to 1.5°C," on page 34).

Urgency amid uncertainty

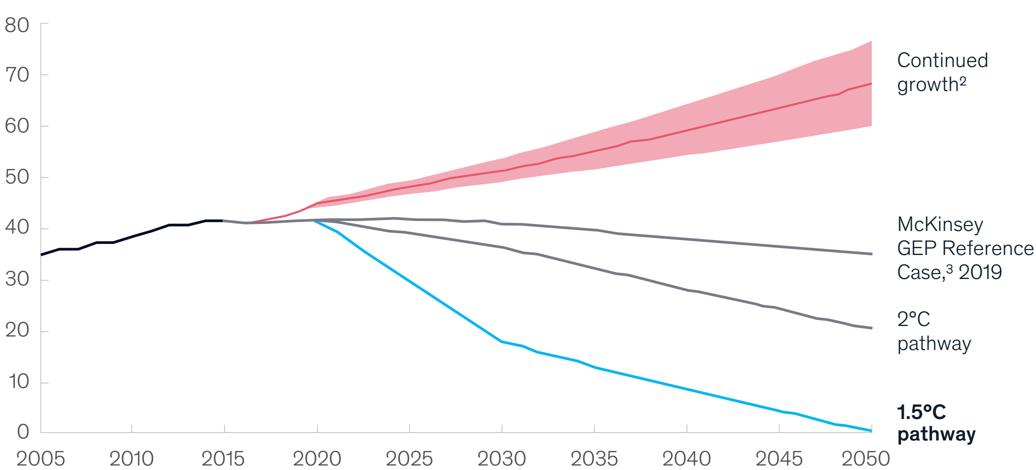
These scenarios represent rigorous, data-driven snapshots of the decarbonization challenge, not predictions; reality may play out quite differently. Still, the implied trade-offs underscore just how stark a departure a 1.5-degree pathway is from the global economy's current trajectory. Keeping to 1.5 degrees would require limiting all future net

Exhibit 1

Rapid declines in CO_2 emissions would be required to reach a 1.5°C pathway.

Projected global CO_2 emissions per scenario[1]

Metric gigatons of CO_2 ($GtCO_2$) per year



[1] In addition to energy-related CO_2 emissions, all pathways include industry-process emissions (eg, from cement production), emissions from deforestation and waste, and negative emissions (eg, from reforestation and carbon-removal technologies such as bioenergy with carbon capture and storage, or BECCS, and direct air carbon capture and storage, or DACCS). Conversely, emissions from biotic feedbacks (eg, from permafrost thawing, wildfires) are not included.
[2] Lower bound for "continued growth" pathway is akin to IEA's *World Energy Outlook 2019* Current Policies Scenario; higher bound based on IPCC's Representative Concentration Pathway 8.5.
[3] GEP = Global Energy Perspective; reference case factors in potential adoption of renewable energy and electric vehicles.

Source: Global Carbon Budget 2019; *World Energy Outlook 2019*, IEA, expanded by Woods Hole Research Center; McKinsey *Global Energy Perspective 2019: Reference Case*; McKinsey 1.5°C scenario analysis emissions of carbon dioxide from 2018 onward to 570 gigatons (Gt),[3] and reaching net-zero emissions by 2050 (Exhibit 2). How big a hill is this to climb? At the current pace, the world would exceed the 570-Gt target in 2031. Although an "overshoot" of the 570-Gt carbon budget is common in many analyses, we have avoided it in these scenarios: the impact of an overshoot in temperature, and thus in triggering climate feedbacks, as well as the effectiveness of negative emissions at decreasing temperatures, are unknown—multiplying the uncertainties in any such scenarios.

And CO_2 is just part of the picture. Although as much as 75 percent of the observed warming since 1850 is attributable to carbon dioxide,[4] the remaining warming is linked to other GHGs such as methane and nitrous oxide. Methane, in fact, is 86 times more potent than CO_2 in driving temperature increases over a 20-year time frame,[5] though it persists in the atmosphere for much less time. Our analysis, therefore, encompassed all three major greenhouse gases: carbon dioxide, methane, and nitrous oxide. Our scenarios imply achieving a reduction of more than 50 percent in net CO_2 by 2030 (relative to 2010 levels)[6] and a reduction of other greenhouse gases by roughly 40 percent over that time frame.

The implication of all this is that reaching a 1.5-degree pathway would require rapid action. Our scenarios reflect a world in which the steepest emission declines would need to happen over the next decade. Without global, comprehensive, and near-term action, a 1.5-degree pathway is likely out of reach.

Regardless of the scenario, five major business, economic, and societal shifts would underlie a transition to a 1.5-degree pathway. Each shift would be enormous in its own right, and their interdependencies would be intricate. That makes an understanding of these trade-offs critical for business leaders, who probably will be participating in some more than others but are likely to experience all five.

Shift 1: Reforming food and forestry

Although the start of human-made climate change is commonly dated to the Industrial Revolution, confronting it successfully would require taking a hard look at everything,

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[3] Our analysis draws on the work of the Intergovernmental Panel on Climate Change (IPCC) by using a remaining carbon budget of 570 metric gigatons (Gt) CO_2 as of January 1, 2018. Remaining within this budget would equate to a 66 percent chance of limiting warming to 1.5 degrees Celsius. For more about the IPCC methodology and how it differs from other carbon-budget estimates (for example, a 420 $GtCO_2$ for a 66 percent chance, and 580 $GtCO_2$ for a 50 percent chance), see Myles R. Allen et al., *Special report: Global warming of 1.5°C*, IPCC, 2018, ipcc.ch.

[4] Karsten Haustein et al., "A real-time global warming index," *Nature*, November 13, 2017, Nature Scientific Reports 7, Article Number 15417, nature.org; Richard J. Millar and Pierre Friedlingstein, "The utility of the historical record for assessing the transient climate response to cumulative emissions," *Philosophical Transactions of the Royal Society*, May 2018, Volume 376, Number 2119, royalsocietypublishing.org.

[5] Any discussion of methane in this article, unless noted otherwise, assumes GWP 20 with inclusion of climate–carbon feedbacks; GWP20 = 20-year global warming potential (GWP). See Gunnar Myhre et al., "Anthropogenic and natural radiative forcing," *AR5 Climate change 2013: The physical science basis*, Intergovernmental Panel on Climate Change, 2018, Assessment Report 5, Chapter 8, ipcc.ch.

[6] Assumes a 50 percent reduction in gross anthropogenic CO_2 emissions—approximately 19 gigatons (Gt)—coupled with approximately 2 Gt of negative emissions, for a net reduction of 54 percent (reaching net emissions of approximately 17 Gt); 2010 emissions at 38.5 Gt, see Joeri Rogelj et al., "Mitigation pathways compatible with 1.5°C in the context of sustainable development," *Special report: Global warming of 1.5°C*, Intergovernmental Panel on Climate Change, 2018, Chapter 2, ipcc.ch.

Sidebar

About the research

This article's foundation is a bottom-up, sector-by-sector assessment of greenhouse-gas emissions and abatement potential. Starting with the status quo for each source of emissions (exhibit), we reviewed with McKinsey colleagues and select external experts the technically feasible emission-reduction levers over different time horizons. It was immediately clear that a 1.5-degree pathway would be unreachable if all investments modeled must deliver positive economic returns (and many likely won't, given that the externalities of emissions and related climate effects are not fully priced in). We therefore relaxed this assumption, which implies the need for regulatory incentives to account for challenging abatement opportunities.

To create 1.5-degree-pathway scenarios, we established a binding constraint based on forecasts from the Intergovernmental Panel on Climate Change (IPCC): a remaining carbon budget of 570 gigatons (Gt) for CO_2 as of January 1, 2018, and a complementary reduction of non-CO_2 gases to tackle the warming effects of methane and nitrous oxide. An infinite set of permutations could, theoretically, enable the global economy to remain within these parameters. But constraints such as the time it takes for emerging technologies to achieve meaningful penetration, along with politics and regional barriers, reduce the degrees of freedom. As shown in the accompanying scenario descriptions, the three future states depicted here incorporate different variations on such barriers to implementation.

Anthropogenic greenhouse-gas (GHG) emissions per sector and type of gas

Carbon dioxide (CO_2) | Methane (CH_4) | Other GHGs[1]

	Metric gigatons of CO_2 equivalent ($GtCO_2e$[2]) in 2016, by source, %: Carbon dioxide	Methane	Other GHGs	Total GHGs, metric gigatons	Share of total GHG emissions
Industry[3]	45	46	9	25	33%
Agriculture/ livestock	6	80	14	15	20%
Power	100			12	17%
Transport	100			8	10%
Waste[4]		98	2	6	8%
Net deforestation	100			6	7%
Buildings	100			3	4%

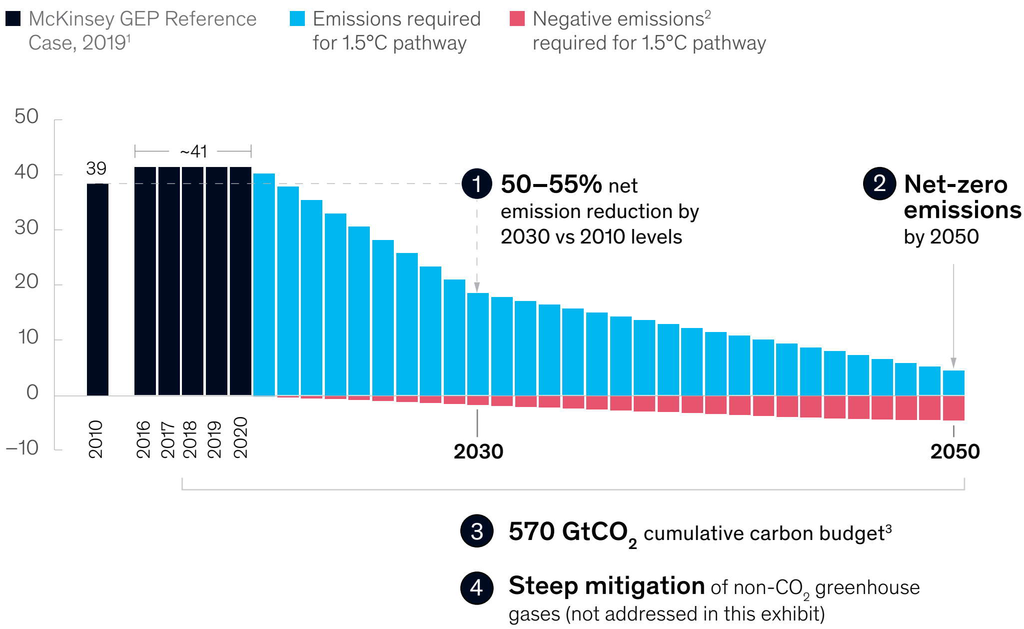
[1] Includes emissions from hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.
[2] Non-CO_2 emissions converted into CO_2e using 20-year global-warming-potential values from IPCC Assessment Report 5.
[3] Includes cement, chemical production, iron and steel, mining, oil and gas, and low- to medium-temperature and high-temperature industries, among others.
[4] Includes food waste, biological treatment of solid waste, incineration and open burning of waste, solid-waste disposal, and wastewater treatment and discharge.

Source: Emissions Database for Global Atmospheric Research (EDGAR), 2015; FAOSTAT, 2015; IEA, 2015; McKinsey *Global Energy Perspective 2019: Reference Case*; McKinsey 1.5°C scenario analysis

Exhibit 2

A paced transition to a 1.5°C pathway has four requirements.

Cumulative global CO_2 emissions, current and historical, metric gigatons of CO_2 ($GtCO_2$) per year



[1] GEP = Global Energy Perspective reference case.
[2] Achieved, for example, from reforestation and carbon-removal technologies such as bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS).
[3] Budget of 570 $GtCO_2$ emissions from 2018 onward offers a 66% chance of limiting global warming to 1.5°C, when assessing historical temperature increases from a blend of air and sea-surface temperatures.

Source: Corinne Le Quéré et al., Global Carbon Budget 2018, *Earth Systems Science Data*, 2018, Volume 10, Number 4, doi.org; IPCC; McKinsey *Global Energy Perspective 2019: Reference Case*; McKinsey 1.5°C scenario analysis

including fundamentals such as the trees that cover the earth, as well as the food we eat and the systems that grow and supply it.

Changing what we eat, how it's farmed, and how much we waste

The world's food and agricultural systems are enormously productive, thanks in no small part to the Green Revolution that, starting in the 1960s, boosted yields through mechanization, fertilization, and high-yielding crop varieties. However, modern agricultural practices have depleted CO_2 in the soil, and, even though some CO_2 is absorbed by crops and plants, agriculture remains a net emitter of CO_2. Moreover, agricultural and food systems generate the potent greenhouse gases methane and nitrous oxide—meaning that this critical system contributes 20 percent of global GHG emissions[7] each year. Moreover, population growth, rising per capita food consumption in emerging markets, and the sustained share of meat in diets everywhere mean that agricultural

[7] Does not include land use, land-use change, or forestry. Non-CO_2 emissions converted using 20-year global-warming-potential values. See T. F. Stocker et al., *AR5 Climate change 2013: The physical science basis*, Intergovernmental Panel on Climate Change, 2018, Assessment Report 5, ipcc.ch.

emissions are poised to increase by about 15 to 20 percent by 2050, absent changes in global diets and food-production practices.

The livestock dilemma. The biggest source of agricultural emissions—almost 70 percent—is from the production of ruminant meat. Animal protein from beef and lamb is the most GHG-intensive food, with production-related emissions more than ten times those of poultry or fish and 30 times those of legumes. The culprit? Enteric fermentation inherent in the digestion of animals such as cows and sheep. In fact, if the world's cows were classified as a country in the emissions data, the impact of their GHG emissions (in the form of methane) would put cows ahead of every country except China.

Delivering the emissions reduction needed to reach a 1.5-degree pathway would imply a large dietary shift: reducing the share of ruminant animal protein in the global protein-consumption mix by half, from about 9 percent in current projections for 2050 to about 4 percent by 2050.

Changing the system. The agricultural system itself would need to change, too. Even if consumption of animal protein dropped dramatically, in a 1.5-degree world, the emissions from remaining agricultural production would need to fall as well.

New cultivation methods would help. Consider rice, which currently accounts for 14 percent of total agricultural emissions. The intermittent flooding of rice paddies is a common, traditional growing method—the flooding prevents weeds—that results in outsize methane emissions as organic matter rots. To reach a 1.5-degree pathway, new cultivation approaches would need to prevail, leading to a 53 percent reduction in the intensity of methane emissions from rice cultivation by 2050.

Finally, about one-third of global food output is currently lost in production or wasted in consumption. To achieve a 1.5-degree pathway, that proportion could not exceed 20 percent by 2050. Curbing waste would reduce both the emissions associated with growing, transporting, and refrigerating food that is ultimately wasted, and the methane released as the organic material in wasted food decomposes.

Halting deforestation

Deforestation—quite often linked to agricultural practices, but not exclusively so—is one of the largest carbon-dioxide emitters, accounting for nearly 15 percent of global CO_2 emissions. Deforestation's outsize impact stems from the fact that removing a tree both *adds* emissions to the atmosphere (most deforestation today involves clearing and burning) and *removes* that tree's potential as a carbon sink.

Even after accounting for ongoing reforestation efforts, deforestation today claims an area close to the size of Greece every year. Achieving a 1.5-degree pathway would mean dramatically slowing this. By 2030, if all fossil-fuel emissions were rapidly reduced (as in our first scenario), and all sectors of the economy pursued rapid decarbonization, deforestation would still need to fall about 75 percent. In the other two scenarios, where reduced deforestation serves to help counteract slower decarbonization elsewhere,

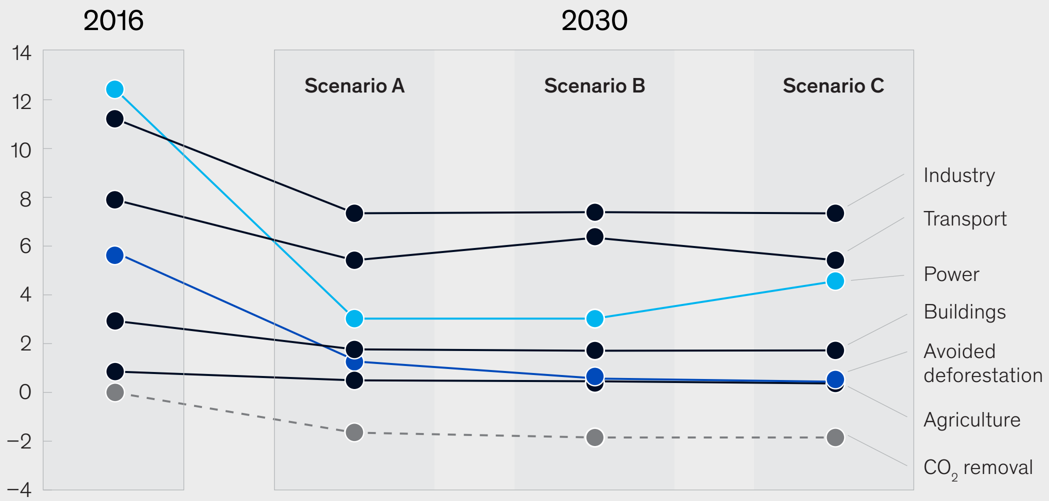
(continued on page 38)

Three paths to 1.5°C

To help understand the challenges of mitigating climate change, we modeled three scenarios. This allowed us to account for flexibility in how fast various large emitters of greenhouse gases (GHGs) might decarbonize—without being predictive. While the scenarios are not forecasts, we hope they nonetheless serve as a useful addition to existing analytic perspectives on GHG abatement. The scenarios address only CO_2 emissions (the most prevalent anthropogenic greenhouse gas and key to any GHG-abatement scenario). While achieving a 1.5°C pathway is technically achievable, it would require all sectors to decarbonize. Should one lag behind, others would need to move faster. The scenarios help define some of these trade-offs.

Three challenging—yet possible—scenarios could limit warming.

Emissions per source, metric gigatons of CO_2 ($GtCO_2$) in 2016 and 2030



Scenario A
The decarbonization pace is set by technology readiness, cost-effectiveness, and ease of implementation

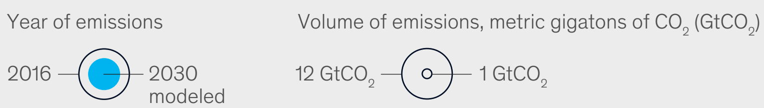
Scenario B
Oil fuels transport for longer; reforestation and curbing deforestation abate the additional emissions

Scenario C
Coal and gas generate power for longer; reforestation and curbing deforestation abate the surplus CO_2

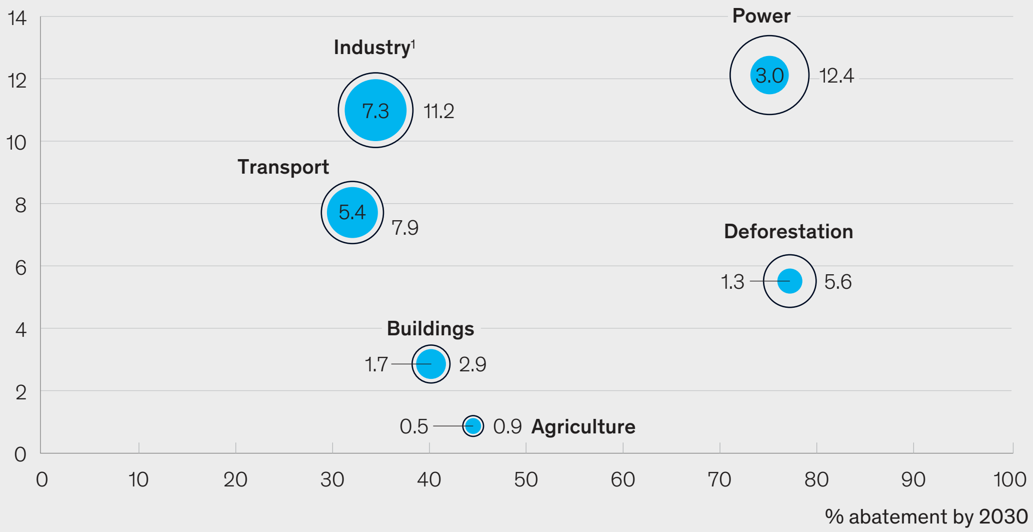
Source: McKinsey *Global Energy Perspective 2019: Reference Case*; McKinsey 1.5°C scenario analysis

Scenario A: Significant and steady decarbonization

A paced transition, enabled by regulation and targeted investment, would require immediate action but would support a significant and steady decrease in emissions. By 2030, all sectors/sources would have abated at least 30% of their 2016 CO_2 emissions.

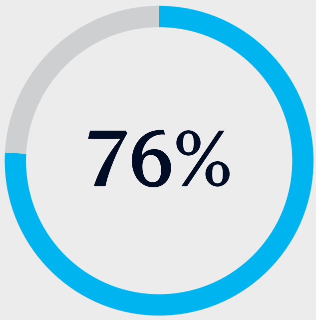


CO_2 emissions per source in 2016,[2] $GtCO_2$

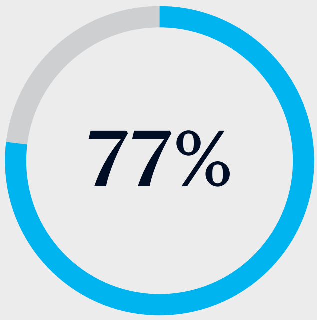


The heavy hitters

Share of category's total 2016 emissions



of the power sector's CO_2 emissions abated by 2030



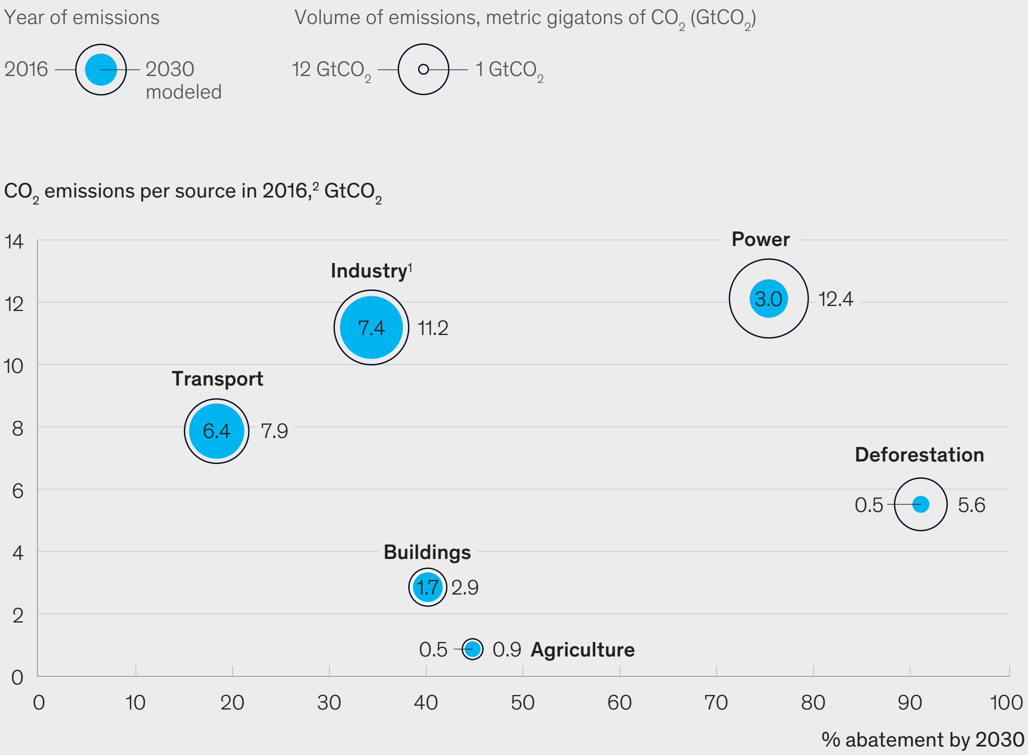
of deforestation's CO_2 emissions abated by 2030

[1] Includes cement, chemical production, iron and steel, mining, oil and gas, and low- to medium-temperature and high-temperature industries, among others.
[2] Carbon-dioxide removal (not pictured here) would abate 4% of 2016 CO_2 emissions in Scenario A.

Source: McKinsey 1.5°C scenario analysis

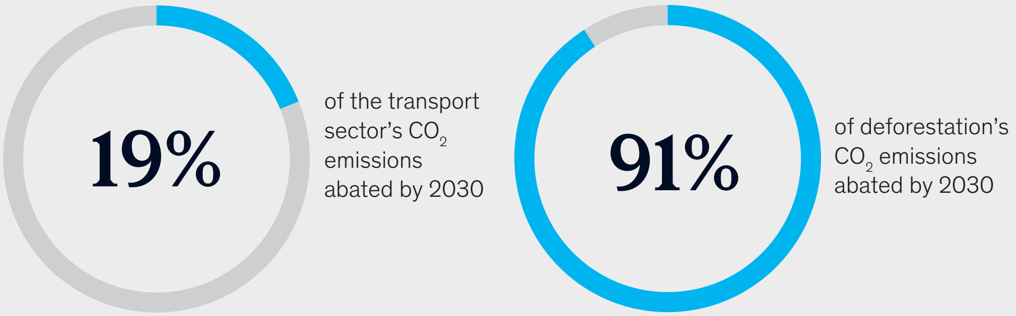
Scenario B: Oil decarbonizes more slowly

Oil continues to be the major fuel for transport, and that sector decarbonizes more slowly. To compensate, reforestation would need to speed up, and 90% of CO_2 emissions from deforestation would have to be abated by 2030. In this scenario, all sectors/sources except transport would manage to abate by at least one-third of their 2016 emissions by 2030.



Trade-offs

Share of category's total 2016 emissions



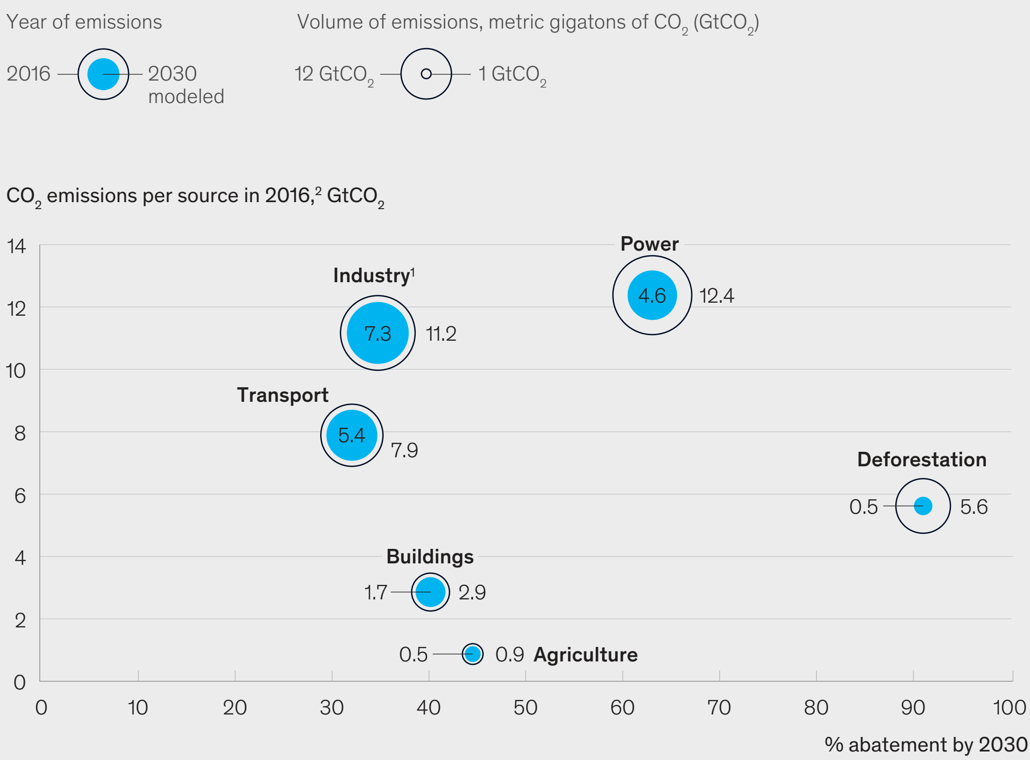
[1] Includes cement, chemical production, iron and steel, mining, oil and gas, and low- to medium-temperature and high-temperature industries, among others.

[2] Carbon-dioxide removal (not pictured here) would abate 5% of 2016 CO_2 emissions in Scenario B.

Source: McKinsey 1.5°C scenario analysis

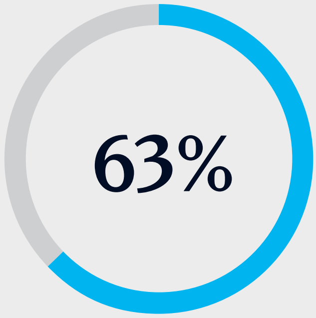
Scenario C: Power decarbonizes more slowly

Coal and gas generate power for longer, compensated by faster reforestation, and abate 90% of all CO_2 emissions from deforestation. In this scenario, all sectors/sources would abate more than 30% of their emissions.

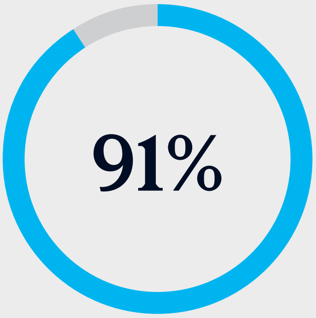


Trade-offs

Share of category's total 2016 emissions



of the power sector's CO_2 emissions abated by 2030



of deforestation's CO_2 emissions abated by 2030

[1] Includes cement, chemical production, iron and steel, mining, oil and gas, and low- to medium-temperature and high-temperature industries, among others.
[2] Carbon-dioxide removal (not pictured here) would abate 4% of 2016 CO_2 emissions in Scenario C.

Source: McKinsey 1.5°C scenario analysis

Carbon avoided is carbon abated

The role of greater efficiency in achieving a 1.5-degree pathway goes beyond improving the operations of any single industry. After all, carbon avoided is as beneficial as carbon abated. As part of our analysis, we therefore studied the impact of greater efficiency, as well as how smart substitution of lower-carbon alternatives and demand-reducing regulations could help lower CO_2 across all scenarios. Taken together, these actions could potentially, by 2050, help bypass about 15 percent of today's emissions (exhibit).

By 2050, reducing demand could help bypass approximately 15 percent of today's CO_2 emissions.

Efficiencies

Insulation and home-energy management could reduce demand for space heating and cooling, lowering CO_2 emissions 30% by 2050

Substitutes

Alternative building materials—eg, cross-laminated timber—could reduce the demand for cement[1]

Recycling

Replacing an additional 20% of inputs to the steel-production process with scrap steel could lower emissions from iron ore use

Recycling could cover ~60% of plastics demand by 2050

Consumption patterns shift

Remote communication and modal shifts in transportation could reduce emissions in the aviation sector 10% by 2030

Measures such as a tax on internal-combustion-engine vehicles—eg, London's congestion charge—would decrease the kilometers traveled per vehicle

[1] In our scenarios, electrification also plays a modest role in decarbonizing marine transport, especially for coastal vessels such as ferries. In aviation, electrification could account for up to 2 percent of the sector's final energy consumption by 2030 and about 6 percent by 2050.

Source: *McKinsey Global Energy Perspective 2019: Reference Case*; McKinsey 1.5°C scenario analysis

deforestation would need to be nearly halted as early as 2030. Either outcome would require a combination of actions (including regulation, enforcement, and incentives such as opportunity-cost payments to farmers) outside the scope of our analysis.

Shift 2: Electrifying our lives

Electrification is a massive decarbonization driver for transportation and buildings—powerful both in its own right and in combination with complementary changes such as increased public-transportation use and the construction or retrofitting of more efficient buildings.

Electrified road transport

The road-transportation sector—passenger cars and trucks, buses, and two- and three-wheeled vehicles—accounts for 15 percent of the carbon dioxide emitted each year. Nearly all of the fuels used in the sector today are oil based. To decarbonize, this sector would need to shift rapidly to a cleaner source of energy, which in the scenarios we modeled was predominantly electricity, and leverage either batteries with sustainably produced electricity or fuel cells with sustainably produced hydrogen to power an electric engine.[8] (Biofuels would also contribute to road transportation. The role of those fuels is discussed later.)

In our first scenario (rapid fossil-fuel reduction), road transportation could reach a 1.5-degree pathway through a rapid migration to EVs powered by a mix of batteries and hydrogen fuel

[8] In our scenarios, electrification also plays a modest role in decarbonizing marine transport, especially for coastal vessels such as ferries. In aviation, electrification could account for up to 2 percent of the sector's final energy consumption by 2030 and about 6 percent by 2050.

cells, and supported by deep, renewable power penetration. Sales of internal-combustion vehicles would account for less than half of global sales by 2030 and be fully phased out by 2050.

These shifts would, in turn, prompt a rapid increase in demand for batteries, challenging that industry to scale more quickly and improve its sustainability (for more, see "Building a more sustainable battery industry," on page 113).

One lever for smoothing the transition would be reducing overall mileage driven by personal vehicles through policies that discouraged private-vehicle usage, such as banning cars in city centers, taxing vehicles on a per-mile-traveled basis, and encouraging the use of public transport. By 2030, such measures could reduce by about 10 percent the number of miles traveled by passenger cars.

To be sure, the rate of change implied in this scenario is dramatic (sales of EV passenger vehicles,[9] for example, would need to grow nearly 25 percent a year between 2016 and 2030). Nonetheless, the scope of the task will be familiar to global OEMs, which have themselves been prioritizing the shift to electrification.

What if the electrification of road transportation was still aggressive but more gradual—specifically, if sales of internal-combustion vehicles still accounted for more than half of total sales by 2030, as we assumed in our second scenario? In that case, reaching a 1.5-degree pathway would necessitate dramatic levels of CO_2 sequestration, implying the need for unprecedented levels of reforestation to cover the difference, as we describe later.

Electrified buildings

Electrification would also help decarbonize buildings, where CO_2 emissions represent about 7 percent of the global total. Space and water heating, which typically rely on fossil fuels such as natural gas, fuel oil, and coal, are the primary emission contributors. By 2050, electrifying these two processes in those residences and commercial buildings where it is feasible would abate their 2016 heating emissions by 20 percent (if the electricity were to come from clean sources). By expanding the use of district heating and blending hydrogen or biogas into gas grids for cooking and heating, the buildings sector could potentially reduce nearly an additional 40 percent of emissions. Both would be required to reach a 1.5-degree pathway in our rapid fossil-fuel-reduction scenario.

Across all three scenarios, the share of households with electric space heating would have to increase from less than 10 percent today to 26 percent by 2050. To make the most of electric heating, buildings would need to replace traditional heating equipment with newer, more efficient technologies. Improved insulation and home energy management would also be necessary to maximize the benefits of electric heating and enable further emissions reductions by 2050.

The good news is that electric technologies are already available at scale, and their economics are often positive. However, the combination of higher up-front costs, long

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[9] Includes battery electric, fuel-cell electric, plug-in, and hybrid vehicles.

Across the board, embracing the circular economy and boosting efficiency would enable a wide cross-section of industries to decrease GHG emissions, reduce costs, and improve performance.

payback times, and market inefficiencies often prevents consumers and companies from acting.[10] Moreover, the average life span of currently installed (but less efficient) equipment can span decades, making inertia tempting for many asset owners, and a broad-based shift to electric heating more challenging.

Shift 3: Adapting industrial operations

The role of electrification could not stop with buildings and cars. It would need to extend across a broad swath of industries as part of a collection of operational adaptations that would be part of achieving a 1.5-degree pathway.

Electrified industries

Industrial subsectors with low- and medium-temperature heat requirements, such as construction, food, textiles, and manufacturing, would need to accelerate electrification of their operations relatively quickly. By 2030, more than 90 percent of the abatement for mid- to low-temperature industries depends on electrifying production with power sourced from clean-energy sources. All told, these industries would need to electrify at more than twice their current level by 2050 (from 28 percent in 2016 to 76 percent in 2050) to achieve a 1.5-degree pathway. For more about the economics of industry electrification, see "Hybrid equipment: A first step to industry electrification," on page 86.

Electrification would prove more difficult for process industries with high-temperature requirements, such as iron and steel, or cement (among the biggest CO_2 emitters). These subsectors, along with others such as chemicals, mining, and oil and gas that are also challenging and expensive to decarbonize, would put a premium on efficiency efforts (including recycling and the use of alternative materials) and would depend heavily on innovation in hydrogen and clean fuels.

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[10] For more on improving energy efficiency in buildings, see "Resource revolution: Meeting the world's energy, materials, food, and water needs," McKinsey Global Institute, November 2011, on McKinsey.com, and view the interactive.

[11] Thomas Hundertmark, Mirjam Mayer, Chris McNally, Theo Jan Simons, and Christof Witte, "How plastics waste recycling could transform the chemical industry," December 2018, McKinsey.com.

Greater industrial efficiency

Across the board, embracing the circular economy and boosting efficiency would enable a wide cross-section of industries to decrease GHG emissions, reduce costs, and improve performance (see sidebar "Carbon avoided is carbon abated"). By 2050, for example, nearly 60 percent of plastics consumption could be covered by recycled materials.[11] Similarly, steelmakers might be able to reduce GHG emissions by further leveraging scrap steel, which today accounts for nearly one-third of production. Cement manufacturers, meanwhile, would need to abate their current CO_2 emissions, which accounted for 6 percent of global CO_2 emissions in 2016, by more than 7 percent by 2030 through a range of short-term efficiency improvements, including the greater use of advanced analytics.

Tackling fugitive methane

Another big operational adaptation would be "fugitive methane," or the natural gas that is released through the activities of oil and gas companies, as well as from coal-mining companies (Exhibit 3). Each would need to tackle the issue to reach a 1.5-degree pathway.

For oil and gas companies, methane is the largest single contributor of GHGs. The good news, as our colleagues write, is that, while eliminating fugitive methane is challenging, many abatement options are available—often with favorable economics (for more, see "Meeting big oil's decarbonization challenge," on page 89).

Coal mines, meanwhile, release the gas as part of their underground operations. Solutions for capturing methane (and using it to generate power) exist but are not commonly implemented.[12] Moreover, there are no ready solutions for all types of mines, and the investment is not economical in many cases.

Shift 4: Decarbonizing power and fuel

Widespread electrification would hold enormous implications for the power sector. We estimate that electrification would at least triple demand for power by 2050, versus a doubling of demand, as reported in *Global Energy Perspective 2019: Reference Case*.[13] The power system would have to decarbonize in order for the downstream users of that electricity—everything from factories to fleets of electric vehicles—to live up to their own decarbonization potential. Renewable electricity generation is therefore a pivotal piece of the 1.5-degree puzzle. But it's not the only piece: expanding the hydrogen market would be vital, given the molecule's versatility as an energy source. Expanding the use of bioenergy would be important, too.

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[12] In the United States, for example, the Coalbed Methane Outreach Program—part of the Environmental Protection Agency—works with the coal-mining industry to support project development and to help overcome technical and other barriers to implementation.

[13] The impact of increased demand for electricity on its price is beyond the scope of our analysis. For further discussion of the issue, see *Global Energy Perspective 2019: Reference Case*, January 2019, McKinsey.com; and Arnout de Pee, Dickon Pinner, Occo Roelofsen, Ken Somers, Eveline Speelman, and Maaike Witteveen, "How industry can move toward a low-carbon future," July 2018, McKinsey.com, which examines the trade-offs involved in the decarbonization of four industrial commodities: ammonia, cement, ethylene, and steel.

Renewables
Replacing thermal assets with renewable energy would require a dramatic ramp-up in manufacturing capacity of wind turbines and solar panels. By 2030, yearly build-outs of solar and wind capacity would need to be eight and five times larger, respectively, than today's levels.[14]

It would also entail a massive reduction in coal- and gas-fired power generation. Indeed, to remain on a 1.5-degree pathway, coal-powered electricity generation would need to decrease by nearly 80 percent by 2030 in our rapid fossil-fuel-reduction scenario. Even in the scenario where coal and gas generate power for longer, the reduction would need to be about two-thirds by 2030. The sheer scope of this shift cannot be overstated. Coal today accounts for about 40 percent of global power generation. What's more, by 2030 the amount of electricity generated by natural gas would have to decrease by somewhere between 20 and 35 percent. As it stands, nearly one-quarter of the world's power is generated using natural gas.

A fast migration to renewable energy would bring unique regional challenges, most notably the need to match supply and demand at times when the sun doesn't shine and the wind doesn't blow. In the nearer term, a mix of existing approaches could help with day-to-day and seasonal load balancing, although emerging technologies such as hydrogen, carbon capture and storage, and more efficient long-distance transmission would ultimately be needed to reach a 1.5-degree pathway.

Bioenergy
Increasing the use of sustainably sourced bioenergy—for instance, biokerosene, biogas, and biodiesel—would also be required in any 1.5-degree-pathway scenario. Our scenarios approached bioenergy conservatively (abating about 2 percent of the CO_2 needed by 2030 to reach a 1.5-degree pathway). Its most pressing mandate over that time frame would be substituting for oil-based fuels in aviation and marine transport, until which time sustainably sourced synthetic fuels would account for a larger share. Nonetheless, any scale-up of bioenergy would need to acknowledge the realities of land use, and it would also need to strike a balance between the desire for sustainable energy, on the one hand, and the basic human need to feed a growing world population, on the other.

Hydrogen
Hydrogen produced from renewable energy—so-called green hydrogen—would play a huge part in any 1.5-degree pathway. "Blue hydrogen," which is created using natural gas and the resulting CO_2 emissions stored via carbon capture and storage, would also play a role. This is because about 30 percent of the energy-related CO_2 emitted across sectors is hard to abate with electricity only—for example, because of the high heat requirements of industries such as steelmaking. Hydrogen's potential is strongest in the steelmaking and chemical industries; the aviation, maritime, and short-haul trucking segments of the transport sector; oil- and gas-heated buildings; and peak power generation. In addition, green hydrogen has at least some potential in a range of

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[14] Nuclear power could also contribute to the supply of low-carbon power, but it is largely outside the scope of our analysis. In our modeling, we assumed that nuclear capacity will grow 6 percent between 2020 and 2050, in line with McKinsey's *Global Energy Perspective 2020: Reference Case* (forthcoming on McKinsey.com).

other sectors, including cement, manufacturing, passenger cars, buses and short-haul trucks, and residential buildings. Scaling the hydrogen market would require efforts across the board, from building the supporting infrastructure to store and distribute it to establishing new technical codes and safety standards. For more, see the Hydrogen Council's 2017 report, *Hydrogen scaling up: A sustainable pathway for the global energy transition*.

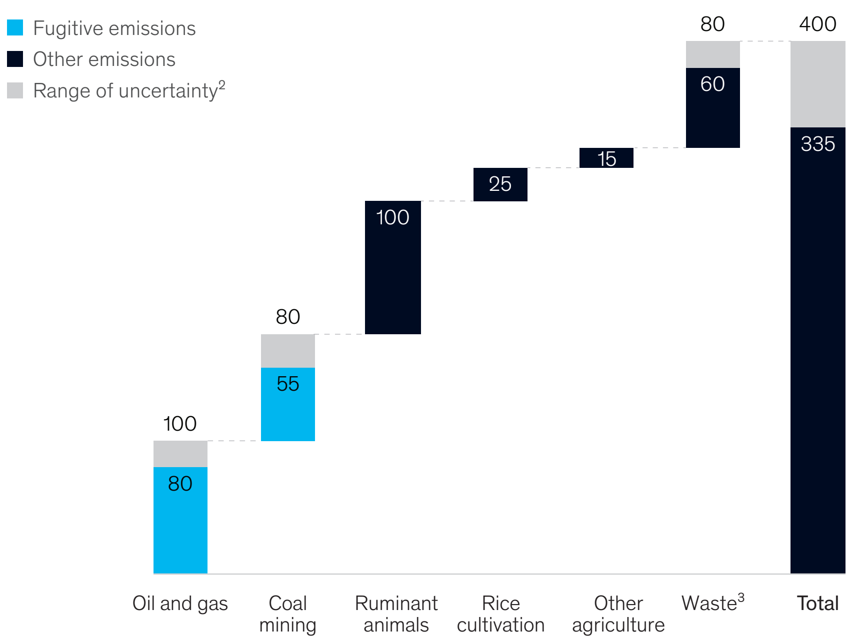
Shift 5: Ramping up carbon-capture and -sequestration activity

Deep decarbonization would also require major initiatives to either capture carbon from the point at which it is generated (such as ammonia-production facilities or thermal-

Exhibit 3

Methane emissions would need to be reduced to reach a 1.5°C pathway.

Anthropogenic methane emissions,[1] 2016, metric megatons of methane ($MtCH_4$)



Note: Major uncertainties affect estimates of fugitive emissions. There is no global consensus on their monitoring.

[1] The methane emissions depicted here—when expressed as metric gigatons of CO_2 equivalents and based on 20-year global-warming-potential values (GWP20) from IPCC Assessment Report 5—are as follows: oil and gas (7 Gt); coal mining (5 Gt); ruminant animals (8 Gt); rice cultivation (2 Gt); other agriculture (1 Gt); waste (6 Gt). GWP20 values include climate-carbon feedbacks.

[2] Ranges of uncertainty: for oil and gas, assumes upper bound of +25% (shown); for coal mining, assumes a lower bound of –45%, an average of 55 Mt (shown), and an upper bound of +40% (shown); for waste, assumes a range based on lowest and highest values in available literature (shown).

[3] Includes treatment and disposal of solid waste, incineration and open burning of waste, and wastewater treatment and discharge.

Source: Emissions Database for Global Atmospheric Research (EDGAR), 2015; FAOSTAT; Global Carbon Project; IEA; McKinsey *Global Energy Perspective 2019: Reference Case*; McKinsey 1.5°C scenario analysis

By 2050, the world would need to have reforested an area nearly one-third the size of the contiguous United States.

power plants) or remove carbon dioxide from the atmosphere itself. Currently, it is impossible to chart a 1.5-degree pathway that does not remove CO_2 to offset ongoing emissions. The math simply does not work.

Carbon capture, use, and storage

Developing the nascent carbon capture, use, and storage (CCUS) industry would be critical to remaining on a 1.5-degree pathway. In simplest terms, this suite of technologies collects CO_2 at the source (say, from industrial sites). CCUS would prevent emissions from entering the atmosphere by compressing, transporting, and either storing the carbon dioxide underground or using it as an input for products.

In the first, more rapid decarbonization scenario, the amount of CO_2 captured via CCUS each year would have to multiply by more than 125 times by 2050 from 2016 levels, to ensure that emissions stay within the 1.5-degree-pathway budget. This is a tall order that exceeds the relatively bullish forecasts of McKinsey researchers who have been investigating both the challenges and the potential of CCUS, suggesting that more innovation and regulatory support would be needed for it to play a central role.

Technology-based carbon-dioxide removal

While reducing CO_2 emissions is a vital part of reaching a 1.5-degree pathway, it would not be enough by itself. Additional carbon dioxide would need to be removed from the atmosphere. Carbon-dioxide removal involves capturing and permanently sequestering CO_2 that has already been emitted, through either nature-based solutions or approaches that rely on technology, which are promising but nascent. Examples of the latter include direct air capture (which is operating at a pilot plant in Iceland).

Reforestation at scale

Even in an extremely optimistic scenario for these technologies, though, we would still need large-scale, nature-based carbon-dioxide removal, which is proved at scale: it is what trees and plants have been doing for millions of years. Over the next decade, a massive, global mobilization to reforest the earth would be required to achieve a 1.5-degree pathway. In our scenarios, reforestation represents the key lever to compensate for the hardest-to-abate sectors, particularly for pre-2030 emissions.

All the scenarios we modeled would require rapid reforestation between now and 2030. At the height of the effort in that year, an area the size of Iceland would need to be reforested annually. By 2050, on top of nearly avoiding deforestation and replacing any forested areas lost to fire, the world would need to have reforested more than 300 million hectares (741 million acres)—an area nearly one-third the size of the contiguous United States. As we noted earlier, the pace of reforestation would need to be faster still should either the transport or power-generation sectors decarbonize more slowly than depicted in our scenarios. Under those circumstances, the requisite annual reforestation would need to be nearly half the size of Italy by 2030.

How feasible would this be? The necessary land appears to be available. Mass reforestation has taken place, admittedly at a much smaller scale, in China. And carbon-offset markets could help catalyze reforestation (and innovation). That said, it is difficult to imagine reforestation taking place on the scale or at the pace described in this article absent coordinated government action—on top of the shifts described in the scenarios themselves.

Will these five shifts become the building blocks of an orderly transition to a decarbonized global economy? Or will slow progress against them be a warning sign that the climate is headed for rapid change in the years ahead? While unknowable today, the answers to these questions are likely to emerge in a remarkably short period of time. And if the global economy is to move to a 1.5-degree pathway, business leaders of all stripes need knowledge of the shifts, clarity about each one's relevance to their companies, insights into the difficult trade-offs that will be involved, and creativity to forge solutions that are as urgent and far-reaching as the climate challenge itself. Q

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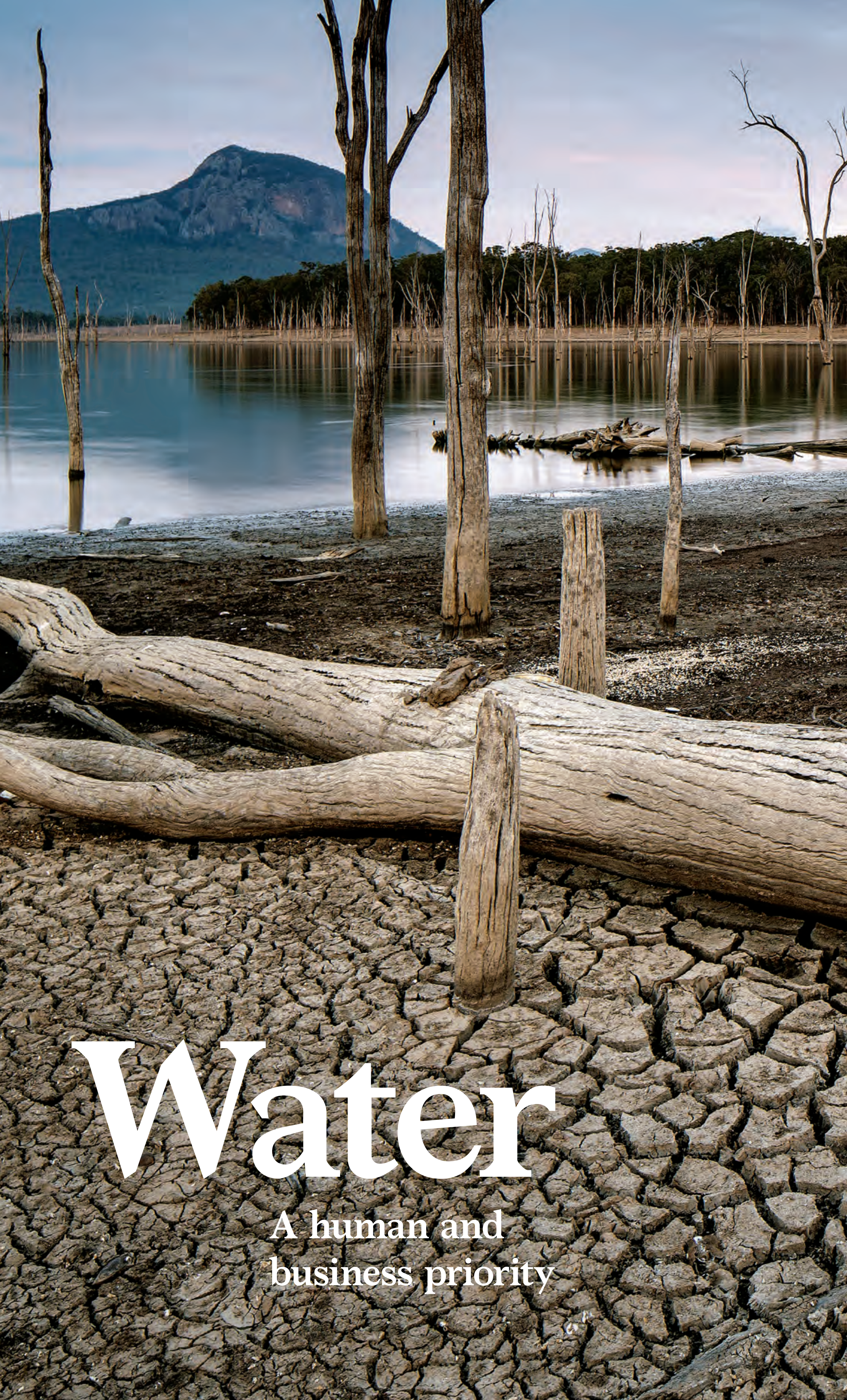
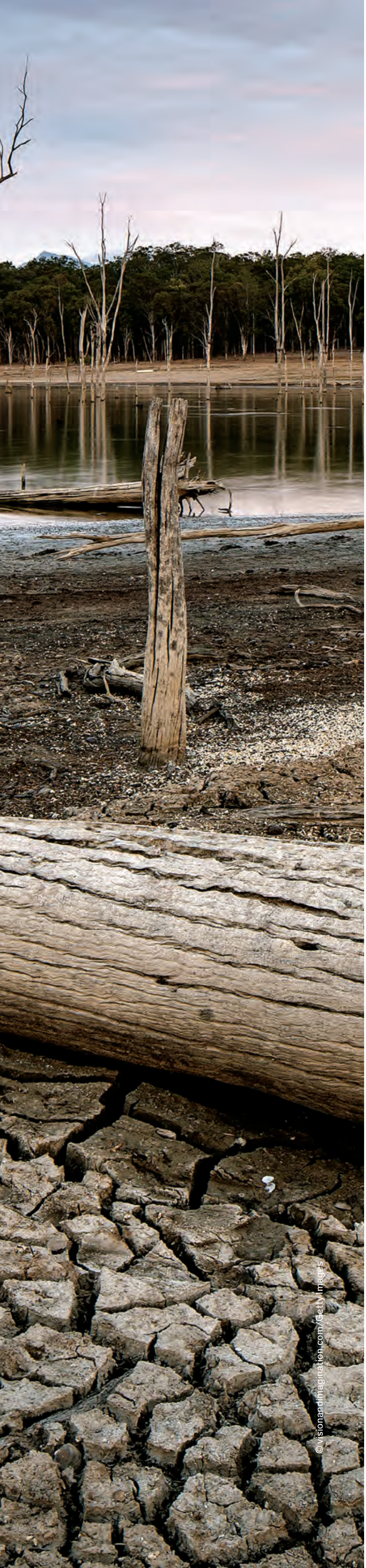


Water

A human and business priority



Water stress increases risk for communities and businesses. Through proactive individual and collective action, businesses can combat the water crisis.

by Thomas Hundertmark, Kun Lueck, and Brent Packer

Water is the lifeblood of humanity. With it, communities thrive. But, when the supply and demand of fresh water are misaligned, the delicate environmental, social, and financial ecosystems on which we all rely are at risk. Climate change, demographic shifts, and explosive economic growth all exacerbate existing water issues.

However, hope is not lost. Businesses can play a leading role in mitigating the water issue to limit not just their own risk but also the risk of all stakeholders relying on these systems. This can be accomplished by directing action through three spheres of influence: direct operations, supply chain, and wider basin health.

Water today

Water is as important to the world's economy as oil or data. Though most of the planet is covered in water, more than 97 percent of it is salt water. Fresh water accounts for the rest, although most of it is frozen in glaciers, leaving less than 1 percent of the world's water available to support human and ecological processes. Every year, we withdraw 4.3 trillion cubic meters of fresh water from the planet's water basins. We use it in agriculture (which accounts for 70 percent of the withdrawals), industry (19 percent), and households (11 percent).

These percentages vary widely across the globe. In the United States, industrial usage (37 percent) is almost as high as agricultural (40 percent); in India, on the other hand, agriculture claims 90 percent of water withdrawals, while only 2 percent is put to work for industry. China's withdrawals are 65 percent agriculture, 22 percent industrial, and 13 percent for household use. Considering that some of the agricultural usage is directed toward industry—for example, half of the production of maize, which is one of the top five global crops by total acreage and water consumption, is used for producing ethanol—the figures may understate how critical water is to business.

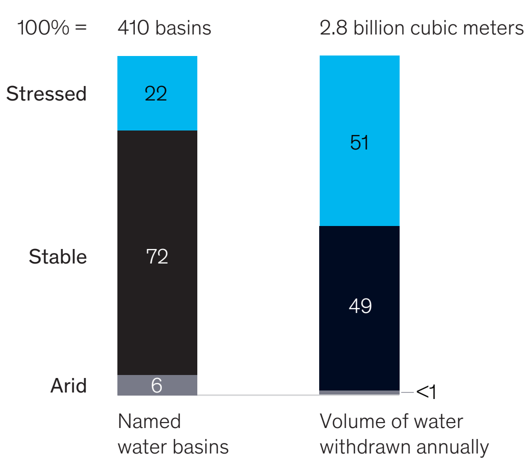
All industries rely on water in some way. A company's water footprint can be seen in four key areas of its value chain: raw materials, suppliers, direct operations, and product use. Consider, for example, a T-shirt across its value chain—raw materials (cotton), suppliers (cotton-to-fabric processer), direct operations (final manufacturing, shipping, and retail), and product use (washing the shirt at home). Food and beverage companies use water as an ingredient in the products they sell, of course, but they also use it to irrigate, rinse, and clean crops, and to feed livestock. Metals and mining companies need water for dust control, drilling, and slurry when transporting products. In the tech industry, suppliers require ultrapure water for certain manufacturing processes, and data centers require water for cooling. Forest-products companies rely on water for making pulp and paper. Apparel companies rely on water to grow raw materials and wash garments. Even insurance companies are affected by water through claims related to water, such as crop-production insurance. Water's uses and effects are as varied as business itself.

The availability of fresh water also varies greatly by location. The majority of the world's fresh water is divided among 410 named basins, which are areas of land where all water that falls or flows through that region ultimately ends at a single source. These include the Huang He, Nile, Colorado River, Indus, and many others. Of these 410 named basins, almost a quarter (90) are considered "high stressed" (meaning that their ratio of total

Exhibit 1

Much of the world's water supply is drawn from stressed water basins.

% of named[1] basins and withdrawals by stress level[2]



[1] "Named" basins are the world's most significant basins. About 1.3 billion cubic meters of water are withdrawn annually from smaller, unnamed basins.
[2] A basin is considered stressed when the ratio of total annual withdrawals to total available annual supply exceeds 40 percent.

Source: World Resources Institute

annual withdrawals to total available annual supply exceeds 40 percent). These 90 highly stressed basins account for just 13 percent of the total area of named water basins but account for 51 percent of withdrawals (Exhibit 1). About half are located in three countries with enormous water needs and high economic activity: China, India, and the United States.

The water crisis is here, and it's getting worse

Water risk is not a worry to be addressed in some nebulous future. The supply of fresh water has been steadily decreasing while demand has been steadily rising. In the 20th century, the world's population quadrupled—but water use increased sixfold. The strain is already apparent. In 2018, in the midst of a severe drought, Cape Town, South Africa, came close to experiencing a so-called Day Zero, where the city would have literally run out of water. To avoid that peril, the city government put quotas on agricultural, business, and domestic usage. The government also got lucky: rain replenished its basin just in time. All in all, the drought drove at least 5.9 billion rand (approximately $400 million) in economic losses across the Western Cape.

This event, and others like it, are just a taste of what's to come. As McKinsey's 2009 report *Charting our water future: Economic frameworks to inform decision-making* made clear, climate change, population growth, and changing consumer habits are increasing water stress for many regions.[1] The recent McKinsey Global Institute report *Climate risk and response: Physical hazards and socioeconomic impacts* notes that many of the world's basins could see a supply decline of around 10 percent by 2030 and up to 25 percent by 2050.[2] By 2050, according to UN estimates, one in four people may live in a country affected by chronic shortages of fresh water. The World Bank estimates that the crisis could slow GDP by 6 percent in some countries by 2050 as well.

Water stress is a risk multiplier. Alone, it is a powerful risk with the potential to upend socioeconomic and ecological systems. When compounded with other risks, such as those related to food and energy systems, politics, and infrastructure, it becomes detrimental.

The clear and increasing business risk

Two-thirds of businesses have substantial risk in direct operations or in their value chain. As water stress grows, they will experience that risk in four forms: physical, regulatory, reputational, and stakeholder.

Physical risks can be critical and costly. In some locations, key water sources may be inaccessible or unfit for use. A primary physical risk is having too little water, which can be a costly problem. A 2015 drought in Brazil drove up General Motors' water costs there by $2.1 million, and its electricity costs rose an additional $5.9 million.

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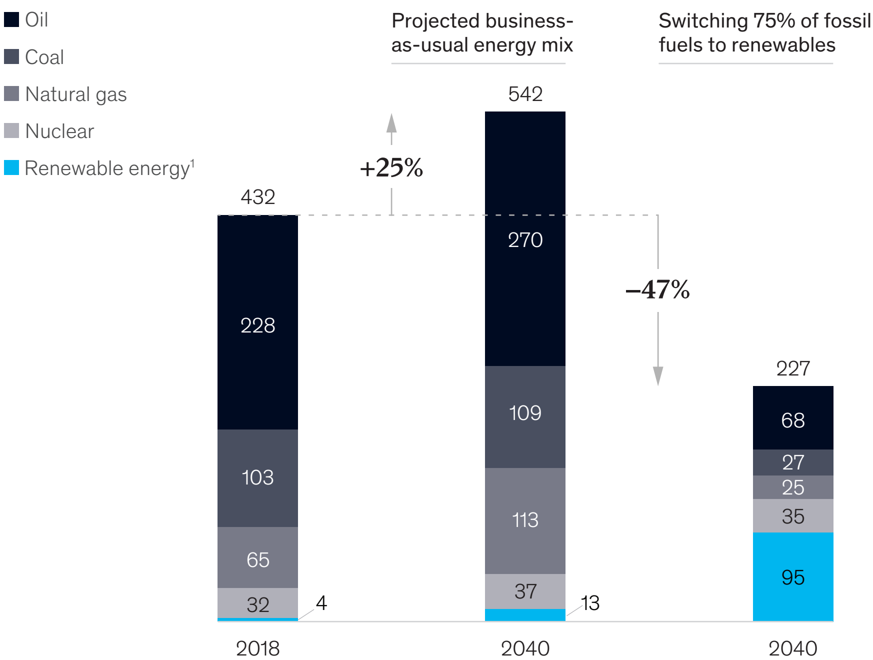
[1] "Charting our water future," November 2009, McKinsey.com.

[2] "Climate risk and response: Physical hazards and socioeconomic impacts," McKinsey Global Institute, January 2020, McKinsey.com.

Exhibit 2

Shifting to renewables would save water.

Total water footprint for energy production globally, billion cubic meters



[1] Includes solar, wind, hydro, and biodiesel.

Source: International Energy Agency; James Meldrum et al., "Life water cycle use for electricity generation: A review and harmonization of literature estimates," *Environmental Research Letters*, March 2013, Volume 8, Number 1; Edward Spang et al., "The water consumption of energy production: An international comparison," *Environmental Research Letters*, October 2014, Volume 9, Number 10; US Energy Information Administration

As the crisis worsens, companies may find themselves increasingly beholden to the whims of government regulators. When Chinese regulators mandated in 2015 that paper-makers cut water consumption by 10 percent, Chenming Group, one of the top ten players in the global paper industry and the leading player in the Chinese market, responded by upgrading its assembly line with advanced equipment that reduced daily water consumption by 45 percent. In 2017, the state government of Kerala, India, facing a severe drought, restricted PepsiCo's groundwater consumption by 75 percent.

A company's pro-environment reputation is becoming increasingly critical. A 2018 Nielsen survey found that 81 percent of global customers say it is important for companies to improve the environment.[3] Consumers are voting with their dollars for companies that align with these principles. The same survey found that 73 percent of customers would change their purchasing habits to reduce environmental impact. In the age of single-tweet public-relations crises, the best defense is getting ahead of issues before they strike.

[3] "Unpacking the sustainability landscape," Nielsen, November 9, 2018, nielsen.com.

By 2050, one in four people may live in a country affected by chronic shortages of fresh water.

Stakeholder risk is rapidly growing as more companies and influential bodies become aware of the other types of business risk. These significant players are able to exert outsize influence on other businesses to nudge them toward practices that are consistent with their own sustainability and business ethos. BlackRock CEO Larry Fink cited water risk in his 2020 letter to CEOs, stating, "What happens to inflation, and in turn interest rates, if the cost of food climbs from drought and flooding?" BlackRock, which has nearly $7 trillion in assets under management, was a founding member of the Task Force on Climate-related Financial Disclosures (TCFD) and is engaging with the companies it invests in to ensure that they follow these guidelines. Moreover, BlackRock is working internally to continually improve the standards of its own reporting in this domain as well. In addition to BlackRock, more than 600 other investment firms with $69 trillion in total assets under management now urge their companies to report on water-related risks and act to mitigate them. (For more, see "'Bring the problem forward': Larry Fink on climate risk," on page 62.)

How businesses can tackle the problem

The water issue is the reverse of the carbon problem; the cause is global, but its manifestation is highly spatial and can be addressed in a concentrated way. Not all basins have equal priority. In fact, several basins have water withdrawals that are well within sustainable limits. Rather than tackling water use across every geography, a more efficient route is for companies to understand how they are interacting with basins that are projected to become water stressed and focus efforts there. Apple, for example, anchors its water stewardship policies by mapping its global water use against regions with heightened water risk. As a result, it focuses its efforts on three regions accounting for 52 percent of its total water use: Maiden, North Carolina; Mesa, Arizona; and Santa Clara Valley, California.

There are three spheres of influence that companies can affect to help mitigate water stress: direct operations, supply chain, and wider basin health. Some companies are already taking action in all three areas.

Direct operations

Within their four walls, companies have several levers they can use to reduce water stress. They can implement water measurement and reporting practices, even including water use in relevant company key performance indicators (KPIs). They can aggressively identify and eliminate water leaks in their operations and introduce new technologies that reduce water stress.

In 2010, Ford set a goal of using 30 percent less water per car by 2014. It reached that goal through a combination of new KPIs and operational improvements. The introduction of internal water metering alone drove conservation behaviors to the department level and helped save around $5 million worldwide. A dry-paint-spray system eliminated water from the car-painting process, and a new lubricant that replaced water in the manufacturing process saved about 280,000 gallons per production line.

Colgate-Palmolive partnered with a water-technology company to meet its sustainability goals for a plant located in a water-scarce basin in Mexico. Its processes require a significant amount of water to ensure proper sanitation for the toothpaste, deodorant, and soap products produced. The new solutions were able to reduce the plant's water use by 1.8 million gallons annually while also significantly reducing the amount of time required for cleaning and sanitizing.

Supply chain
Companies can further reduce water stress by using their influence to ensure that their suppliers and their suppliers' suppliers are equally rigorous about their own contributions to water stress. There are three critical levers to pull: reducing energy use and shifting to renewables, setting supplier standards, and sending water-expert teams to help key suppliers identify and implement efficient water-usage solutions.

Water is required to both extract many energy sources and generate energy through steam-powered turbines. The reduction of energy consumption and the market shift toward renewable sources has the dual effect of lowering greenhouse-gas emissions and reducing water withdrawals. With the transition to a more decarbonized world, new energy-investment decisions can consider water benefits alongside carbon, cost, reliability, and other lenses. The production and use of fossil fuels requires up to four times more water than the production of renewables. If the future energy mix of the planet remains the same as it is now, withdrawals from water basins for energy can grow by 25 percent by 2040. On the other hand, switching 75 percent of fossil-fuel consumption to renewables by that time, per individual countries' Paris Agreement targets, can reduce the water footprint of energy by 47 percent (Exhibit 2).

Companies can also set reporting standards for suppliers. In 2014, Levi Strauss launched a Recycle & Reuse compliance program, which requires that each supplier meet certain limits; use a blend of at least 20 percent recycled water in its facility processing, landscaping, cooling, and plumbing; and provide flow-meter data that tracks the amount of recycled water used on Levi Strauss products.

Nike has successfully implemented a water-supplier initiative, which the company refers to as the Minimum Water Program. Teams work closely with the company's largest materials suppliers and others to ensure good water practices by offering their own expertise to assist their suppliers. The program has been a success—in 2019, Nike achieved its initial goal of reducing fresh water used in textile dyeing by 20 percent, 18 months ahead of schedule.

Wider basin health

Some businesses may choose to go further by using their influence in partnerships that promote water resilience.

During the United Nations' 2012 Conference on Sustainable Development, 45 of the world's largest companies united to advocate for governments to implement sensible water policies. The companies (including Bayer, Coca-Cola, GlaxoSmithKline, Merck, and Nestlé) signed a special communiqué demanding that governments raise the price of water to a fair and appropriate price. The companies committed to ongoing lobbying to support water-positive policies, such as a fair market price for water. Without price increases, water users do not have feedback mechanisms that incentivize conservation and the development of new technologies to cut usage.

Another significant initiative is the Water Resilience Coalition, a creation of the UN Global Compact's CEO Water Mandate. Launched in March 2020, it is built around a water-resilience pledge that binds signatory companies to a set of water goals to be addressed by collective action in water-stressed basins.

As with other key components of climate change, the time has come to address the water crisis head-on. Businesses have a key role to play. Q

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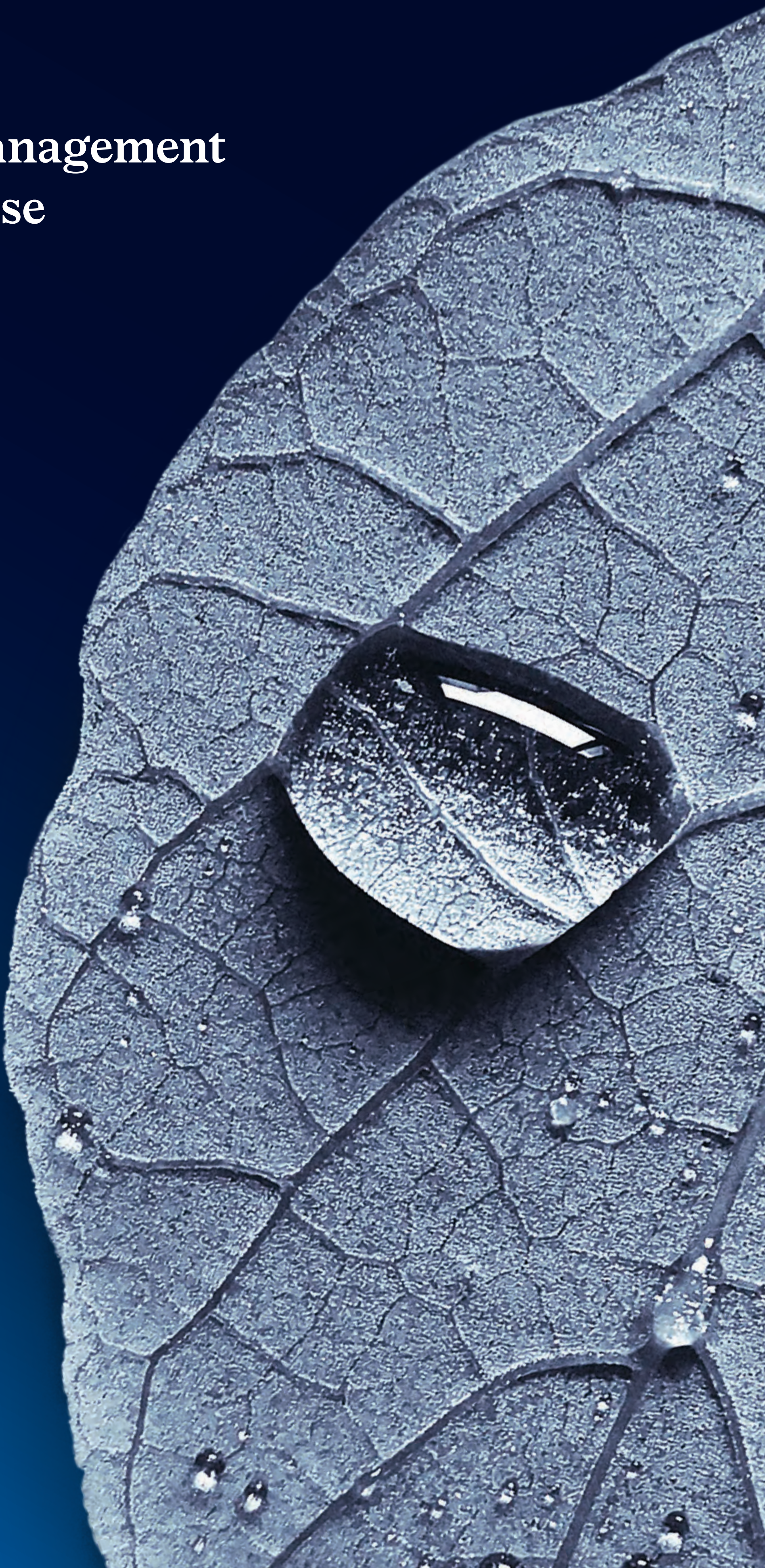
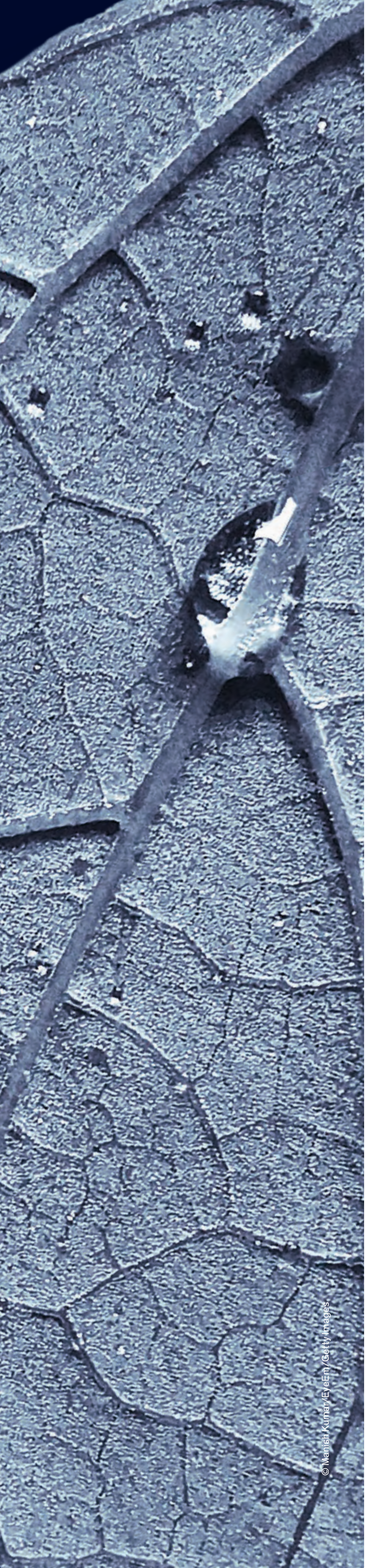
The top-management response





Addressing climate change in a post-pandemic world

The coronavirus crisis holds profound lessons that can help us address climate change—if we make greater economic and environmental resiliency core to our planning for the recovery ahead.

by Dickon Pinner, Matt Rogers, and Hamid Samandari

A ferocious pandemic is sweeping the globe, threatening lives and livelihoods at an alarming rate. As infection and death rates continue to rise, resident movement is restricted, economic activity is curtailed, governments resort to extraordinary measures, and individuals and corporations scramble to adjust. In the blink of an eye, the coronavirus has upended the world's operating assumptions. Now, all attention is focused on countering this new and extreme threat, and on blunting the force of the major recession that is likely to follow.

Amid this dislocation, it is easy to forget that just a few short months ago, the debate about climate change, the socioeconomic impacts it gives rise to, and the collective response it calls for were gaining momentum. Sustainability, indeed, was rising on the agenda of many public- and private-sector leaders—before the unsustainable suddenly became impossible to avoid.

Given the scope and magnitude of this sudden crisis, and the long shadow it will cast, can the world afford to pay attention to climate change and the broader sustainability agenda at this time? Our firm belief is that we simply cannot afford to do otherwise. Not only does climate action remain critical over the next decade, but investments in climate-resilient infrastructure and the transition to a lower-carbon future can drive significant near-term job creation while increasing economic and environmental resiliency. And with near-zero interest rates for the foreseeable future, there is no better time than the present for such investments.

To meet this need and to leverage this opportunity, we believe that leaders would benefit from considering three questions:

- What lessons can be learned from the current pandemic for climate change?

- What implications—positive or negative—could our responses to the pandemic hold for climate action?

- What steps could companies, governments, and individuals take to align our immediate responses to the pandemic with the imperatives of sustainability?

What follows is our attempt at providing some initial answers to these questions, in the hope that they will inspire ideas and actions that help connect our immediate crisis response with priorities for recovery.

Potential lessons from the current pandemic

Understanding the similarities, the differences, and the broader relationships between pandemics and climate risk is a critical first step if we are to derive practical implications that inform our actions.

Fundamental similarities

Pandemics and climate risk are similar in that they both represent *physical shocks*, which then translate into an array of socioeconomics impacts. By contrast, financial shocks—whether bank runs, bubble bursts, market crashes, sovereign defaults, or currency devaluations—are driven largely by human sentiment, most often a fear of lost value or liquidity. Financial shocks originate from within the financial system and are frequently remedied by restoring confidence. Physical shocks, however, can be remedied only by understanding and addressing the underlying physical causes. Our recent collective experience, whether in the public or the private sector, has been more often shaped by financial shocks, not physical ones. The current pandemic provides us perhaps with a foretaste of what a full-fledged climate crisis could entail in terms of simultaneous exogenous shocks to supply and demand, disruption of supply chains, and global transmission and amplification mechanisms.

Pandemics and climate risk also share many of the same attributes. Both are *systemic*, in that their direct manifestations and their knock-on effects propagate quickly across an interconnected world. Thus, the oil-demand reduction in the wake of the initial coronavirus outbreak became a contributing factor to a price war, which further exacerbated the stock market decline as the pandemic grew. They are both *nonstationary*, in that past probabilities and distributions of occurrences are rapidly shifting and proving to be inadequate or insufficient for future projections. Both are *nonlinear*, in that their socio-economic impact grows disproportionally and even catastrophically once certain thresholds (such as hospital capacity to treat pandemic patients) are breached. They are both *risk multipliers*, in that they highlight and exacerbate hitherto untested vulner-abilities inherent in the financial and healthcare systems and the real economy. Both are *regressive*, in that they affect disproportionally the most vulnerable populations and subpopulations of the world. Finally, neither can be considered a "black swan," insofar as experts have consistently warned against both over the years (even though one may argue that the debate about climate risk has been more widespread). The coronavirus outbreak seems to indicate that the world at large is equally ill prepared to prevent or confront either.

Furthermore, addressing pandemics and climate risk requires the same fundamental shift, from optimizing largely for the *shorter-term performance* of systems to ensuring equally their *longer-term resiliency*. Healthcare systems, physical assets, infrastructure services, supply chains, and cities have all been largely designed to function within a very narrow band of conditions. In many cases, they are already struggling to function within this band, let alone beyond it. The coronavirus pandemic and the responses that are being implemented (to the tune of several trillion dollars of government stimulus as of this writing) illustrate how expensive the failure to build resiliency can ultimately prove. In climate change as in pandemics, the costs of a global crisis are bound to vastly exceed those of its prevention.

Finally, both reflect "tragedy of the commons" problems, in that individual actions can run counter to the collective good and deplete a precious, common resource. Neither pandemics nor climate hazards can be confronted without true *global coordination and cooperation*. Indeed, despite current indications to the contrary, they may well prove, through their accumulated pressures, that boundaries between one nation and another are much less important than boundaries between problems and solutions.

Key differences

While the similarities are significant, there are also some notable differences between pandemics and climate hazards.

A global public-health crisis presents *imminent, discrete, and directly discernible dangers*, which we have been conditioned to respond to for our survival. The risks from climate change, by contrast, are *gradual, cumulative, and often distributed dangers* that manifest themselves in degrees and over time. They also require a present action for a future reward that has in the past appeared too uncertain and too small given the implicit "discount rate." This is what former Bank of England Governor Mark Carney has called the "tragedy of the horizon."[1]

Another way of saying this is that the *timescales* of both the occurrence and the resolution of pandemics and climate hazards are different. The former are often measured in weeks, months, and years; the latter are measured in years, decades, and centuries. What this means is that a global climate crisis, if and when ushered in, could prove far lengthier and far more disruptive than what we currently see with the coronavirus (if that can be imagined).

[1] "Breaking the tragedy of the horizon—climate change and financial stability—speech by Mark Carney," Bank of England, September 29, 2015, bankofengland.co.uk.

Finally, pandemics are a case of *contagion* risk, while climate hazards present a case of *accumulation* risk. Contagion can produce perfectly correlated events on a global scale (even as we now witness), which can tax the entire system at once; accumulation gives rise to an increased likelihood of severe, contemporaneous but not directly correlated events that can reinforce one another. This has clear implications for the mitigation actions they each call for.

Broader relationships

Climate change—a potent risk multiplier—can actually contribute to pandemics, according to researchers at Stanford University and elsewhere.[2] For example, rising temperatures can create favorable conditions for the spread of certain infectious, mosquito-borne diseases, such as malaria and dengue fever, while disappearing habitats may force various animal species to migrate, increasing the chances of spillover pathogens among them. Conversely, the same factors that mitigate environmental risks—reducing the demands we place on nature by optimizing consumption, shortening and localizing supply chains, substituting animal proteins with plant proteins, decreasing pollution—are likely to help mitigate the risk of pandemics.

The environmental impact of some of the measures taken to counter the coronavirus pandemic have been seen by some as a full-scale illustration of what drastic action can produce in a short amount of time. Satellite images of vanishing pollution in China and India during the COVID-19 lockdown are a case in point. Yet this (temporary) impact comes at tremendous human and economic cost. The key question is how to find a paradigm that provides at once environmental and economic sustainability. Much more easily said than done, but still a must-do.

What could happen now?

While we are at the initial stages of a fast-unfolding crisis, we can already start seeing how the pandemic may influence the pace and nature of climate action, and how climate action could accelerate the recovery by creating jobs, driving capital formation, and increasing economic resiliency.

Factors that could support and accelerate climate action

For starters, certain temporary adjustments, such as teleworking and greater reliance on digital channels, may endure long after the lockdowns have ended, reducing transportation demand and emissions. Second, supply chains may be repatriated, reducing some Scope 3 emissions (those in a company's value chain but not associated with its direct emissions or the generation of energy it purchases). Third, markets may better price in risks (and, in particular, climate risk) as the result of a greater appreciation for physical and systemic dislocations. This would create the potential for additional near-term business-model disruptions and broader transition risks but also offer greater incentives for accelerated change.

There may, additionally, be an increased public appreciation for scientific expertise in addressing systemic issues. And, while not a foregone conclusion, there may also be a greater

[2] See Andrew Winston, "Is the COVID-19 outbreak a black swan or the new normal?," *MIT Sloan Management review*, March 16, 2020, sloanreview.mit.edu; and Rob Jordan, "How does climate change affect disease?," Stanford Earth, School of Earth, Energy & Environment, March 15, 2019.

Understanding the similarities, the differences, and the broader relationships between pandemics and climate risk is a critical first step if we are to derive practical implications that inform our actions.

appetite for the preventive and coordinating role of governments in tackling such risks. Indeed, the tremendous costs of being the payer, lender, and insurer of last resort may prompt governments to take a much more active role in ensuring resiliency. As for the private sector, the tide may be turning toward "building back better" after the crisis.[3]

Moreover, lower interest rates may accelerate the deployment of new sustainable infrastructure, as well as of adaptation and resilience infrastructure—investments that would support near-term job creation. And, lastly, the need for global cooperation may become more visible and be embraced more universally.

If past is prologue, both the probability of such shifts and their permanence are likely to be proportional to the depth of the current crisis itself.

Factors that may hamper and delay climate action

Simultaneously, though, very low prices for high-carbon emitters could increase their use and further delay energy transitions (even though lower oil prices could push out a number of inefficient, high-emission, marginal producers and encourage governments to end expensive fuel-subsidy regimes). A second crosscurrent is that governments and citizens may struggle to integrate climate priorities with pressing economic needs in a recovery. This could affect their investments, commitments, and regulatory approaches—potentially for several years, depending on the depth of the crisis and hence the length of the recovery. Third, investors may delay their capital allocation to new lower-carbon solutions due to decreased wealth. Finally, national rivalries may be exacerbated if a zero-sum-game mentality prevails in the wake of the crisis.

What should be done?

In this context, we believe all actors—individuals, companies, governments, and civil society—will have an important role.

[3] María Mendiluce, "How to build back better after COVID-19," World Economic Forum, April 3, 2020, weforum.org.

For governments, we believe four sets of actions will be important. First, build the capability to model climate risk and to assess the economics of climate change. This would help inform recovery programs, update and enhance historical models that are used for infrastructure planning, and enable the use of climate stress testing in funding programs. Second, devote a portion of the vast resources deployed for economic recovery to climate-change resiliency and mitigation. These would include investments in a broad range of sustainability levers, including building renewable-energy infrastructure, expanding the capacity of the power grid and increasing its resiliency to support increased electrification, retrofitting buildings, and developing and deploying technologies to decarbonize heavy industries. The returns on such investments encompass both risk reduction and new sources of growth. Third, seize the opportunity to reconsider existing subsidy regimes that accelerate climate change. Fourth, reinforce national and international *alignment and collaboration* on sustainability, for inward-looking, piecemeal responses are by nature incapable of solving systemic and global problems. Our experiences in the weeks and months ahead could help inform new paths toward achieving alignment on climate change.

For companies, we see two priorities. First, seize the moment to decarbonize, in particular by prioritizing the retirement of economically marginal, carbon-intensive assets. Second, take a systematic and through-the-cycle approach to building resilience. Companies have fresh opportunities to make their operations more resilient and more sustainable as they experiment out of necessity—for example, with shorter supply chains, higher-energy-efficiency manufacturing and processing, videoconferencing instead of business travel, and increased digitization of sales and marketing. Some of these practices could be expedient and economical to continue, and might become important components of a company-level sustainability transformation—one that accompanies the cost-efficiency and digital-transformation efforts that are likely to be undertaken across various industries in the wake of the pandemic.

When it comes to resilience, a major priority is building the capability to truly understand, qualitatively and quantitatively, corporate vulnerabilities against a much broader set of scenarios, and particularly physical events. In that context, it will also be important to model and prepare for situations where multiple hazards would combine: it is indeed not difficult to imagine a pandemic resurgence coinciding with floods or fires in a given region, with significant implications for disaster response and recovery. The same holds true for public entities, where resilience thinking will have to take greater account of the combination and correlation of events.

For all—individuals, companies, governments, and civil society—we see two additional priorities. First, use this moment to raise *awareness* of the impact of a climate crisis, which could ultimately create disruptions of great magnitude and duration. That includes awareness of the fact that physical shocks can have massive nonlinear impacts on financial and economic systems and thus prove extremely costly. Second, build upon the *mindset and behavioral shifts* that are likely to persist after the crisis (such as working from home) to reduce the demands we place on our environment—or, more precisely, to shift them toward more sustainable sources.

By all accounts, the steps we take in the decade ahead will be crucial in determining whether we avoid runaway climate change. An average global temperature rise above 1.5 or 2°C would create risks that the global economy is not prepared to weather. At an emission rate of 40 to 50 gigatons of CO_2 per year, the global economy has ten to 25 years of carbon capacity left. Moving toward a lower-carbon economy presents a daunting challenge, and, if we choose to ignore the issue for a year or two, the math becomes even more daunting. In short, while all hands must be on deck to defeat the coronavirus and to restart the economy, to save lives and livelihoods, it is also critical that we begin now to integrate the thinking and planning required to build a much greater economic and environmental resiliency as part of the recovery ahead. Q

Dickon Pinner and **Matt Rogers** are senior partners in McKinsey's San Francisco office, and **Hamid Samandari** is a senior partner in the New York office.

‘Bring the problem forward’: Larry Fink on climate risk

The physical impact of climate change will lead to a major capital reallocation, says the head of BlackRock, the world’s largest asset manager.

During a 40-year career, BlackRock CEO Larry Fink has learned that financiers seldom ignore risks to their businesses: “Once they recognize a problem,” says Fink, “they bring that problem forward.” Fink himself has made a practice of bringing problems to the fore in his yearly letters to CEOs and clients. When he focused on climate risk in his 2020 letter to CEOs and a related letter to clients from BlackRock’s global executive committee, citing work by McKinsey and others, he sought to advance a discussion that he’d seen accelerate during the previous year—and to spur executives and policy makers to act. In this commentary, adapted from an interview with McKinsey’s Rik Kirkland in February 2020, Fink expands on certain themes from his 2020 letters, including the threats that climate change poses to the poor and vulnerable, the diverging interests of advanced and developing countries, the importance of fair policy solutions, and the value of better nonfinancial reporting.

The *Quarterly*: *Why did you choose to concentrate on climate risk in your CEO and client letters this year?*

Larry Fink: Throughout the year, and more frequently as the year progressed, the question of climate change was raised by all our clients throughout the world, whether in Saudi Arabia or in Houston or in Sacramento or in Europe. And it was raised not just by our clients but by regulators and government officials. At the same time, we were witnessing more evidence of the physical impact from climate change. All this really hit me when I was sitting down to write my CEO letter, which I generally try to do right after the August break.

I was just writing down all the themes that I wanted to talk about. Climate risk was actually not a major component of the first draft. But then, in September, when I had meetings with the UN [United Nations] in New York City and then with the IMF [International Monetary Fund] in Washington, the urgency of the conversation became very clear to me.

The *Quarterly*: *What were you hearing from your clients? What keeps them up at night?*

Larry Fink: As finance now starts looking at potential climate risks, it raises so many different capital-allocation questions. One great question was asked by a client—I’d say among the smartest clients we have worldwide. This client said, “We never think about climate change as a risk. And yet we've been great investors over the long run because our time frame is ten to 15 years. Now, through the lens of sustainability and climate impact, how do I think about our strategy for today? Can we expect the same type of positive outcomes and liquidity? Should we factor in the physical impact on some of our investments—whether physical investments, like real estate, or municipal investments in cities and states?"

They raised many large questions about whether they should think about investing differently and whether they should add the lens of climate risk to their long-term investment strategy. And the answer is yes.

The *Quarterly*: *A key point you made in your letters is that we may see a "fundamental reshaping of finance," with a significant reallocation of capital "in the near future." How will that happen? Can you give an example?*

Larry Fink: Well, if 5 percent or 10 percent or 20 percent of our clients are starting to ask these questions and trying to design strategies to effectuate the climate theme over a long horizon, that in itself is a capital reallocation. We're hearing this in our conversations with insurance companies, which are looking at climate change and how they should insure. That represents a major societal issue that's unfortunately very regressive. We don't talk about how regressive this could become.

Larry Fink

is the founder, chairman, and CEO of BlackRock. Before founding the asset-management company, in 1988, Fink was a member of the Management Committee at The First Boston Corporation and served as a managing director there. Fink is a member of the board of trustees for the World Economic Forum.

In the United States, insurance rates are generally set by state insurance commissioners. It's very hard for an insurance company to raise rates extensively even if it thought a jurisdiction may have real, physical climate risk. So, suppose you buy a house, and you think you're going to live in that house for 20 years. Your insurance has to be renewed every year. But the house is in an area where the insurance company does not have the ability to raise rates unless reinsurance rates are raised. Ultimately, it'll be able to raise rates. In the interim, it may say, "I can't provide you with coverage anymore." Then you have this long-term asset that you want to protect, but the insurance companies may not insure you. That is another form of capital allocation and reallocation.

And we're starting to see more evidence of climate change and its impact on capital allocation. I do believe that if you're a long-term investor, you'd better frame all your investments through that lens.

The *Quarterly*: *Are investors able to do this now? And if they can't, why not?*

Larry Fink: Investors need more transparency. This is why in my letter I asked for greater disclosure, using SASB [Sustainability Accounting Standards Board] and TCFD [Task Force on Climate-related Financial Disclosures]. The key is gaining the ability to compare and contrast different companies. We could use that transparency to assess company A with respect to company B, or industry A with industry B, and try to come up with a better strategy.

Most investors are not going to abandon hydrocarbons, but they want a portfolio that will be more persistent in a more sustainable way. If it's possible to score how every company is doing, investors are going to look to us to be actively investing and searching for a better portfolio composition with higher sustainability or ESG [environmental, social, and governance] scores. That's what we're going to do. And that's where I do see huge movement.

The *Quarterly*: *You make the point that most investors won't abandon hydrocarbons. Why not? And what are the implications of that?*

Larry Fink: If we believe we can stop using coal today, we're fooling ourselves. There are more coal plants being built—countries are adding new coal plants right now. We don't want to talk about that. We don't want to think about it, but that's the reality. The answer is not to think that we can just run away from coal worldwide. It is to create better science and technology to find ways to help make coal cleaner.

As much as we may change our behavior in the United States as a very wealthy country, and as much as Canada and Europe might change their behavior, there are many parts of the world that are just beginning their growth curve and their wealth creation. It's very hard for us to be judging them on their economic path. And there lies the problem. We could do all that we are potentially able to do, and even that will not be enough, because so many other parts of the world are just adding more and more carbon to our air. That's not going to change anytime soon. So we need to be fair and just. We need to be open-minded.

The *Quarterly*: *The need for "fair and just" policy solutions is something you wrote about in your letters. What do you mean by that?*

Larry Fink: One of the biggest tools that governments could use—one of the biggest tools the environmental groups are recommending—is a carbon tax. A carbon tax is an incredibly regressive way of taxing people. The wealthy are not impacted as much as the less fortunate, who are trying to meet their budgets every day and have to pay higher heating bills. A carbon tax makes their lives much more difficult. This is why I've said we need to work with governments to try to minimize how regressive the impact of climate change is going to be.

We need to make sure that if there is a carbon tax, all the money is going to renewables and redistribution. And there should be some type of credit back to those people who

“We’re starting to see more evidence of climate change and its impact on capital allocation. If you’re a long-term investor, you’d better frame all your investments through that lens.”

—Larry Fink, CEO of BlackRock

cannot afford to pay the tax. The problem is that in so many states, a component—if not all—of the carbon tax would be used to fill a budget gap. This is where we need the combination of public and private working together. We should have a plan so that all that added tax would not go to fill our deficits, but would go for infrastructure spending, renewable technology, and redistribution.

There’s another issue we haven’t even spoken about. If the science is right about climate change, the impact on the subtropical and equatorial parts of the world will be devastating—the density of the population is so heavily oriented to the equatorial parts of the world. That’s also going to be the area that’s most harmed. We have to have this conversation. We have to be thoughtful about it. And if I’m right about finance moving this forward, this problem is probably coming sooner than later.

The *Quarterly*: *What will it take to address these issues? Are we ready?*

Larry Fink: I’ve witnessed five or six different crises in my career. Some of them were quite severe. All of them were financial in nature, whether it was the high-yield crisis or the dot-com crisis or the Thai crisis of 1997–98, the real-estate crises, and the Great Recession. We were able to mitigate these crises and reduce their severity through monetary policy. In unison, all the central banks tried to correct these financial difficulties. In most cases, the duration of these crises was short. Sometimes they were very severe. Many families were impacted. But the crises were short.

When you start thinking about climate-change impact, whether you believe in 5 percent of the science or 100 percent of the science, it becomes apparent that we don’t have a global government body to arrest this problem. This is going to require every government, small and large, to start finding ways of mitigating it. Q

The remarks here from Larry Fink have been adapted from a February 2020 interview conducted by **Rik Kirkland,** a partner in McKinsey’s London office.

Taking ownership of a sustainable future

Three CEOs offer lessons on their pursuit of sustainability.

by CB Bhattacharya

At the height of his career in 1994, Ray Anderson, the former CEO of carpet manufacturer Interface, was asked by a customer: "What is your company doing for the environment?" This question would come to define the rest of his life and what he would later call his "midcourse correction." Anderson discovered for the first time that Interface was doing more harm than good to the environment and came to describe himself as a "plunderer." Awakened and with an urgent need to set a new course for Interface, he committed the company to becoming the world's first environmentally sustainable—and, ultimately, restorative—carpet manufacturer, shaking the foundations of the petroleum-intensive carpet-manufacturing industry in the process. Thereafter, he went on a quest to prove that sustainability was not just the right thing to do but also the smart thing

to do. He set aggressive zero targets in many areas: zero waste to landfill, zero fossil fuel energy use, zero process water use, and zero greenhouse-gas emissions. Today, Interface is a "mission zero" company with zero environmental footprint.

Anderson's story illuminates the visceral need at the heart of leadership: to drive change for the better. Confronted daily with media reports about climate change and other environmental ills, some corporate leaders today are uncomfortably numb and find themselves asking whether they are doing enough. Despite genuine interest in tackling the problem and becoming part of the solution, many still suffer from collective inertia—some wait or hope for other companies or governments to respond, while others just don't know where to start, or even don't realize there is a lot more they could do. After numerous interviews with top-level executives, senior managers, and a host of employees from dozens of publicly listed companies across the world, my research revealed that senior leaders making real progress on the sustainability front are those who tackle it with what organizational psychologists refer to as an ownership mentality. Simply put, they "own" the problem and then extend and infuse the feelings of ownership and connection across their organization and to the external world.[1]

Ownership is an inherent part of the human condition; as Jean-Paul Sartre famously said: we are what we have.[2] By taking ownership of sustainability, and by instilling that sense of ownership among colleagues across the organization and beyond, leaders can create meaningful solutions to the complex problems we face today. The journey to sustainability ownership varies from leader to organization. But we can get a useful sense of these journeys through the stories of pathfinding CEOs, some of whom I interviewed for my latest book, *Small Actions, Big Difference* (Routledge, October 2019). In what follows, you'll find lessons distilled from the journeys taken by Enel CEO Francesco Starace, former Coca-Cola Enterprises[3] chairman and CEO John F. Brock, and former Unilever CEO Paul Polman, each of whom illustrates different facets of the dramatic and lasting impact that can emerge when leaders own sustainability. As you read their stories, ask yourself: What might your particular quest look like, and how will you own up to it?

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[1] Organizational scholars define psychological ownership as the feelings of possessiveness and connection that we develop toward an appealing object, such as a person, company, or even an idea. We express these feelings with terms like "my," "mine," and "our."

[2] The philosopher Jean-Paul Sartre once wrote, "The totality of my possessions reflects the totality of my being. I am what I have. . . . What is mine is myself." Jean-Paul Sartre, *Being and Nothingness: A Phenomenological Essay on Ontology*, trans. Hazel E. Barnes, New York, NY: Washington Square Press, 1956.

[3] In May 2016, Coca-Cola Enterprises merged with two other Coca-Cola bottling plants to create Coca-Cola European Partners, the largest independent Coca-Cola bottler based on revenues. John Brock stepped down as CEO at the end of 2016.

Enel's CEO on facing reality with purpose

Francesco Starace, chief executive of Enel, a company transformed under his leadership from a large, traditional electric utility into a renewable-energy powerhouse, told me a story from the 1980s, when he was still a middle manager, in a remote corner of the Middle East, building a power plant with a team of engineers. His company at the time was transporting crude oil to power the plant, one truck at a time. This had him scratching his head. "You had all the trucks coming down, unloading the oil to fuel the plant. And there was a transmission line from the plant—but there was no load to feed,"[4] Starace recalled.

After looking into the matter a bit, Starace discovered that the power plant was the cornerstone of a dubious social-engineering effort. "The idea was that the whole area needed to be electrified. Houses needed to be built, air-conditioning needed to be put in these houses, so that the nomad tribes living in the area would finally stop moving around and sit in these air-conditioned homes and watch TV." None of it made any sense to him—neither the social experiment itself nor the building of a power plant to fuel it—and he could further see that the idea of trucking in fuel oil to the desert was hardly sustainable.

Decades later, he remembers this experience as an epiphany: it was the first time he had begun thinking about the sustainability of an energy company, about how it fit into a bigger picture, about whether its approach could be sensibly carried forward into the future. At this moment, with this experience in a remote part of the desert, a spur formed that began digging into his flank thereafter. He began broadening his view of corporate purpose to extend beyond profit. He began weighing financial interest against its social and environmental costs and effects. And, before long, he came to realize that an energy company's business could not center around the cultivation of new habits in specific groups of people simply to boost their consumption of electricity. Instead, an energy company's business had to involve asking these groups what use they could make of electricity. He began to rethink why an energy company does what it does, and for whom, and for what purpose. He began broadening his understanding of why business exists in society and realized that businesses are worth preserving to the extent that they contribute to causes bigger than themselves. And from this insight a guideline emerged: businesses must put purpose before profit.

As his career progressed, Starace came to further see that purpose and profit were in fact closely aligned. He saw how purpose, contoured with the values and mindsets of sustainability, could in fact drive profit. From there, his own role became clear, too: it was up to him to own the journey that would take his company from one driven solely by profit to one in which purpose fueled profitability. He explained to me when we spoke that "it's not because we want to change things that we do it; we do it because it is the only thing we can do going forward, there is no other alternative."

This journey from real-world epiphany to questioning a company's purpose is one that many of the top executives I interviewed have encountered. Personal experience

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[4] The load of a power plant is the level of demand for electricity from customers.

> **“You have to face up to the facts about why you do what you do.”**
>
> **—Francesco Starace, CEO of Enel**

often has more impact on a person’s behavior than a rational argument or an abstract concept. Working in communities affected by climate change, going to the front lines to see firsthand how consumers are affected by a company’s products and services, and talking to employees about the future of their children and grandchildren—these are all time-tested ways in which newfound purpose comes to life. Crossing an emotional barrier, as Starace did in the 1980s, and identifying with a company’s purpose in a new and very personal way enables leaders to build their personal sense of sustainability ownership and address the critical problems of our world. Ultimately, as Starace told me, “You have to face up to the facts about why you do what you do.”

Actions speak louder than words for the former CEO of Coca-Cola Enterprises

John Brock, then CEO of Coca-Cola Enterprises (CCE, now Coca-Cola European Partners), told me in 2015: “If you go back ten years, the question was, ‘What the hell’s a carbon footprint?’ I mean, ten years ago, it was not even on the radar, except in limited circles.” Today, calculating carbon footprints not only is popular for companies but has gained traction among individuals, too. Brock describes his sustainability journey as a long personal commitment that morphed and changed over time starting back in the 1980s while he was at Cadbury-Schweppes in London. “It’s fair to say my definition of sustainability at the time was meaningfully narrower than it is today.” Previously focused on simply making good decisions for the future of the planet, Brock describes his evolution of thinking to incorporate social issues such as gender and ethnic diversity and community service and well-being: “Being responsible and relevant to the communities in which we operate. And working with them to help understand what we can do and they can do together.”

When I asked, “What do you need to get sustainability going?” Brock’s response to leaders was clear: decide what’s important, communicate it, and act on it. “If you have the personal commitment but aren’t willing to invest the time, money, and resources, it’s not going to happen. And if you don’t have the personal commitment, even if you invest the time, money and resources, it won’t happen.” Brock himself was known for pounding his message of sustainability every chance he could. “I don’t ever give a speech—and frankly nor do any of my senior team members—without talking about sustainability. It’s just a constant pound, pound, pound.”

Turning personal commitment into action is one way to own the problem, but where to start? Sustainability is about myriad initiatives and projects, across every site a company has, in the back and front offices, and in any number of places beyond the office and factory walls. The number of potential points of focus, and the exponential number of combinations, makes this task very difficult and overwhelming. It's easier to do nothing, or to continually push back the start date.

One way that leaders can break this impasse is by asking a series of questions aimed at establishing concrete priorities for sustainability: Where is the company's growth likely to come from in the future? What trends will affect demand for our products and supply of our raw materials? What do customers, employees, suppliers, and investors want from the business? The leadership team should also look at hard issues such as water use, waste generation, carbon-dioxide emissions, and labor conditions.

This concretizing process gives leaders the chance to bring stakeholder views into the organization, and it allows senior leaders to become more forward-looking. Brock championed this process and, to reflect its importance, increased the frequency with which the board's corporate-sustainability committee gathered from twice a year to every time the board met. "It's the personal commitment, and then it's turning that personal commitment—through whatever it takes—into action. That's what has to happen."

Unilever's former CEO knows you can't go it alone

Through his public actions and declarations as the former CEO of Unilever, it is clear that from the start of his career Paul Polman has had a deep sense of duty to society and the world. Intending to be a priest or doctor, he eventually settled on economics and business as the best way to improve people's lives.[5] But it was while looking into his children's eyes that Polman's desire to tackle climate change and inequality, to ensure their future well-being, gathered real urgency.[6] Since then, he has been on a crusade, galvanizing support for sustainability. During our conversation, Polman explained, "Leadership for me is not just driving a company, [it's] about making it do the right thing. It's really about helping to transform entire markets and behaviors beyond those your own company is engaged in to the benefit of all." True leadership in turbulent times is about having the vision and fortitude to establish a new normal.

Polman clearly sees the need for collective action. As he told me, "At the end of the day, the issues that we need to solve are so big that no one can do it alone." Many of the top executives I spoke to agreed that an important first step to driving sustainability efforts is for leaders to move past individual ownership of very big problems and to turn them into collective-ownership issues. There are fewer and fewer problems specific to any one company, industry, or even country. As a result, global initiatives—preventing climate change, deforestation, or declining biodiversity—demand that we take a collective approach toward ownership.

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[5] "Paul Polman launches sustainability consulting firm Imagine," Consultancy.org, July 17, 2019, consultancy.eu.

[6] Jo Confino, "Moments of revelation trigger the biggest transformations," *Guardian*, November 9, 2012, theguardian.com.

The systemic nature of these challenges, and the fact that solutions are often not apparent or straightforward, make the need for collaboration even stronger. But that in itself can be tricky. As Polman explained, “There’s a fine line between arrogance and self-confidence, between humility and humanity, when you implement programs with external collaborators.” The size and skill that large companies can bring to the table may at times inadvertently overpower the voices of others. Balancing the need to push progress at a steady pace without undermining your partners becomes ever more important to solving the problems at hand.

Polman went on to say: “Global warming is a complex issue not fully understood by many leaders. You have to be a very good systemic thinker to deal with it. Rather than worry about it, you need to think about how you are going to adapt your business model or how you can make transformational change happen.” The “how” becomes the most important thing, not the “what.” Climate change is our problem and it needs our collective solution.

Challenged with the existential crisis of our times, corporate leaders must avoid inertia and take ownership of sustainability. As in the examples here, through a journey of personal transformation, many leaders today are reimagining their company’s corporate purpose and the role of business in society and reinforcing the sense of sustainability ownership through a course of action both internally and externally that benefits not only people and planet but also profit. When you take ownership of sustainability, you bring to life a new leadership mandate for you and your top team. What are you waiting for? Q

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Feeding the world sustainably

A burst of technology in the 1960s—the Green Revolution—raised agricultural output significantly across developing economies. Since then, rising incomes have boosted protein consumption worldwide, and brought new challenges: greenhouse-gas emissions from agriculture are rising (more than a fifth of all emissions worldwide), while a host of practices, from waste to overfishing, threaten the sustainability of food supplies.

Innovation and advanced technologies could again make a powerful contribution in the years ahead. For example, digital and biotechnologies could improve the health of ruminant livestock, requiring fewer, methane-producing animals to meet the world's protein needs. Genetic technologies could play a supporting role by enabling the breeding of animals that produce less methane. Meanwhile, AI and sensors could help food processors sort better and slash waste, and other smart technologies could identify inedible by-products for reprocessing. Data and advanced analytics also could help authorities better monitor and manage the seas to limit overfishing—while enabling boat crews to target and find fish with less effort and waste. Agriculture is a traditional industry, but its quest for tech-enabled sustainability offers valuable lessons.

Agriculture takes center stage in the drive to reduce emissions

Cross-sector investment opportunities will lead the way.

by Daniel Aminetzah, Joshua Katz, and Peter Mannion

More than one-fifth of the world's greenhouse-gas (GHG) emissions stem from agriculture—over half from animal farming.[1] Unless these emissions are actively addressed, they will probably increase by 15 to 20 percent by 2050 as the Earth's population rises and the need for food continues to grow. Limiting the impact of climate change will require shifts in what we eat, how much we waste, and how we farm and use our land.

There is no clear path to fully eliminating agricultural emissions. Nonetheless, a wave of transformation is within reach of the food industry and the broader agricultural market. Historically, agricultural innovation has arisen at points of intersection with other industries as creative firms borrowed and built on advances in areas such as human health, chemicals, advanced engineering, software, and advanced analytics. Cross-cutting opportunities portend the next wave of innovation to reduce agricultural emissions by capturing food-process efficiencies (exhibit).

While the abatement costs vary and the market opportunities continue to evolve, mitigation measures could reduce emissions by about 20 to 25 percent by 2050.[2] In this article, we highlight the top three cost-negative or cost-neutral measures in which business actors will play a critical role. Scaling up these solutions will require investment, technological innovation, and behavioral change—particularly among farmers around the world.

Zero-emissions farm equipment

The largest amount of emissions abatement from a single measure can be achieved by shifting from traditional fossil-fuel equipment—such as tractors, harvesters, and dryers—to their zero-emission counterparts. This transition alone would realize cost savings of $229 per ton of carbon-dioxide equivalent (tCO_2e)[3] and transform the $139 billion global agricultural-equipment industry.

Unfortunately, the current market penetration of zero-emission equipment is lower in farming than it is in consumer vehicles: market leaders are only at the stage of piloting proofs of concept. The right investments by machinery manufacturers would make it possible to achieve total-cost-of-ownership parity between, for example, tractors powered by internal-combustion engines and tractors powered by zero-emissions sources (such as battery

[1] Does not include land use, land-use change, and forestry. Non-CO_2 emissions converted using 20-year global-warming-potential (GWP) values based on the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC).

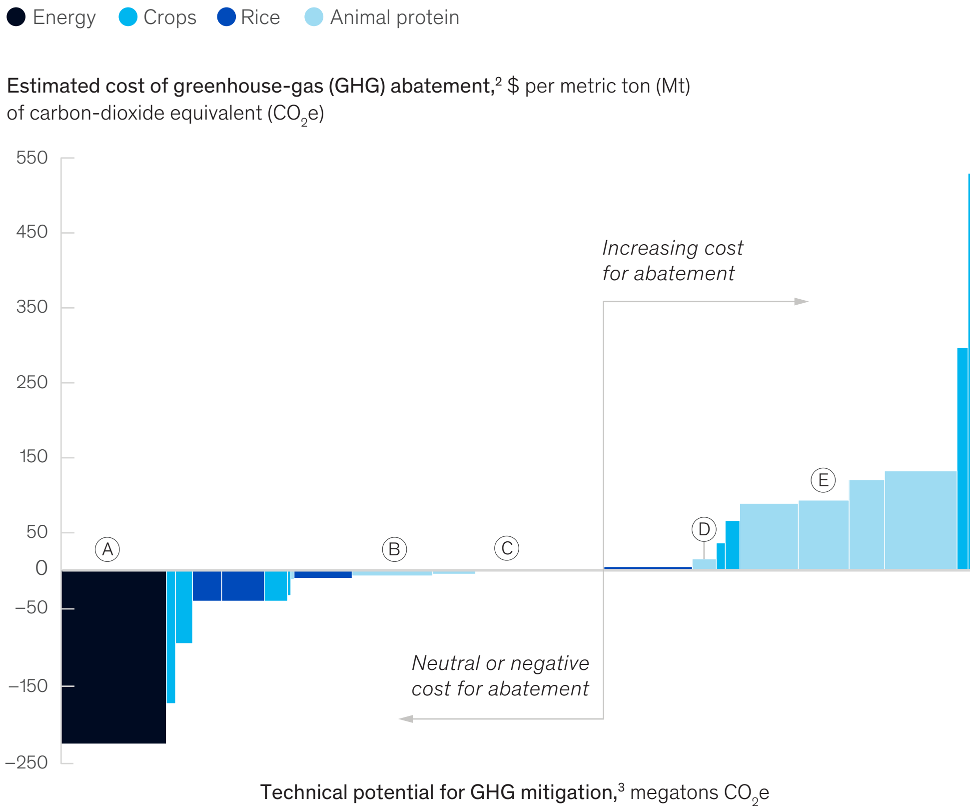
[2] For more, see *Agriculture and climate change: Reducing emissions through improved farming practices*, on McKinsey.com.

[3] Used to compare emissions of greenhouse gases.

Exhibit

Abatement measures in agriculture open up cross-sector opportunities—including opportunities that either save money or are cost neutral.

Top 25 mitigating measures for agriculture[1] and associated abatement costs



Some abatement measures offer cross-sector investment opportunities beyond agriculture. For example:

(A) Automotive
Transition to zero-emissions farm machinery and equipment
–$229/Mt$CO_2$e

(B) Animal health/ pharmaceutical
Improved health monitoring and illness prevention
–$5/Mt$CO_2$e

(C) Genetics
GHG-focused breeding and genetic selection
0/MtCO_2e

(D) Chemicals
Apply nitrification inhibitors on pasture
+$15/Mt$CO_2$e

(E) Energy
Expand use of anaerobic manure digestion
+$92/Mt$CO_2$e

[1] Implementing all 25 measures would reduce GHG emissions from agriculture by 20%.
[2] Based on 20-year global warming potential (GWP) cited in fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC).
[3] Based on 100-year GWP cited in IPCC's fifth assessment report.

electric power) by around 2030.[4] Like early investors in passenger electric vehicles (EVs), investors in agricultural EV technology are now poised to benefit from first-mover advantage. AGCO's Fendt, Rigitrac, and Escorts' Farmtrac each showcase electric-tractor models, and John Deere has battery-run and corded electric-tractor prototypes. If electric farm equipment captured just 10 percent of the 2030 market, this would represent an opportunity of $13 billion.

Battery capacity and charging speeds have been the main obstacles to the adoption of electric farm equipment. However, battery weight is less problematic for farm equipment than for passenger vehicles. A rapid reduction in prices for batteries, which alone account for up to 40 percent of tractor-component costs, will help further overcome adoption barriers.[5]

Animal health monitoring

As our colleagues have noted, achieving a 1.5-degree warming pathway[6] would require a significant reduction in human consumption of animal protein (for more, see "Climate math: What a 1.5-degree pathway would take," on page 26). The agricultural sector has a major role to play by meeting the world's animal-protein needs with fewer, healthier animals that generate lower emissions from enteric fermentation and by improving manure management. These steps could reduce emissions by more than 400 million tons of carbon-dioxide equivalent ($MtCO_2e$) by 2050 (realizing savings of $5 per tCO_2e) and generate productivity benefits that would improve agricultural economics.

Emerging biological technologies and computational capabilities, such as gene sequencing and artificial intelligence, enable farmers to detect disease early—and even prevent it—by applying predictive algorithms to existing and new sources of data. For example, Moocall, an Irish company collaborating with Vodafone, aims to reduce cow mortality rates from birth-related complications by up to 80 percent by placing (on the animal's tail) a palm-sized sensor alerting farmers to how long a cow has been calving. In North America, which has the third-largest cow inventory (after Brazil and China), overall cattle-herd productivity improvements could reach 8 percent.[7]

However, implementing these technologies has proved to be expensive, and they are not yet well understood or embraced by farmers. Moreover, health challenges vary greatly by region and species, so a silver bullet is unlikely. Innovative business models and commercial investment will be required to overcome these barriers: for example, the global technology company Fujitsu has developed an algorithm-based "connected cow" service to make milk production more profitable.[8] We expect more commercial investment in coming years, given the continued decline in the cost of such technologies and their multiple applications, including new vaccinations and advanced diagnostics.

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[4] See Markus Forsgren, Erik Östgren, and Andreas Tschiesner, "Harnessing momentum for electrification in heavy machinery and equipment," April 2019, McKinsey.com.

[5] See Forsgren et al., "Harnessing momentum."

[6] A 1.5-degree pathway is an estimate of the extent of change required by each sector of the global economy to curb increases in greenhouse-gas emissions sufficiently and limit temperature increases in the years ahead to 1.5 degrees Celsius above preindustrial levels—a level of increase that, scientists estimate, would reduce the odds of initiating the most dangerous and irreversible effects of climate change.

[7] "Study to model the impact of controlling endemic cattle diseases and conditions on national cattle productivity, agricultural performance and greenhouse gas emissions," ADAS, February 2015, randd.defra.goc.uk.

[8] "Akisai Food and Agriculture Cloud GYUHO SaaS (cattle breeding support service)," Fujitsu, fujitsu.com.

Achieving a 1.5-degree-warming pathway would require a significant reduction in human consumption of animal protein.

GHG-focused breeding

New breeding programs using sophisticated genetic-selection capabilities can help curb enteric fermentation, potentially reducing overall emissions by 500 $MtCO_2e$ at virtually no cost by 2050. Today, breeding for methane efficiency has achieved a 20 percent variation in methane production. More GHG-focused programs will be possible as increasing demand for animal protein continues to drive growth in the animal genetic-products market (worth $4.2 billion in 2018).

While genetic-breeding programs are still in their infancy, government and industry are leading the effort to drive adoption. In November 2019, a consortium funded by the New Zealand agricultural sector and the country's govern-ment launched a "global first" genetics program to breed sheep that produce less methane per mouthful of grass.[9] Even with such programs, large-scale adoption throughout the industry will require economic incentives: market payments or credits for methane reductions.

To implement solutions at scale, additional investments will be needed in genetic-selection capabilities to address the immaturity and lack of breed-specificity of most genetic programs. New breeding techniques, such as those using CRISPR-Cas9,[10] could lower barriers to entry for innovators and allow for more specificity.

A new agricultural ecosystem will be needed to mitigate the increase in agricultural GHG emissions while meeting the world's food needs. In the near term, the reduction of emissions will depend largely on today's technologies and opportunities. But next-horizon technologies (such as gene editing, novel feed additives, and aerobic rice) are also needed. Players in industries ranging from automotive and energy to pharmaceuticals have important roles to play. It will take a village to feed our global village. Q

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For the full report on which this article is based, see Agriculture and climate change: Reducing emissions through improved farming practices*, on McKinsey.com.*

[9] "Sheep farmers now able to breed 'low-methane' sheep," Pastoral Greenhouse Gas Research Consortium, pggrc.co.nz.

[10] A new technology that allows editing of DNA sequences.

Using artificial intelligence in the fight against food waste

AI can help accelerate the move toward a circular economy in the agricultural sector.

by Anna Granskog, Eric Hannon, and Chirag Pandya

Roughly one-third of all food is wasted before it is consumed by people. The methane emissions that result are 86 times more potent in driving temperature increases than CO_2 emissions are, when looking over a 20-year time frame.[1] Emerging applications for artificial intelligence (AI) are helping to create opportunities for "designing out" food waste in the value chain: from farming, processing, and logistics to consumption. In effect, AI can accelerate the transition to an agricultural circular economy, in which growth is decoupled from the consumption of finite resources. Circular-economy principles, which historically have taken root slowly and gradually, rest on designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. Here are three areas where AI has the potential to jump-start a circular economy in agriculture, while potentially unlocking more than $100 billion in value for players globally.[2]

Efficient farming practices

AI can help farmers avoid expensive and time-consuming field trials by identifying the best-performing regenerative agriculture practices. For example, CiBO Technologies uses data analytics, statistical modeling, and AI to simulate field trials and agricultural ecosystems under different conditions. Global stakeholders could learn to improve profitability and sustainability by exploring possible outcomes virtually without the risk of damaging the environment or sacrificing yield. Combining AI algorithms with robotic technologies can further automate and increase control in the farming process. For instance, AI can be used to interpret images of crops, such as strawberries, to help determine when food should be harvested; the harvesting, in addition, can be done with autonomous robots. This might reduce food waste in the field, and it could enable more accurate yield forecasting by improving information along the supply chain and by maximizing storage and cooling facilities.

Reducing food waste

AI algorithms can help with food sorting during processing by analyzing images and data from cameras, X-rays, lasers, and near-infrared spectroscopy. The ability to automatically sort nonuniform produce, such as carrots and potatoes, can reduce waste by sorting for best use, size, shape, and quality, removing a manual process that can be time consuming,

[1] Francois-Marie Breon et al., "Anthropogenic and natural radiative forcing," *AR5 climate change 2013: The physical science basis*, Intergovernmental Panel on Climate Change (IPCC), 2013, fifth assessment report, Chapter 8, ipcc.ch.

[2] For more, see *Sustainability blog*, "How AI can unlock a $127B opportunity by reducing food waste," blog entry by Clarisse Magnin, March 27, 2019, McKinsey.com.

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expensive, and inaccurate. Some companies, such as Wasteless, are helping supermarkets and other retailers sell food before the expiration date by using AI-enabled tracking and dynamic pricing. In institutional and restaurant settings, new tools are now being used to capture, track, and categorize data on food waste. What's more, algorithms can forecast and predict sales, enabling restaurants, retailers, and other hospitality institutions to connect supply to demand more effectively.

Repurposing inedible nutrients

Even if all surplus food were redistributed, a large volume of inedible by-products, along with food waste, would continue to be generated. Could these organic materials contain value that could be repurposed? The Massachusetts Institute of Technology's Senseable City Lab and the Alm Lab, for instance, are offering a glimpse of the potential with their Underworlds prototype smart-sewage platform. The platform combines physical infrastructure and biochemical measurement technologies with artificial intelligence to interpret and act on findings about the pathogens in human sewage; eventually this knowledge could repurpose sewage for use in regenerative food systems.

AI is poised to play an important role for agriculture in the transition to a circular food system. It could revolutionize the way food is grown, harvested, distributed, and enjoyed. As more data sources become available and as computational capabilities grow, AI could help match food supply and demand more effectively, improve supply-chain efficiency, and curb overproduction, overstocking, and waste. Q

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This piece is based on the report Artificial intelligence and the circular economy: AI as a tool to accelerate the transition*, written in collaboration with the Ellen MacArthur Foundation and Google, with research and analytical support provided by McKinsey & Company.*

Making fisheries sustainable—and profitable—with advanced analytics

Data and digital technologies could transform a traditional industry while helping stem the damage to ocean ecosystems.

by Julien Claes, Elin Sandnes, and Antoine Stevens

Gathering data and applying the power of advanced analytics can help tackle problems in surprising ways. The distressed state of the oceans is a case in point. Decades of overfishing is depleting the oceans at an alarming rate, at a time when the emerging world increasingly depends on seafood for protein. Finding a more sustainable means of fishing while preserving ocean ecosystems is a sprawling problem. The fishing industry is feeling the effects: today, it takes five times the effort to haul in a catch as it did in 1950.[1] We looked at how fisheries, government authorities, and food companies could deploy advanced analytics to improve monitoring and raise the efficiency of their operations. In addition to giving the fishing industry new tools for more profitable, sustainable operations, there's also a climate bonus: reeling in a ton of fish protein has less than a tenth of the greenhouse-gas intensity of equivalent protein harvested from ruminant livestock.

Oceans in danger

The demand for fish is growing twice as fast as the world's population growth rate. As boats trawl for a profitable haul, they are moving into new and deeper waters. Yet the catch is declining, with aquaculture rising steadily to meet demand (Exhibit 1). The effect on the ecosystem is stark: half of the world's fish species stocks are overexploited, rebuilding, or collapsing (Exhibit 2). This degradation in biodiversity comes on top of the effects of climate change, which are warming oceans and changing their chemistry.

Recognizing the threats, national governments have moved to strengthen and improve management and regulation. Yet regional gains often are negated by overfishing or illegal catches in adjacent zones. Many of today's efforts, including reporting of catches, industry information sharing, and regulatory enforcement, could be bolstered by tighter collaboration.

A bounty of data

Much like agriculture onshore, the fishing industry is geographically dispersed with operators large and small. Farmers plow their fields guided by data on weather and soil conditions. While most fisheries still operate in a traditional way, something similar is starting to take shape in fishing. Radar and optical sensors on satellites can pick up patterns in the ocean environment such as temperature and signals of fish movements. While that information is valuable for fisheries, it also helps authorities track boat

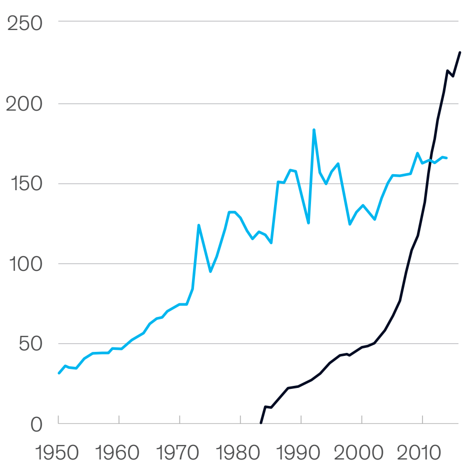
[1] Measured in kilowatt-hours expended.

Exhibit 1

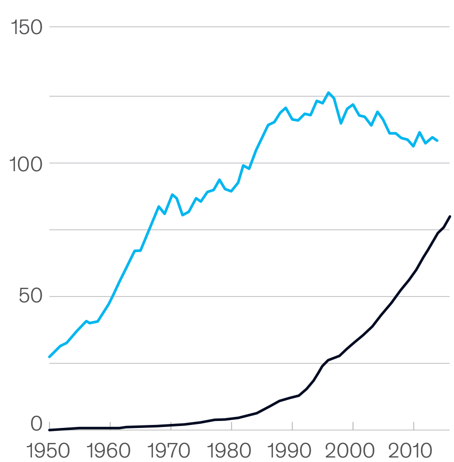
As wild-fish capture has declined, aquaculture has risen to meet demand.

Wild catch[1] — Aquaculture

Global fish value, $ billion



Global fish production, million metric tons



[1] Excludes aquatic mammals; alligators, caiman, and crocodiles; seaweeds; and other aquatic plants.

Source: Food and Agriculture Organization of the United Nations; Sea Around Us, University of British Columbia and the University of Western Australia, 2014

locations and movement. Camera-equipped drones, meantime, operating not only in the air but undersea, give some boats today a more comprehensive view of nearby fishing conditions. Looking forward, advanced sensors and monitors could automatically collect data on the gear used, species caught or discarded, volume of hauls, and more that's often done by fishermen. Governments, meanwhile, have pushed for better data to help keep watch on illegal fishing, mandating that larger vessels be equipped with monitoring systems that transmit location, speed, and direction.

Over time, much more information could be integrated with Internet of Things technologies that link sensors to satellite- and land-based communications networks. Crunching the data by using advanced analytics and machine learning would ultimately help balance competing interests—helping fisheries manage a risky, volatile business while providing authorities with better information for policing and shaping sustainability policies.

Turning the tide with analytics

Let's look on deck. Boat captains with larger commercial fisheries have used technologies such as sonar, though many still rely on intuition, experience, and basic observations to navigate and detect fish. Contrast that with what's potentially ahead: fish detection supported by targeted analytic models that could provide daily forecasts for entire fishing territories, helping to track species that are in high demand. And Internet of Things sensors that monitor ocean conditions could help boats define optimal, energy-efficient routes.

Then there's the catch itself. Fishermen often have low visibility into what's in their nets until it's pulled onboard—leading to waste. Intelligent sensors of the future will allow crews to automatically and continually monitor parameters such as species and fish size. One analytics tool that larger companies already are using factors in sea temperatures and plankton clusters to model where fish will be, lowering costs for targeting desired species and reducing waste. Poorer regions stand to benefit as well. Fishermen in emerging markets are already gaining greater access to market information by using their cell phones.

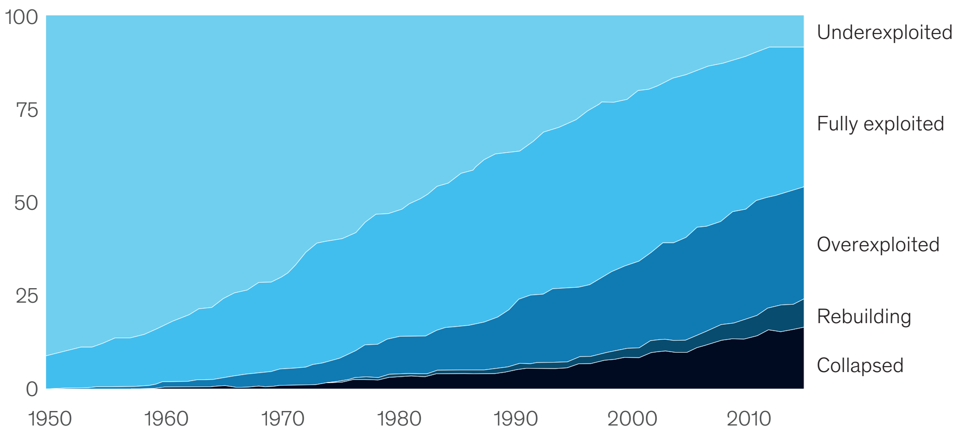
On shore, fisheries managers often plan operations hobbled by data scarcity—using landed catches that furnish little forward visibility. Analytics tools promise to offer a more dynamic view of fleets, allowing managers to guide boats and continually monitor stocks. Automatic scanning and intelligent systems that monitor product quality could replace manual sorting of catches. Quality and traceability loom large, as sustainability-conscious consumers demand greater transparency into how and where fish are caught. What's ahead? Researchers are investigating tagging fish using radio frequency identification (RFID) and certifying catches with distributed ledger technologies (blockchain).

For authorities, analytics can help bridge a different gap. Information on fishing activity is partial at best, and coordination among multiple stakeholders—governments, industry, and NGOs—is challenging. That said, sharing the flow of information from advanced monitoring technologies would give authorities a real-time vision of global fishing activities. It would also help them design more efficient surveillance plans across territorial waters. Decentralized, reliable information-management systems requiring little human intervention could ease adoption. One example: analytics-software tools can flag when a boat slows down in a no-take zone, alerting authorities to the suspicious behavior. NGOs are helping to change mindsets. To promote sustainability research, Global Fishing Watch distributes information gleaned from government and satellite data on more than 65,000 fishing vessels. Over time, shared, detailed catch data from cameras and image-recognition software powered by

Exhibit 2

Nearly half of the world's fish stocks are overexploited, rebuilding, or have collapsed.

Status of global wild-fish stock,[1] %



[1] Stock status is evaluated by looking at the trends displayed by the lines separating the categories, rather than the vertical % values, due to the imprecise/changing definitions of the categories. Rebuilding stocks are stocks recovering from collapsed status.

Source: Sea Around Us, University of British Columbia and the University of Western Australia, 2014

artificial intelligence will help governments fine-tune regulations and fishing quotas more dynamically to manage ocean resources.

Looking ahead

Our modeling research suggests that for fisheries, there are financial incentives for analytics-guided strategies. We found that optimizing fishing activity over an entire season, monitoring of equipment to minimize downtime, identifying fuel economies from analyzing navigation data, and implementing information-based labor efficiencies could reduce industry costs by $11 billion, or just under 15 percent of today's spending.

For governments, one obstacle will be confronting geopolitical challenges. Some bad actors will continue efforts to game a system where the regulatory map has gaps and where some nations benefit by turning a blind eye to wayward fisheries. Better data and analytics capabilities should move the enforcement needle, helping pinpoint hot spots where illegal fishing continues and identifying chronic offenders for enforcement action. The benefits of data sharing and better analytics tools, meanwhile, will continue to align the interests of fisheries and governments for better resource management. An era of precision fisheries will be key to sustaining the oceans' riches. Q

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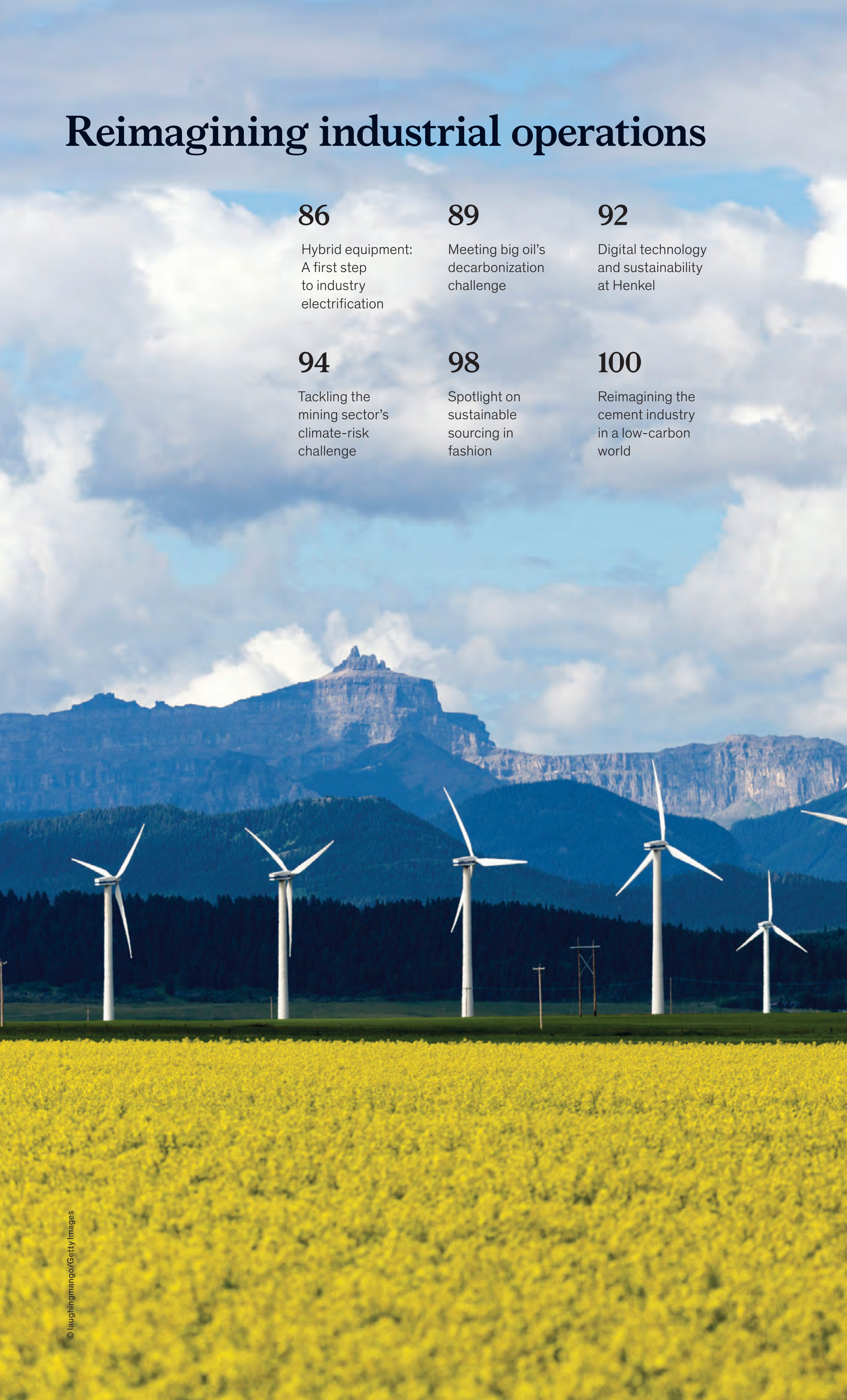
The authors wish to thank Anupama Agarwal, Philip Christiani, Michael Chui, and Bryce Hall for their contributions to this article.

→ *For more, see "Precision fisheries: Navigating a sea of troubles with advanced analytics," on McKinsey.com.*

Reimagining industrial operations



Ever since the steam engine helped launch the Industrial Revolution, large-scale operations have boosted living standards, provided richer choices than our ancestors dreamed of—and generated unintended consequences, including pollution. In this compilation, McKinsey experts and corporate leaders describe emerging opportunities for industrial operators to help lead the way to a lower-carbon future. These range from introducing hybrid-electric equipment (a first step for some) and fully electrifying operations (a key emissions-abatement lever for oil and gas companies), to boosting efficiency through digitization, advanced analytics, and artificial intelligence (practices profiled in a case study of the chemical and consumer-goods company Henkel).

Also on the table: business-model innovation aimed at satisfying demand for lower-carbon technologies and more sustainable products (opportunities for miners and cement makers); as well as reorienting supply chains toward more “circular” practices (which is described by apparel executives, the linear descendants of the textile innovators who started the Industrial Revolution). These quick-hit overviews should serve as useful thought starters, and sources of inspiration, for leaders in any industry seeking to chart their own sustainability journey.

Hybrid equipment: A first step to industry electrification

Shifting from fossil fuels to full electrification is a big leap for many factories; for some, hybrid equipment offers a practical step to meet long-term financial and environmental goals.

by Ken Somers, Eveline Speelman, and Maaike Witteveen

For more than a century, fossil fuels have been essential to powering the world's largest factories. While a sweeping change won't happen overnight, electrification is on the rise, and our recent Global Energy Perspective shows that by 2035 renewables could produce more than half of the world's electricity—in most regions at a lower cost than through fossil-fuel generation.[1] The falling costs of both electrical equipment and renewable electricity generation itself are expected to boost electrification of industrial processes. Regulators, for their part, will continue to bear down on companies' greenhouse-gas emissions. Meeting the 1.5-degree Celsius pathway advocated by the Intergovernmental Panel on Climate Change (IPCC) would require multiple industrial subsectors to electrify at more than twice their current levels by 2050, which are beyond their current economics (for more, see "Climate math: What a 1.5-degree pathway would take," on page 26). All told, about half of the fuel consumed for energy in industry *could* be electrified with available technology (exhibit).

But practical considerations may slow full-scale electrification for many companies, regions, and applications. Hybrid equipment that can switch between conventional fuel and electricity may, on a case-by-case basis, be a cost-effective first step, particularly for processes such as drying and melting, whose heat requirements collectively account for about 35 percent of fuel consumption for energy in industry today.

Hybrid: The future begins now

The costs of fossil fuels versus electric power vary, and there is a good deal of uncertainty as to when electric power will become decisively and irreversibly cheaper. Cost-effectiveness depends not only on the relative prices of fossil fuels and renewable electricity at a given industrial site at the moment of purchase, but also on carbon pricing (a rise in which would make industry electrification more feasible), and on whether electric equipment is more energy efficient than conventional equipment over time. Energy costs can be well over ten times greater than capital-investment costs over the lifetime of a typical industrial furnace or boiler, so the stakes are high.

Rather than waiting it out, companies in some circumstances can make a partial switch to electricity right now, by going hybrid for specific applications—using equipment that can run

[1] See *Global Energy Perspective 2019: Reference Case*, January 2019, McKinsey.com.

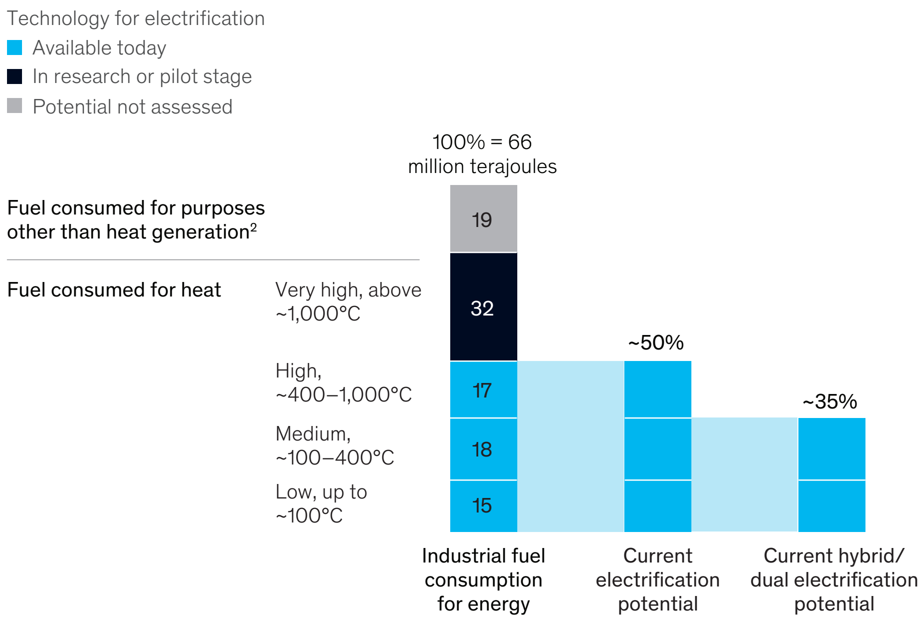
on either electricity or conventional fossil fuel—or installing additional electrical equipment such as electrical boilers in a "dual" setup. Such dual or hybrid equipment is available for producing low- and medium-temperature heat, with steam boilers; key sectors using steam boilers include the chemical, petrochemical, and food industries. Although part-time electrification might not be an end-state solution, hybridization offers significant benefits for industrial companies and society.

With hybrid equipment, companies can make more cost-effective energy choices, using electricity when it costs less than fossil-fuel energy (such as at times of peak renewables production) and switching back to fossil fuels when electricity prices are high. That ties into an additional cost-benefit component: payments that industrial companies could collect as a result of "grid balancing" practices. Grid operators can reward customers for consuming the excess electricity that is generated during peak periods of renewable generation. Making these payments helps grid operators avoid the even greater costs they incur when grids experience strain or outages as more intermittent renewables such as solar or

Exhibit

About half of the fuel consumed for energy in industry can be electrified with available technology.

Estimated share of industrial fuel consumption for energy in 2017,[1] %



[1] Figures do not sum to 100%, because of rounding. Sectors included are chemicals and petrochemicals, iron and steel, nonmetallic minerals, nonferrous metals, food and tobacco, transport equipment, machinery, textile and leather, wood and wood products, paper pulp and print, mining, industrial feedstock and other industrial nonenergy use. Excludes industrial fuel consumption for feedstock and current industrial electricity consumption.
[2] Approximately 80% of fuel consumed for energy in industry is fuel consumed for heat. Other uses include HVAC, refrigeration and cooling, and on-site transport. Industrial energy consumption for which the source data does not specify a sector is assigned to this category as well.

Source: Arnout de Pee et al., "Decarbonization of industrial sectors: The next frontier," June 2018, McKinsey.com; expert interviews; "Manufacturing energy and carbon footprints (2014 MECS)," US Department of Energy Efficiency & Renewable Energy, September 2018, energy.gov; Nicolas Pardo et al., *Heat and cooling demand and market perspective*, Joint Research Centre, 2012, publications.jrc.ec.europa.eu; *World Energy Balances 2017*, OECD Publishing, 2017; McKinsey analysis wind power come online. With hybrid equipment, industrial facilities could pocket incentives when grid operators reward them for consuming electricity during these higher-output, lower-demand times. Indeed, grid payments, fees, and connection costs are critical factors that can make or break a business case, and often require contractual renegotiation or regulatory intervention.

In addition, hybrid equipment can enable direct use of electricity from a nearby intermittent renewable-production site, such as a solar or wind farm. Such an off-grid setup could lower electricity costs for industrial companies significantly, as grid-connection costs, taxes, and other levies are mitigated or avoided. Industry could even be considered as a cheap battery, using electricity when available and switching back to fossil-fuel power when required, serving to help stabilize an entire grid.

The right mix

Purchasing hybrid equipment is most sensible when a company replaces expired equipment or sets up a new facility. For greenfield plants, companies should seriously consider full electric to be future ready. Installing hybrid equipment during replacements and new construction in the near term, though, could make electrification more economical than installing conventional equipment now and switching to electric equipment later. As renewable-electricity prices fall in other regions, hybridization could become an economical near-term option at even more industrial sites.

Changeovers of equipment on industrial sites are slow paced, as the lifetime of industrial equipment can exceed 50 years with regular maintenance. The optimal mix of equipment types will also vary over time based on local factors such as energy prices, regulation, and current setup of the industrial site. These challenges, though, should be interpreted not as a call to go slowly as new technologies continue to be perfected, but as a clarion for industry to begin changing now.

Making the switch can have positive, second-order consequences as well. When industrial players significantly increase their electricity consumption as electricity prices drop below that of conventional fuel, that decreased price level may well act as a floor in the power market. This could further spur the energy transition as it increases the attractiveness of investments in renewable-energy production. Cost leaders, ever focused on how to best allocate their capital, will be ready as the shift gains momentum. Q

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The authors wish to thank Occo Roelofsen for his contributions to this article.

Meeting big oil's decarbonization challenge

Oil and gas companies face a serious, even existential decarbonization challenge. One source of quick progress: addressing their own direct emissions.

by Chantal Beck, Stephen Hall, and Eveline Speelman

Any discussion about how to mitigate climate change invariably leads to oil and gas. Consumption of the industry's fuels creates one-third of all greenhouse gases (GHG), and operations from oil and gas companies account for another 9 percent of GHG emissions directly. The total—42 percent—is the largest share attributed to any single industry.

Consequently, the pressure on oil and gas producers to change is substantial—and rising. Investors are demanding stronger emissions-reductions plans or are divesting from fossil fuels entirely; wind and solar energy are becoming more effective and affordable; and governments everywhere are eyeing aggressive emissions-reduction targets, with many pledging net carbon neutrality by 2050 or sooner.

For fossil-fuel providers, the long-term implications of such trends are significant, even existential. (For more about what it would take to reach a 1.5-degree Celsius pathway, including the implications for the global consumption of oil and gas, see "Climate math: What a 1.5-degree pathway would take," on page 26). Indeed, to help keep temperatures below the 1.5-degree threshold set by the Intergovernmental Panel on Climate Change (IPCC), the industry would have to cut its direct emissions 90 percent by 2050, relative to today's levels. Clearly, reaching this target would be easier if the use of oil and gas declined. But even if demand doesn't fall by much, the sector can abate the majority of its direct emissions now and more cost effectively than companies may realize.

Unwelcome by-products

The production-related activities of oil and gas companies contribute 9 percent of global GHG emissions (3.7 $GtCO_2e$).[1] The biggest GHG culprit—linked to more than 60 percent of the industry's emissions—is natural gas. The gas (primarily methane) often accompanies oil discoveries, but since it is less valuable than oil it is typically burned off. Flaring, or the intentional burning of natural gas, converts the methane into CO_2 and accounts for 14 percent of the industry's direct emissions.

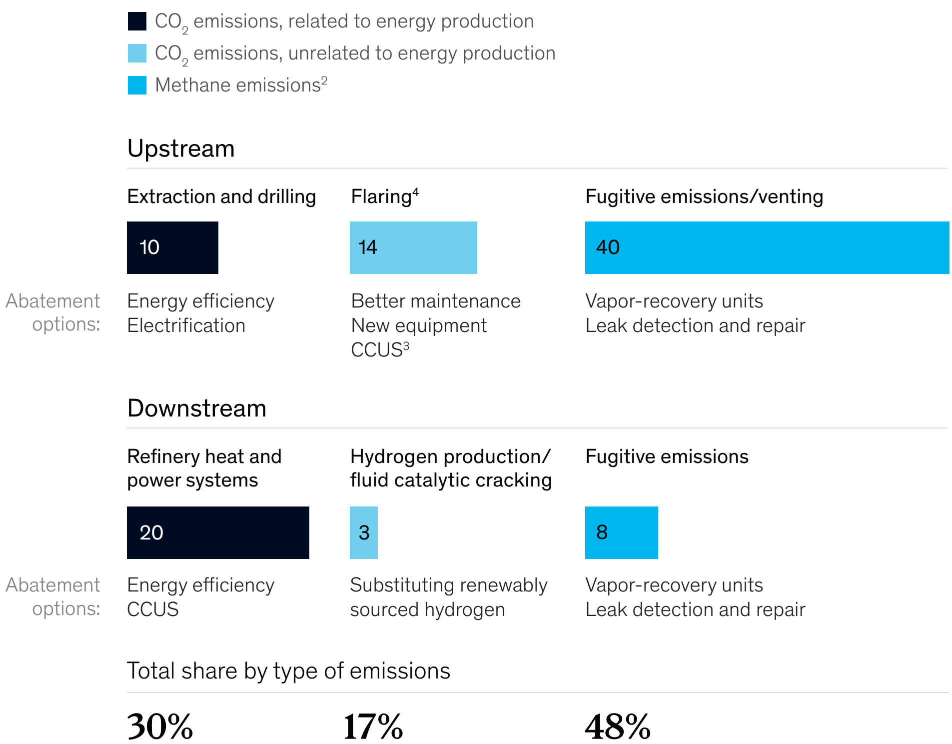
Unburned gas, meanwhile—whether released intentionally or accidentally—represents the largest single source of the industry's direct GHG emissions, at 48 percent. Any methane released into the atmosphere is worrying, as the gas is 86 times more effective than carbon

[1] CO_2e stands for "carbon-dioxide equivalent," a standard unit used to measure greenhouse gases. Emissions are measured in metric tons of CO_2e per year, or multiples such as million ($MtCO_2e$) or billion ($GtCO_2e$) metric tons.

Exhibit

Flaring, venting, and leakage of natural gas produces more than 60 percent of the industry's direct greenhouse-gas emissions.

Share of greenhouse-gas emissions in oil and gas industry by production stage,[1] %



Explanation of terms

Flaring is the intentional burning of gas that emerges during oil and gas extraction and industrial processes.
Venting is the intentional release of CO_2, methane, or other gases into the atmosphere without combustion.
Fugitive emissions include unintentional leaks—eg, those caused by equipment failure or accidents.

[1] Fugitive emissions from midstream are included in upstream to be consistent with IEA's World Energy Outlook 2018 classification; share by type of emissions does not sum to 100%, because midstream energy-related emissions from transport are not modeled—their contribution to the industry's direct emissions is 5%.
[2] Assumes global warming potential (GWP) for methane of 28 on a 100-year horizon.
[3] Carbon capture, use, and storage.
[4] Includes only CO_2 component of flaring; methane component is included in fugitive emissions/venting category.

dioxide at trapping heat during the first 20 years of its release. By all accounts, the amount of methane released each year through oil and gas operations is considerable; in 2017 it was equivalent to 6 percent of the global energy sector's total GHG emissions.[2] Other sources of oil and gas emissions, as shown in the exhibit, occur along the industry's value chain, including downstream production activities, which account for about 30 percent of the industry's direct GHG emissions.

Making moves

While the economics underpinning various decarbonization initiatives depend on factors

[2] *Tracking fuel supply: Methane emissions from oil and gas*, International Energy Agency, November 2019, iea.org.

such as a company's geography and asset mix, our work highlighted a range of options across the industry's value chain—everything from advanced leak detection in pipelines, and renewable-power alternatives for equipment, to carbon-capture and -storage technologies, and the use of bio-based feedstocks in refining. Most options cost less than $50 per ton CO_2e on average (exhibit). The key is to start by prioritizing the most economic moves. One company found that about 40 percent of the initiatives it identified had a positive net present value, and that an additional 30 percent would be "in the money" if the company assumed an internal carbon price of $40 per ton.

Upstream initiatives that typically offer fast paybacks include electrifying equipment and changing power sources. For example, replacing on-site generators with a solar photovoltaic and battery setup helped one oil and gas company reduce its emissions considerably, while breaking even on the investment in five years. Similarly, better leak detection helped another company identify the seals in its pressure-safety valves where methane was escaping. Now, the company sells the captured gas. Another company found that 70 percent of its flaring emissions were the result of poor equipment reliability. The resulting operational improvements helped the company reduce these emissions and improve the overall production of its wells. The collective impact of such moves is huge: we estimate that reducing fugitive emissions and flaring could contribute 1.5 $GtCO_2e$ in annual abatement by 2050, at a cost of less than $15 per ton.

In some circumstances, however, reducing methane emissions would require new infrastructure. Gas flaring in the US Permian Basin, for example, reached an all-time high in the first quarter of 2019, a worrying trend for decarbonization efforts. New gas-processing facilities and pipeline construction would help in situations where oil discoveries otherwise outpace a company's ability to capture and transport the gas. Nonetheless, infrastructure expenses are understandably difficult to entertain in circumstances where it can be more economical for a company to flare natural gas than capture and sell it.

Addressing such thorny dilemmas will test the leadership of oil and gas executives, even as it gives them opportunities to signal the industry's willingness to decarbonize and chart a new future for the industry. And they will want all the good will they can get, recognizing, of course, that the bigger challenge is not the industry's direct GHG emissions but the combustion of its products. Still, every improvement helps, and the speed at which the operational opportunities can be implemented might help gain valuable momentum for the hard work that lies ahead. Q

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Digital technology and sustainability at Henkel

Operational excellence is lowering costs and emissions at a "lighthouse" manufacturer.

by Francisco Betti, Enno de Boer, and Yves Giraud

The industrial sector is a top energy consumer and the source of more than one-quarter of global CO_2 emissions. Process optimization and increased energy efficiency are key to reducing emissions, and digital technology is a big piece of the puzzle.

The World Economic Forum, in collaboration with McKinsey, has been studying how top companies are improving operations using Fourth Industrial Revolution (4IR) technologies. The research has spanned thousands of manufacturing sites, and an independent panel has identified 44 manufacturing "lighthouses," company sites that are resetting benchmarks in areas such as productivity, sustainability, and customization. Henkel, a new member of this Global Lighthouse Network, is using 4IR technologies to lower its carbon footprint across a network of facilities, including the company's Düsseldorf factory, singled out as a 4IR lighthouse site. A closer look at the company's practices offers lessons for manufacturers everywhere.

Efficiency in practice

Henkel, the German chemical and consumer-goods company, is widely known for its consumer brands—think Dial, Persil, Schwarzkopf, and Loctite. Henkel's adhesive technologies are used in phones, shoes, cars, and planes. The company is seeking to reduce carbon emissions from its 185 production sites by three-fourths by 2030. To do so, it is working to improve its energy efficiency: Henkel aims to triple its value creation relative to the carbon footprint of its operations, products, and services and to halve its energy use per ton of product at its production sites by 2030 (as compared with 2010). This equates to improving its efficiency by a hefty 5 to 7 percent per year.[1]

Digital technology is central to these efforts. Henkel's Laundry & Home Care business unit has implemented a digital backbone that uses the cloud to continuously link global operations end to end. Upon its launch, in 2013, Henkel's Environmental Management System showed simple line diagrams; today, it includes digital twins of the unit's 33 production sites and ten distribution centers. Digital twins are representations (of factories, systems, machines, processes, or products, for example) that incorporate sensor data, user feedback, and other inputs. Each of Henkel's Laundry & Home Care production sites has more than 3,500 sensors, which together with cameras and robots feed 1.5 billion data points into the platform every day.

[1] "Henkel: Sustainable & competitive," CBS News, January 17, 2020, cbsnews.com.

With the help of artificial intelligence and advanced analytics, Henkel is using the data it collects to improve its product quality as well as its operational, financial, and environmental results. The platform tracks and displays efficiency data and energy and water use at each plant (with "traffic light" displays or bar charts, for example), along with data related to fossil fuels, sewage, compressed air, and steam. This allows Henkel to compare the performance of different production sites and identify and promulgate the most effective practices. The platform also helps find patterns and improvement opportunities, as well as malfunctions. For example, if the platform registers an increase in a particular machine's energy or water consumption, it alerts employees automatically to check for leaks in onsite steam and water pipes; workers are similarly notified if a machine exceeds benchmark consumption levels.

These "local" data are shared in real time, aggregated, and used more broadly across the organization. Henkel Laundry & Home Care's supply-chain managers have access to data on the business unit's energy consumption, for example. Employees can also access data from the unit's production sites, processes, and sensors, using it to coordinate improvement measures.

Getting results

The impact of Henkel's moves is evident at the company's lighthouse facility in Düsseldorf, where the platform helped increase overall equipment effectiveness (OEE) for Persil laundry detergent by 30 percentage points compared with the 2010 level. The site's energy consumption fell by 38 percent, water use by 28 percent, and waste by 20 percent compared with 2010 levels. Employees at the Düsseldorf site also benefitted: the digital backbone contributed to a 60 percent improvement in plant safety (for example, through the use of electronic warning zones that automatically shut off forklifts when workers get too close).

The company's digital backbone has helped boost the business unit's efficiency as well: OEE is up more than 10 percent since 2010, and between 2010 and 2019, the unit's energy consumption fell by about one-quarter—a reduction of 800,000 metric tons of CO_2. (The platform itself was responsible for more than half of these savings; data collected through the platform informed investments that helped further reduce consumption.) All told, the business unit achieved energy savings roughly equivalent to the annual energy consumption of 300,000 people (about the population of Cincinnati). In turn, over the course of the past decade, the unit's annual energy costs fell by €18 million; the energy savings attributed to Henkel Laundry & Home Care's digital backbone currently amount to €7.5 million per year. Moreover, the energy savings supported a 36 percent reduction in the business unit's environmental footprint (encompassing energy use, water use, and waste) over the past decade. Q

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The authors wish to thank Henkel's Dr. Dirk Holbach and Wolfgang Weber for their contributions to this article.

Tackling the mining sector's climate-risk challenge

The global mining industry faces increasing physical risks from a changing climate and mounting pressure to decarbonize. Creating a climate strategy is challenging—and increasingly urgent.

by Liesbet Grégoir, Kimberly Henderson, and Jukka Maksimainen

Mining is no stranger to harsh climates: much of the industry already operates in inhospitable conditions. But forecasts of heavy precipitation, drought, and heat indicate that these effects will become more frequent and intense, creating new physical risk for mining operations.

Meanwhile, the industry also faces a stiff decarbonization challenge. Mining operations are directly responsible for 4 to 7 percent of global greenhouse-gas (GHG) emissions, at least three-quarters of which are methane emissions from coal mining.[1] The industry has begun setting emission-reduction goals, with some companies' published targets as high as 30 percent by 2030—significant, although still below a pathway that is aligned with the Paris Agreement.

Rising pressure from the changing climate, as well as from governments and investors, is starting to catalyze additional action. More is needed, and, as it comes, it should help mining companies benefit from emerging opportunities to provide the raw materials needed for new technologies—and to work toward a more sustainable future.

Water stress

Today, 30 to 50 percent of production in copper, gold, iron ore, and zinc is concentrated in areas where water stress is high, and it is likely to grow as climate change causes more frequent droughts and floods.[2] Seven water-stress hot spots stand out: Central Asia, the Chilean coast, eastern Australia, the Middle East, southern Africa, western Australia, and a large zone in western North America. Altering the supply of water to at-risk mining sites, which collectively accounted for roughly $150 billion in revenue in 2017, could disrupt operations at many of them.

To improve resiliency, companies can reduce the water intensity of their mining processes, recycle used water, and reduce water loss from evaporation, leaks, and waste. Longer-term approaches such as dams and desalination plants are possible, but expensive. Companies

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[1] The industry's indirect emissions (also known as "Scope 3" emissions) are much larger, accounting for 28 percent of global GHG emissions. These include the combustion of coal.

[2] High water stress denotes a ratio of water demand to water supply of 40 percent or greater.

can also rely on so-called natural capital—for example, wetland areas—to improve groundwater drainage (For more about how companies can mitigate water stress, see “Water: A human and business priority,” on page 46.)

Flooding can also cause operational disruptions, including mine closures, washed-out roads, and unsafe water levels in tailing dams. Safeguards include improving drainage and pumping techniques, as well as adapting roads (by, for example, using hard metal or crusted rock for speed drying or building sheeted haul roads). First Quantum Minerals did the latter at its Sentinel copper mine in Zambia. Another option for some mines is to bypass trucking altogether with conveyors.

The decarbonization challenge

All industries have critical roles to play in limiting warming to 1.5 degrees Celsius above preindustrial levels, a goal that the Intergovernmental Panel on Climate Change believes will mitigate the worst risks of climate change (for more, see “Climate math: What a 1.5-degree pathway would take,” on page 26). Mining’s piece of the puzzle is big: a reduction by 2050 of at least 85 percent of direct emissions from 2010 levels. (A 50 percent reduction would be more consistent with a 2.0-degree pathway.) Achieving such reductions would require major contributions across the industry’s value chain.

While the decarbonization potential for mines varies by commodity, mine type, power source, and other factors, our work suggests that mines could fully decarbonize their direct CO_2 emissions (equating to roughly one-quarter of the industry’s direct GHG emissions) through a mix of operational efficiency, electrification, and renewable-energy use. Capital investments are required to achieve most of this potential, but certain measures are economical today for many mines.

Moving to renewable sources of electricity should become increasingly feasible, even in

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off-grid environments, as the cost of battery packs is projected to decline by 50 percent by 2030. In some cases, battery electric vehicles have a 20 percent lower total cost of ownership than traditional internal-combustion-engine vehicles. That said, the electrification of mining equipment, such as diesel trucks and gas-consuming appliances, is only starting to become economical, and just 0.5 percent of mining equipment is fully electric at present.

The remaining three-quarters of mining industry GHG emissions would be much tougher to mitigate. These are the emissions that result from coal mining, specifically the release of naturally occurring methane found in many coal beds. While solutions exist for capturing this so-called fugitive methane and using it to generate power, there are no ready solutions for all types of mines, and the required investment is not economical in many cases.

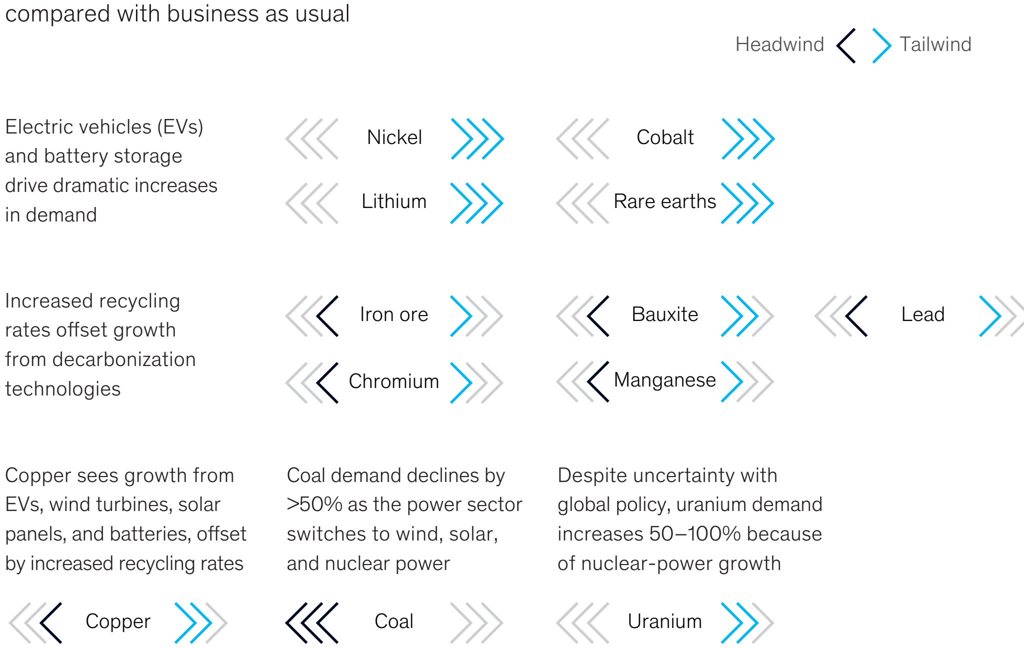
A look ahead: Shifting demand

Against a stark backdrop of physical risks and operational challenges, a warming climate would bring opportunities for some mining companies as well. If global industries commit to cutting emissions in line with Paris Agreement targets, demand would grow for low-carbon technologies such as wind turbines, solar photovoltaics, electric vehicles, energy storage,

Exhibit

Even a 2°C scenario would be a significant deviation from business as usual, leading to a range of demand shifts for many minerals by 2030.

Degree of headwind and tailwind in 2°C scenario[1] in 2030, compared with business as usual



[1] Based on 2°C scenario from International Energy Agency (IEA).

Source: *Energy Technology Perspectives 2017*, IEA, June 2017, iea.org; *The growing role of minerals and metals for a low carbon future*, World Bank, June 2017, documents.worldbank.org; World Bank; McKinsey analysis

There's no sugarcoating it: the effects of climate change on mining companies are likely to be significant, systemic, and long term.

metal recycling, hydrogen fuel cells, and carbon capture and storage. The mining industry could provide raw materials for many such technologies, creating "tailwinds" for mined commodities including copper, nickel, cobalt, and lithium (exhibit).

Meanwhile, the evolution of downstream production processes may boost demand for low-carbon metals. For example, some automotive companies that manufacture products using a carbon-neutral process are asking suppliers to deliver carbon-neutral parts, often made with niche metals. Niche commodities would probably not be able to replace earnings from coal, which currently represents about 50 percent of the global mining market, but they could help manage losses. For miners, a rebalanced portfolio would require sophisticated market intelligence and flexible assets, agile characteristics that could become a competitive advantage in enabling responses to mineral-demand shifts.

There's no sugarcoating it: The effects of climate change on mining companies are likely to be significant, systemic, and long term. Still, by getting creative—through innovation to adapt operations and business models—mines can boost their resilience, and their decarbonization potential. Q

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→ *For the full report on which this article is based, see "Climate risk and decarbonization: What every mining CEO needs to know," on McKinsey.com.*

Spotlight on sustainable sourcing in fashion

Four apparel-industry executives describe the need for collaboration, transparency, and a long-term view.

The good guys will win

Edwin Keh, CEO, HKRITA (The Hong Kong Research Institute of Textiles and Apparel)

I think it is apparent to everybody right now that we have too much of everything—too many brands, and too many manufacturers consuming too much material and producing too much waste. There will be a zero-sum game where the good brands and the good manufacturers will win at the expense of the ones that are not as prepared. Consumers will start picking sides—and the good guys will win.

At HKRITA, the traditional research methodology is an eight- to ten-year timeline, but, for sustainability, that pace is too slow. We are looking to move to a faster cycle in which we do a lot of things in parallel—comparable to software development in how it flows very quickly from an idea to industry scale.

For example, we recently proved the business case for recycling. We opened a recycling mill in Hong Kong to process postconsumer waste, turning it back into usable yarn for manufacturing. In fact, this yarn is now selling at a discount to comparable virgin yarn. If a recycling mill can operate in the most expensive economy in the world, there is no city in the world that has a reason not to recycle.

A race to the top

David Savman, general manager, global production, H&M Group

Sourcing is changing. For decades, it's been about moving further away from home and finding areas with large workforces. Now, it's not a race to the bottom, it's a race to the top—you need the most efficient suppliers, and you need the most mature and developed suppliers. Those two parameters put enormous, and different, demands on the industry.

Within that, sustainable sourcing poses a huge opportunity, as it makes the industry itself sustainable. It's also one of the biggest areas in attracting and retaining talent. But sustainability issues are complex. As an industry, we have work to do in understanding all the elements and collaborating with different stakeholders to meaningfully engage.

There is a misperception that incentivizing sustainability and focusing on cost is a balancing act. A supplier that is a high performer in sustainability will often be the one that offers better control of their cost, as they are efficient—they run a good business and don't waste resources.

Ultimately, there is no downside to transparency. It leads to better engagement with consumers on complex issues and serves as a driver for development. It's easy for brands to hide behind complexity—we need to simplify as much as possible through transparency.

No shortcut to sustainability

Teresa Yang, vice chairman, Esquel Group

Today, the impacts of climate change are undeniably felt by all. Our colleagues across our global operations in China, Malaysia, Sri Lanka, Mauritius, and Vietnam have experienced firsthand the consequences of typhoons, floods, and droughts in increasing frequency and magnitude.

In this regard, I like to think of ourselves as pioneers, having the ability to demonstrate how to manufacture with a minimal impact on the environment. We also look for innovative ways to weave available technology into our operations. Our investment in the water-recycling facilities in Gaoming, China, currently treats 38,000 tons of wastewater and recirculates 2,000 to 3,000 tons of treated water daily back to our manufacturing operations, substantially surpassing regulatory standards. Since 2005, we have reduced per-unit output consumption of water by 67 percent and electricity by 49 percent.

On the recycling front, we are working on reclaiming and recycling cotton waste. With spinning, weaving, and knitting experts working in close collaboration, we are able to create recycled blended yarn of high quality and strength. In recycling, there is still a lot of work needed around the whole supply chain because the collection process and logistics cost of recycling discarded garments are still major challenges.

Investing in sustainability almost never guarantees immediate returns. There is no shortcut to sustainability. Only if we continue to collaborate with clients, governments, suppliers, and partners can we look back years from now and say that the world we live in has improved.

Know your starting point

Cameron Bailey, executive vice president, global supply chain, VF Corporation

In the not-so-distant past, “sustainability” was used primarily as a tool to mitigate reputational risk and ensure compliance. Our world changed quickly, and companies, including VF, have come to clearly understand that transparency and traceability are critical to the future. To that end, [we have] set a goal to trace all products through our entire supply chain and share as much information with our consumers as possible. This may come in the form of “ingredient” labels for our products or pictures or videos direct from the factory floor with testimonials from the workers themselves.

However, like most things within a global supply chain, it’s complicated. Consider our Vans brand: we found there are as many as 56 different suppliers involved to make one pair of shoes. While [traceability] work is tedious, it’s vital to fulfilling our purpose-led commitments. We expect to achieve similar transparency for another 150 products by the end of 2021.

The responsibility of the supply chain is to align the commercial view with our purpose-led vision of protecting the planet and improving the lives of people. An essential first step is to establish a clear baseline of data; you can’t know the best path forward if you don’t know your starting point.

For the full interviews, see “Fashion’s new must-have: Sustainable sourcing at scale,” on McKinsey.com.

Reimagining the cement industry in a low-carbon world

The cement industry is a top source of emissions—but abatement pressures could prompt efforts to reimagine the business.

by Sebastian Reiter, Patrick Schulze, and Ken Somers

As a key component of concrete—the second most consumed product globally after potable water—cement is an integral part of our everyday lives. Cement production is also a major source of global CO_2 emissions, accounting for 7 percent in 2017. Two-thirds of the industry's emissions result from the calcination, or chemical decomposition, of raw materials such as limestone; decarbonization is especially challenging, as carbon emissions are intrinsic to the calcination process.

Nonetheless, our research suggests that, in principle, the industry could reduce its 2017-level emissions by more than three-quarters by 2050 (exhibit). About one-third of the abatement would come from traditional operational measures, with the remainder requiring new technologies and the adoption of alternative building approaches. This innovation imperative would be beneficial for the industry as it increasingly coexists—and competes—with more sustainable building materials. Growth and decarbonization therefore represent big, interrelated challenges: cement makers that pursue technological advancements and rethink their products, portfolios, and partnerships will be better positioned to succeed at both.

Operational advances

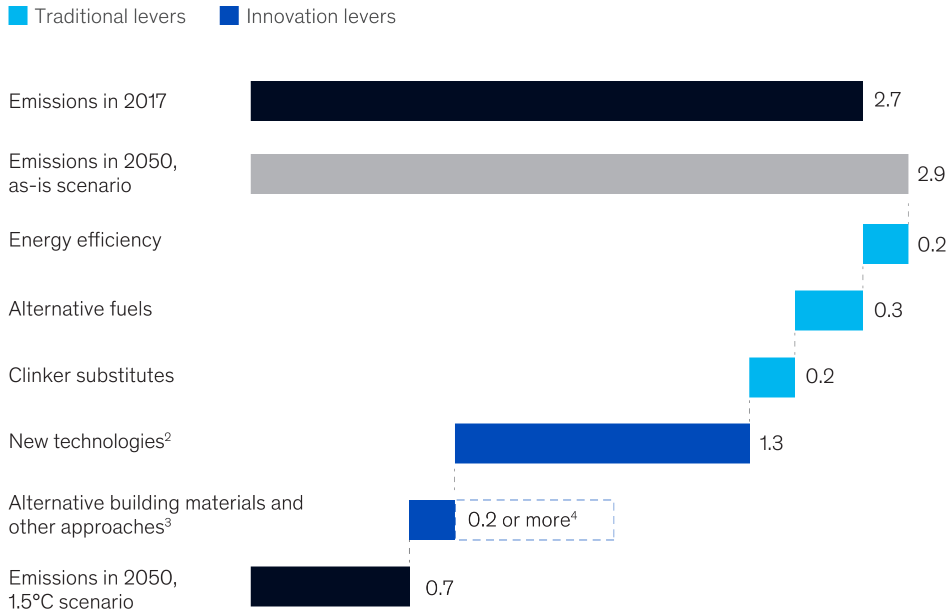
Building on decades of efforts to improve efficiency, traditional abatement levers could reduce emissions by about one-fifth by 2050. Cement kilns use a tremendous amount of heat to produce clinker, the core component of cement. In addition to deploying more clinker substitutes, the industry could reduce energy intensity through better plant utilization and by increasing equipment effectiveness; recovering waste heat could also provide carbon-free electricity. Another promising efficiency lever: advanced analytics. A European cement producer achieved 6 percent fuel savings by creating self-learning models of the kiln's heat profile and optimizing the shape and intensity of the kiln flame. Future cement plants could leapfrog competitors by combining digital and more sustainable operations. Finally, incorporating alternative fuels such as waste and biomass to replace fossil fuels, a multidecade trend in the industry, could reduce emissions by nearly 10 percent by 2050.

None of this will be easy. Biomass supplies vary by region, and other industries are vying for them. Clinker substitutes, too, are limited.

Exhibit

The cement industry could cut three-quarters of its carbon-dioxide emissions by 2050.

Potential CO_2 emissions and reductions,[1] $GtCO_2$ annually



[1] Effect might be smaller or larger depending on speed of shift.
[2] For example, carbon capture, use, and storage; carbon-cured concrete; 3-D printing.
[3] For example, cross-laminated timber, lean design, prefab/modular construction, building information modeling.
[4] Alternative building materials and other approaches will likely play an important role in the decarbonization of the cement industry, but a great deal of uncertainty remains as to how much they will reduce emissions.

Source: "Getting the numbers right," Global Cement and Concrete Association, 2017, gccassociation.org; *Global Cement*, fifth edition, Freedonia Group, May 2019, freedoniagroup.com; *The Global Cement Report*, 13th edition, CemNet, cemnet.com; Umweltbundesamt (German Environment Agency); McKinsey 1.5-degree-pathway model; McKinsey Cement Demand Forecast Model

Natural pozzolans (volcanic rock and ash, for example) have not yet been assessed at scale. And industrial byproducts that serve as clinker alternatives, such as fly ash from coal-fired power plants and slag from steel blast furnaces, could be in shorter supply as the power and steel industries decarbonize and produce less waste.

Technological innovation

Innovation will be critical to achieving the cement industry's sustainability and performance potential, with promising avenues already emerging. For example, Solidia, a New Jersey start-up, uses a lower proportion of limestone in its cement, which results in fewer process and fuel emissions; the company's process also locks in additional CO_2, which is added before the concrete cures.

Adding CO_2 makes the concrete stronger and reduces the amount of cement needed. Carbon-cured concrete could also use CO_2 captured during cement production. Today's methods could sequester up to 5 percent of the CO_2 produced during production, but newer technologies could sequester 25 to 30 percent. Products such as carbon-cured concrete, positioned differently, could earn a "green premium," potentially giving companies an edge among environmentally conscious buyers—and greater pricing power.

On the horizon are carbon capture, use, and storage (CCUS) technologies. While frequently costly and perhaps (for now) more suitable for making higher-value products, such as steel, by 2050, they could more than halve emissions. A number of postcombustion carbon-capture pilots are underway, driven by the large cement players. Other companies are testing oxyfuel combustion, a promising but expensive technology that results in high concentrations of CO_2 in flue gas, which in turn allows for near-total carbon capture.

Ultimately, capitalizing on technology and innovation will require more investment, as well as a shift in mindset for companies that have become too comfortable with the status quo. Many cement players are not used to relying on partnerships, or to operating in the kinds of ecosystems that are second nature in other industries. With innovation timelines of five to ten years, some companies could soon find themselves playing catch-up.

New growth horizons

Sustainability ultimately may be the catalyst that pushes the industry to seek growth via new business models, partnerships, and construction approaches. Cement-based concrete will remain the global construction material of choice, but "sustainable construction" value chains are likely to emerge on the regional and local levels, necessitating a reorientation of many corporate portfolios.

In the United Kingdom, for example, recycled material from construction and demolition waste is increasingly being used to replace aggregates in concrete. Cement makers have been slow to seize the opportunity, ceding the

© Jung Getty/Getty Images

waste-recycling business to local construction companies. Meanwhile, in other markets traditional cement may compete with an improved variety—energetically modified cement (EMC)—which releases less carbon and requires less energy to produce. EMC has already been used (in combination with traditional cement) for a variety of projects in Texas.

Other opportunities lie beyond cement and concrete. Alternative building materials and other approaches will likely play an important role in the decarbonization of the cement industry, though a great deal of uncertainty remains as to how much they will reduce emissions. Cross-laminated timber (CLT), for example, is already in use in a number of markets and has been buoyed by its reputation as a green material. Should roughly 10 percent of cement be replaced with CLT, carbon emissions would be reduced by up to 750 million tons each year (about 2 percent of global emissions).[1]

Additional new value pools include prefab, modular housing, which incorporates off-site production, as well as building information modeling (BIM), which allows stakeholders to visualize products digitally, evaluate various building materials, and plan large projects more efficiently. Greater transparency means less waste and likely a reduction in the amount of cement or concrete required. Indeed, digital technology is at once supporting the cement industry's decarbonization efforts and contributing to its growth challenges.

Cement makers are approaching a moment of truth. Challenges such as decarbonization, ongoing value-chain disruption, and competition against the construction ecosystem's entire patchwork of players all loom large. With the right mindset, decarbonization and reinvention can go hand in hand: just as automakers increasingly view their role as providing mobility—not just making cars—cement companies could likewise be in the business of providing construction solutions. As climate pressures increase and sales of traditional cement and concrete face threats, the combination of new thinking, innovation, and new business models will be critical to helping ensure a profitable—and greener—future. Q

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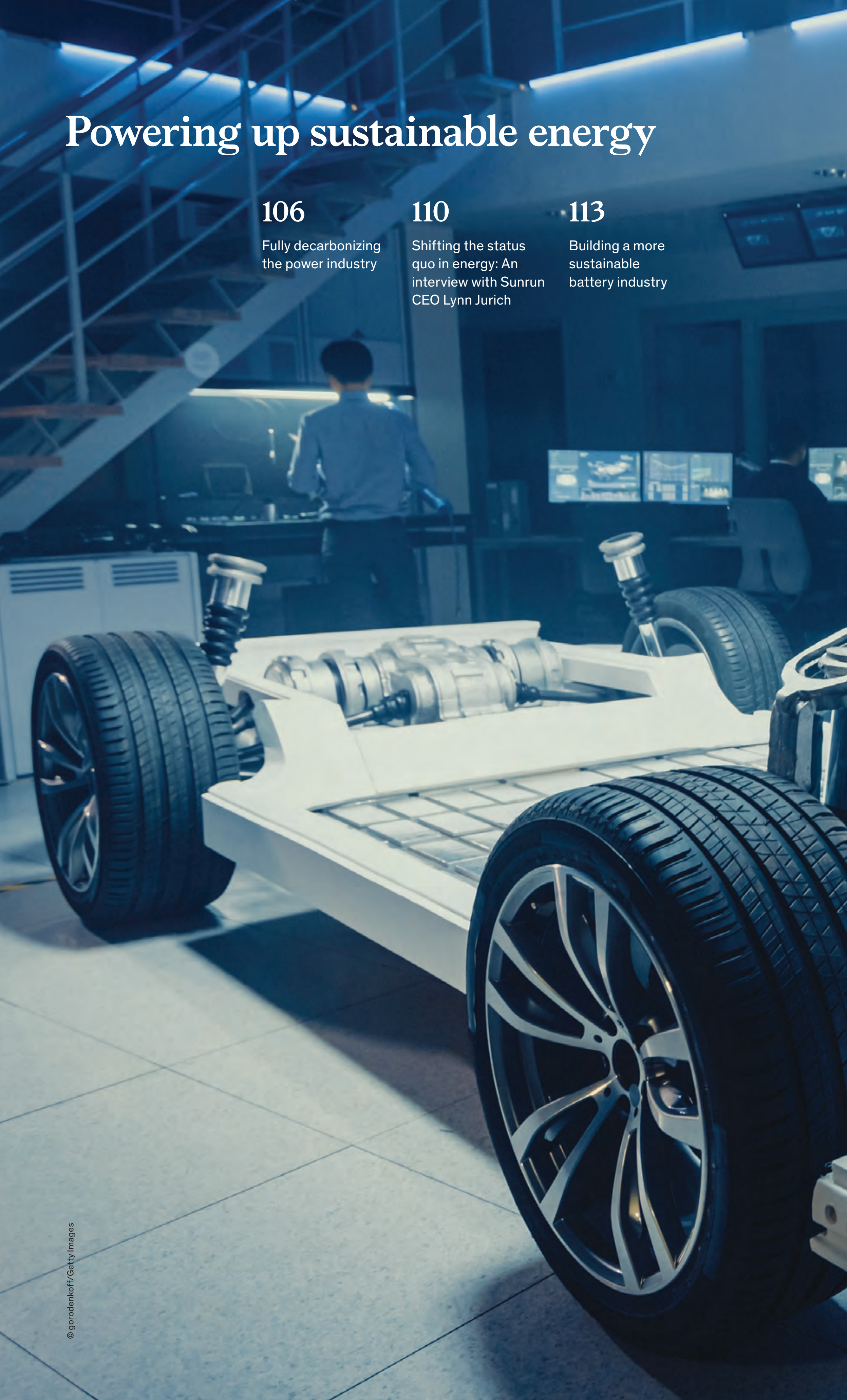
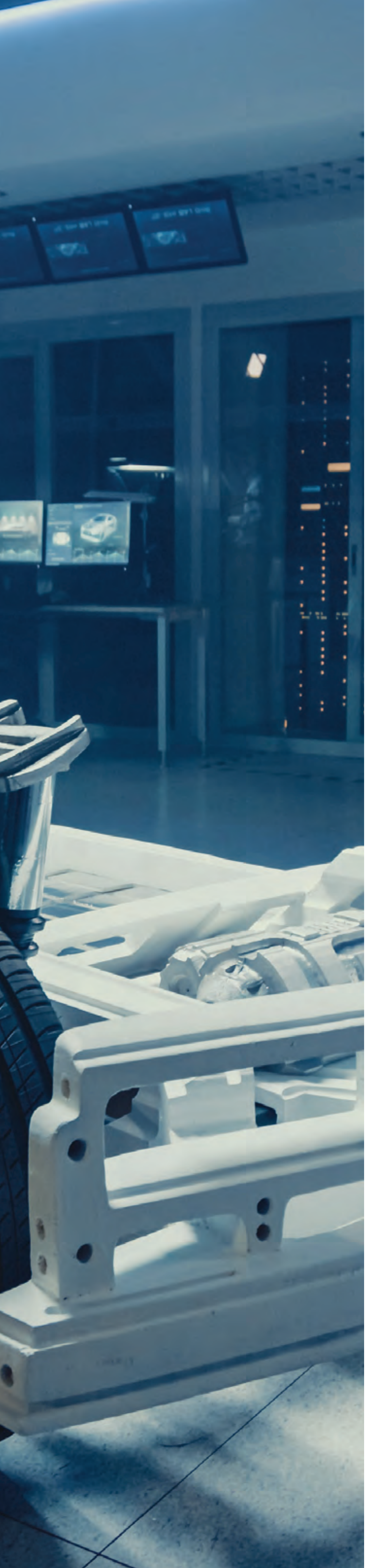
The authors wish to thank Thomas Czigler and Lea Pollert for their contributions to this article.

[1] This would require the sustainable harvesting of about one-tenth of the existing boreal forest (located in the Northern Hemisphere). CLT comes with the advantage of considerable carbon sequestration: for each ton of carbon emissions avoided, two additional tons of carbon are sequestered.

Powering up sustainable energy





Thomas Edison upended the world with his novel idea for an electric utility that would centrally power homes and industry. One hundred forty years later, the power industry has been quietly decarbonizing, even as it remains a marvel of efficiency and reliability. How far could it go? That will depend both on the rate at which the economics of renewables improve, and on the advance of technologies ranging from hydrogen fuels to carbon capture, use, and storage. Also critical: an expansion of the battery industry to store power and keep the grid humming when renewables such as wind and solar power aren't, and to accelerate the penetration of electric vehicles.

In this compilation, McKinsey experts provide snapshots of the opportunities and challenges associated with these transitions, and Lynn Jurich, CEO of the San Francisco–based solar player Sunrun, provides a ground-level view of what it looks like to transform residential solar into a new business model for microgeneration that helps utilities manage their loads.

Fully decarbonizing the power industry

Renewables and new technologies could push power emissions to zero, but would do so in very different ways across markets.

by Jason Finkelstein, David Frankel, and Jesse Noffsinger

Renewable energy is becoming more abundant—and cheaper. But the pace and nature of its expansion will vary considerably across markets. To see how the power industry could provide cheap, reliable, sustainable power, we mapped the world into four key market types (described below), which collectively make up most of the global market, and created pathways that show the most economical way to fully decarbonize each market type by 2040. We conclude that getting to 50 to 60 percent decarbonization is not that difficult technically and is often the most economic option. Getting from there to 90 percent decarbonization is generally technically feasible but sometimes costs more. And getting to 100 percent is likely to be difficult, both technically and economically (exhibit).

'Islanded' markets

As the name implies, these are remote or isolated markets (such as Hawaii) where today's power systems are expensive—they import fuel and lack connections to other power markets. Many have sunny climates, and falling renewable prices mean that these markets could reach over 80 percent decarbonization, largely by choosing the lowest-cost power mix.

Our research suggests that climbing the ladder to 90 percent would mean sizeable new investments in solar, with battery storage for backup when solar cannot generate. That would impose some level of what the industry calls "curtailment costs"[1]—the inability to use all the renewables coming online efficiently—plus related costs of keeping underutilized thermal assets up and running as a backup. Still, this penultimate step could be achieved with lower overall system costs.

Getting to full decarbonization would require using an emerging technology known as P2G2P (power to gas to power), where renewables produce clean hydrogen fuel through electrolysis.[2] That clean hydrogen displaces fossil fuels for backup power. It's a high-cost technology now, but the price tag might be contained since use will be mostly at the margin.

Thermal-heavy, mature markets

These markets have large populations, are heavily powered by thermal facilities today, and have major interconnections to other power markets to manage loads. Examples are the

[1] Curtailment, defined as the purposeful reduction in the output to the grid of a generator from what it could otherwise produce, is a concept that is particularly applicable to renewables because they cannot be controlled like thermal plants.

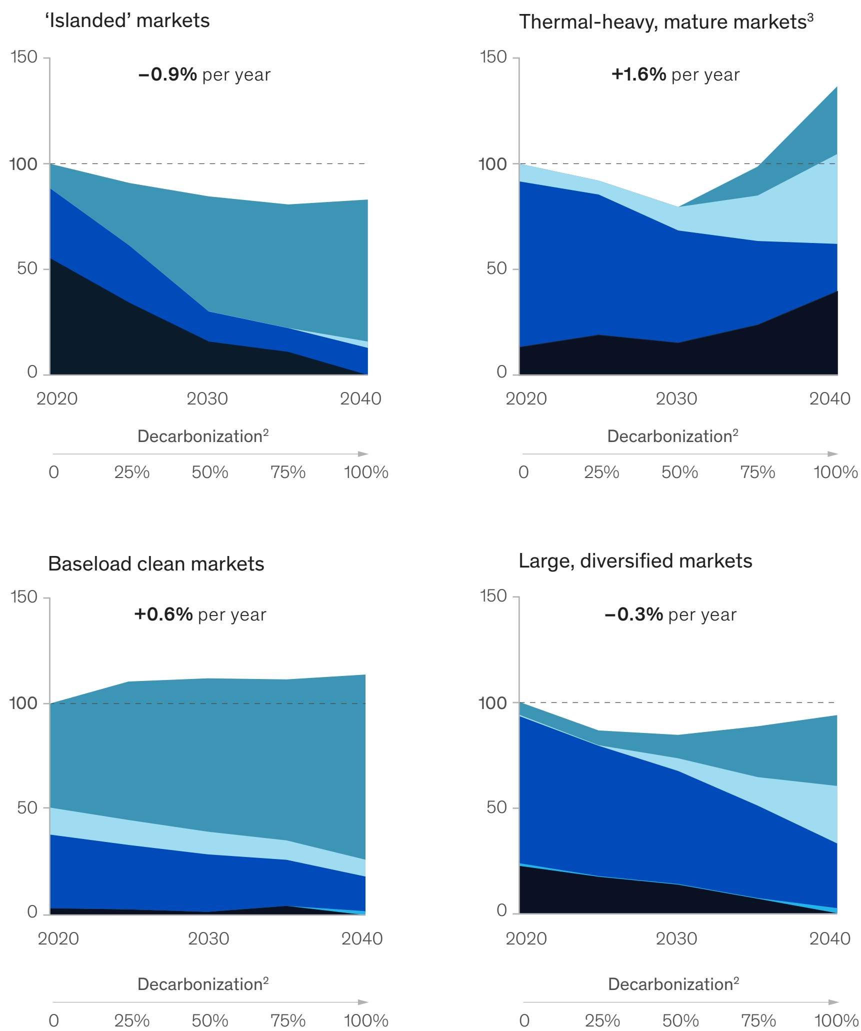
[2] In its most basic form, electric power from renewables drives a current through water to produce clean hydrogen gas.

Exhibit

The pathway and cost of decarbonization will vary, depending on the market.

Total cost of power, by technology type, indexed, real (2020 = 100)

- **Intermittent capacity:** wind, solar, run-of-river hydro
- **Clean dispatchable capacity:** reservoir hydro, nuclear, CCUS,[1] battery, pumped hydro storage
- **Fossil-fuel capacity:** coal, natural gas, oil
- **Clean fuel:** biogas, biomass, uranium
- **Fossil fuel:** coal, natural gas, oil



[1]Carbon capture, use, and storage.
[2]Net total power-sector CO_2-emission reduction relative to starting point.
[3]To achieve 100% decarbonization, fossil fuels continue to play a role via operation of gas plants outfitted with carbon capture, use, and storage (CCUS). The balance of uncaptured emissions from CCUS (~10%) are abated through bioenergy carbon capture and storage and direct air capture.

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US PJM market[3] and Germany. Getting to 90 percent decarbonization would require more wind generation and battery storage. Going the final distance to 100 percent decarbonization would likely rely on carbon capture, use, and storage (CCUS), where emissions from fossil-fuel plants are captured and stored. CCUS capital costs are high, but continuous use for power generation can temper them.

Baseload clean markets

These markets have a substantial core of base-load clean power, such as nuclear plants in France and hydroelectric facilities in Brazil and the Nordic countries. That's a hefty structural advantage: building on a zero-emissions base, they can choose the lowest-cost decarbonization option—in this case, wind—at little or no additional cost (using the base power to balance renewable intermittency) to reach 90 percent decarbonization.

These markets also would be well positioned to achieve full decarbonization through innovation in negative-carbon technologies. The combination of their clean base and renewables would create an opportunity to offset remaining emissions from the small amount of gas-fired "peaking" capacity needed (about 3 percent) with direct air capture (DAC). This technology effectively inhales CO_2 from the atmosphere and stores it underground or dispatches it for industry use. Costs are high but would be manageable in narrow-cast usage.

[3] The PJM Interconnection serves all or part of Delaware; Illinois; Indiana; Kentucky; Maryland; Michigan; New Jersey; North Carolina; Ohio; Pennsylvania; Tennessee; Virginia; Washington, DC; and West Virginia.

Large, diversified markets

This market type comprises large territories, such as California, Mexico, and parts of eastern Australia, where renewables represent only a modest chunk of base power today, and substantial potential exists for additional renewables—principally solar and wind, but also river-based hydro. Our analysis suggests that the most direct path to 90 percent emissions abatement would be greater solar generation, plus storage—backed up by gas facilities to manage intermittency. Although efforts to connect renewables to the grid at large scale would impose some inefficiencies (curtailment costs), overall system costs might decrease as the costs of solar and storage continue to fall.

Getting to 100 percent decarbonization in these markets would require overbuilding of renewables and storage, which in turn would pile on curtailment costs as these new assets are cycled through the system. These markets would need to keep some thermal plants, supported by hydrogen through P2G2P technologies, to run the facilities. While expensive, P2G2P would kick in only if renewables could not produce for multiple days to supply power.

Technology advances could lower costs and accelerate the transition pathways we have described. In addition to direct air capture, CCUS, and P2G2P, advances in longer-duration storage and biomass fuel technologies could also move the needle, as could advances in more traditional areas such as nuclear generation and transmission. Significant penetration levels of electric vehicles could displace a meaningful portion of the stationary batteries that would otherwise be built. Paradoxically, however, they are unlikely to substantially affect system costs, since they do not solve the puzzle of achieving the transition from 90 percent to 100 percent decarbonization. That requires a breakthrough in storage.

The challenge, of course, is that even though the outlines of a new environment have begun to emerge, the power industry operates with time horizons in the decades. The implication is high-stakes strategic decision making under uncertainty, from utilities, regulators, and investors, and an innovation imperative that will vary considerably by market and company. Q

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The authors wish to thank Amy Wagner for her contributions to this article.

→ *For more, see "How to decarbonize global power systems," on McKinsey.com.*

Shifting the status quo in energy: An interview with Sunrun CEO Lynn Jurich

Solar power could play a vital role in decarbonizing power generation—even as it disrupts the status quo.

Shifts in consumer preferences toward sustainability initiatives and renewables could play a key role in decarbonizing the generation of power. With interest in solar power on the rise, the San Francisco–based company Sunrun pioneered a business model that enables more households to access solar panels and batteries. Since its beginning in 2007, the company has grown from two graduate students in an attic to more than 4,000 employees.

In this interview with McKinsey's Katy George, Sunrun CEO Lynn Jurich talks about the importance of creating win–win models with the utilities industry, innovating in the face of disruption, and empowering the front line.

The *Quarterly*: *The word "disruptor" is thrown around a lot, but it's certainly true of Sunrun. How did that happen?*

Lynn Jurich: It was clear to us from the start that solar was going to be the breakthrough renewable technology. We hypothesized that solar is disruptive because it can be distributed at a microlevel. When a new technology emerges, people always try to force it into the way they already do things—and, in the energy industry, that often looks like a hub-and-spoke model, where a centralized energy source is distributed elsewhere for consumption. But one of the disruptive things about solar is that it's more typically sited where the energy is actually consumed.

We wanted to go for the direct-to-consumer market, because we believed that's where you hit grid parity[1] first. It cost a lot more money than we thought it would and posed many challenges along the way. But fast-forward 13 years: we've installed nearly $5 billion worth of residential systems, have 285,000 customers, and have sold our solar service in 22 states, Washington, DC, and Puerto Rico.

The *Quarterly*: *How did you build the capabilities and culture to be successful?*

Lynn Jurich: The business model has evolved over time. We've had to make significant changes in how we attack the market. Our original plan was to own scalable pieces of the value chain. We believed there were advantages to building up a financing capability and making it affordable for people to install solar. So that's the business model we invented—delivering solar as a service. That model gives you scale from finance, reach, distribution to end consumers, and brand.

[1] Grid parity is when the cost of generating electricity from renewable sources reaches or beats the cost of traditionally generated power.

In the beginning, we deliberately didn't handle any of the construction. That's a local business, so we partnered with local companies. It became clear, about six years in, that we needed to be involved in construction as well. That was a massive change for us. We needed to acquire a local solar installer and build out that capability. Furthermore, we were dealing with a completely different business, workforce, and set of challenges there. Not only that, but we had to convince them to take our equity before we were publicly traded.

We also had to make culture shifts—and our culture is still evolving. We primarily had a structured culture, full of people with deep backgrounds in finance and policy. Now, execution is where all the action takes place. The front line is getting more efficient, and the people who talk to our customers are the same people who handle installations. I spend a lot of time in the field myself to better understand the challenges and opportunities. We're also figuring out how to orient the business so that decision making is done locally. People are smart and want to do the right thing. Give them the right context, and the people closest to the action are going to make the best decisions.

The *Quarterly*: *You're competing with local, nimble installers, but you're also competing with utilities. How does this dynamic affect the customer?*

Lynn Jurich: There are many long-standing incumbents in this industry. Their business model is big energy flowing one way and building all the assets for peak demand. Today, it's suddenly getting expensive to maintain that system. There are massive amounts of capital expenditure going into upgrading our utility system—and climate change is making it worse.

Now we're able to sell solar electricity as a service to our customers at a lower price than the utility. Our structural advantage is increasing because our costs are decreasing. What I want to do is work with the utilities—it's not a zero-sum game to me. Instead of having both us and the utilities build infrastructure, we strive for win–win models where we say to the utility, "You have peak demands for power. Instead of powering an expensive fossil-fuel plant, let us tap into thousands of our customers' batteries, coordinate, and dispatch them." We create a response to peak demands, and the customer doesn't need to change their behavior.

I often see people misunderstand risk. The status quo *feels* safer but is actually riskier. If you're a utility commissioner, it's riskier to keep relying on those 30-year-old gas plants than to incentivize a bunch of homes to help meet that demand. Yet this is how so many people react to disruption: with fear and a desire to protect the way things are.

The *Quarterly*: *How would you describe the leadership team's culture? What is most important to you in terms of behavior?*

Lynn Jurich: It's critical that our leadership start from a place of abundance and win–win scenarios; even if those scenarios end up not being possible, it's important to get creative and think in that space. That's what it takes to move quickly and within the time frame necessary to address energy issues as urgent as climate change.

When operating from a place of abundance, we can call each other out when we're getting too attached to our own ideas, and we have a facilitating coach to help us. We make it safe to think freely and say, "What if the opposite of that could be true? Let's be curious about this for a second." You make much better decisions that way.

Also, it's crucial for us to take care of our employees, particularly the ones on the front lines with customers. If your employees are passionate about the purpose, and the company takes care of them, they're going to take care of your customers. Your customer experience is everything in this world. Q

Lynn Jurich is the CEO of Sunrun. This interview was conducted by **Katy George,** a senior partner in McKinsey's New Jersey office.

→ *For the full version of this interview, including Lynn Jurich's views on diversity in the workplace, see "Shifting the status quo in energy: An interview with Sunrun CEO Lynn Jurich" on McKinsey.com. This interview originally appeared in* Voices on Infrastructure: Workforce of the future*, December 2019, McKinsey.com.*

Building a more sustainable battery industry

The ability to store growing amounts of renewable energy is not only critical to combating climate change but will also jump-start a range of economic activity.

by Bernd Heid, Sean Kane, and Patrick Schaufuss

The global battery industry is powering up: we estimate that uses—from electric vehicles to backup power to mobile phones and other consumer products—could increase demand for batteries 17-fold by 2030 (exhibit). That would mean big changes for the industry and could also bring huge benefits.

To understand the potential, we modeled a base-case scenario incorporating today's "industry momentum" rate of battery adoption[1] and comparing it with a high-growth "target scenario." In the latter, a "circular" value chain, new business models, and better cross-border coordination would enable faster adoption and better overall economics. How much better? By 2030, in our target scenario, batteries could contribute up to $185 billion a year in economic value[2] to the global economy. Battery-driven powertrains would replace a growing number of internal-combustion engines (ICE) in transportation and support the use of renewables to generate electricity. The resulting displacement of carbon-based fuels could contribute about 30 percent of the CO_2-emissions abatement needed to limit warming to 2 degrees Celsius above preindustrial levels. Additional progress would be needed to reach a 1.5-degree threshold.

Gearing up the industry

We expect that demand for lithium-ion (Li-ion) batteries will grow to more than 3,500 gigawatt hours (GWh) by 2030, from about 220 GWh in 2019. The structure of demand for Li-ion batteries is shifting rapidly, too. Batteries for consumer electronics could represent a much smaller part of total demand—about 2 percent in 2030, versus 18 percent today. Meanwhile, demand for Li-ion batteries for use in electric cars, trucks, and buses could rise to more than 85 percent of the total, from just 7 percent in 2020.[3] Power storage for the electricity grid would account for 13 percent of demand for new batteries.

In this high-growth target scenario, 120 new large-scale factories would be needed to produce battery cells. The required raw-material inputs would increase up to 40 times, depending on the mineral used. Production of the active materials in battery cells would rise nearly 15-fold. In parallel, a more robust circular value chain, including a network of facilities to refurbish and recycle batteries, would have to expand by orders of magnitude.

[1] We also modeled a growth path in which the adoption of batteries was "unguided" by sustainability considerations.

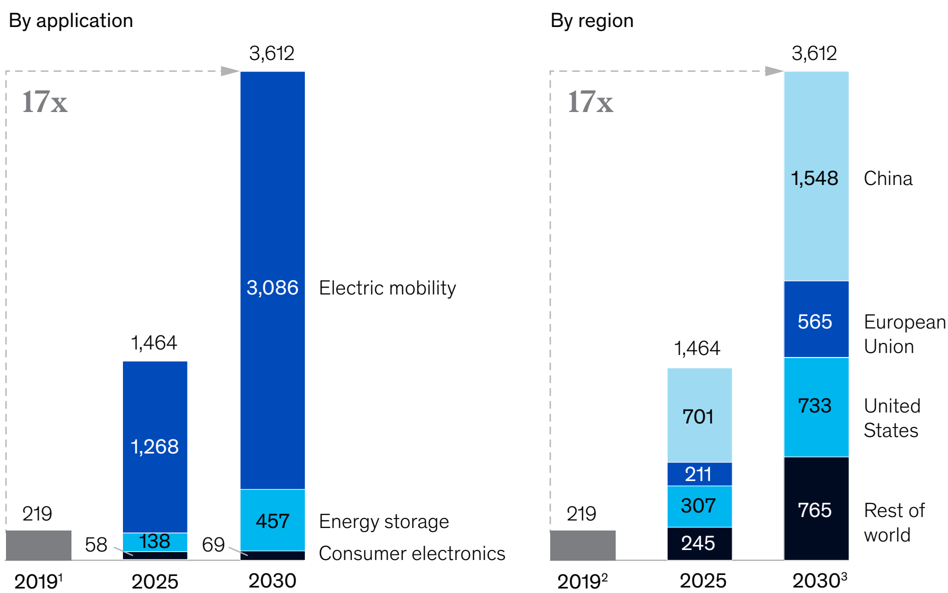
[2] See *A vision for a sustainable battery value chain in 2030: Unlocking the full potential to power sustainable development and climate change mitigation*, Global Battery Alliance, World Economic Forum, September 2019, weforum.org. We define value as global earnings before interest and taxes.

[3] That would represent nearly 25 percent of global sales of new passenger cars in 2030 and 35 percent of sales of commercial vehicles, including buses.

Exhibit

Global battery demand is expected to grow to approximately 3,600 gigawatt hours by 2030.

Global battery demand in gigawatt hours, target case



[1] In 2019, demand for consumer electronics equaled 40 gigawatt hours (GWh); for energy storage, 7 GWh; and for electric mobility, 171 GWh.
[2] In 2019, regional demand totaled 26 GWh for United States, 24 GWh for European Union, 155 GWh for China, and 14 GWh for rest of world.
[3] Figures do not sum to total, because of rounding.

Source: Global Battery Alliance; World Economic Forum; McKinsey analysis

Our research shows that progress toward circularity could improve the industry's economics, particularly for vehicles, since longer usage would increase both the value of batteries and their end-of-life value.[4] This could prove critical to the electric-vehicle (EV) manufacturers' business models, which depend on lower battery costs. A combination of circularity, expected advances in battery technology, economies of scale, and more efficient manufacturing could reduce battery costs by more than 20 percent in 2030 compared with the base case.

Taken together, the economic value of an expanded battery economy could range from $130 billion to $185 billion a year in 2030. More than half of that value would arise from new applications—for example, the growth in electric vehicles, vehicle-charging stations, power-distribution assets, and new technologies that cycle power from batteries in vehicles to the grid. The remaining value would be generated in mining and processing, the production of battery cells and packs, and an expanded recycling industry. Consumers in developing markets would also benefit: with the help of batteries, some 600 million people living in areas beyond the reach of today's power grids could gain access to electricity.

[4] We analyzed five levers in detail: electric shared mobility, smart-charging (V1G) and vehicle-to-grid (V2G) technologies, repair and refurbishment, the repurposing of EV batteries after use, and recycling.

Displacing greenhouse gases

In automobiles, the greater use of batteries could reduce CO_2 emissions by 1.3 gigatons (Gt) a year in 2030 in our target case,[5] or about 25 percent of what's needed from the sector is to achieve decarbonization objectives consistent with a 1.5-degree warming pathway. By 2030, EVs are poised to deliver dramatic emissions advantages over today's ICE vehicles across the full value chain in many regions and segments. Larger passenger EVs in Europe, for example, would curb 60 percent of emissions, while smaller ones in China would perform 35 percent better than ICE vehicles. Those abatement gains would come about because batteries would be more economical to use, boosting ICE-replacement rates, and because battery manufacturing would be more sustainable.[6]

In the power sector, batteries could help abate some 7.1 Gt of CO_2 emissions annually by 2030, about 77 percent of what's needed from the sector to hit decarbonization targets for a 1.5-degree pathway. Batteries, acting indirectly, are an important tool for balancing the power grid: they allow more renewables to come on stream and replace so-called peaker plants, which run on natural gas and now cover intermittent electricity supply—for times when there is no sun or wind. We estimate that 2,200 GWh of renewable power will be added to the world supply by 2030—more than 1.5 times today's levels—and that 480 GWh of additional battery-storage capacity will be needed to accommodate the new renewables. A robust, decentralized battery-storage network would also increase the grid's resilience, since more power would be generated, stored, and distributed locally, and businesses and homeowners would play a greater role than they do now.

The way forward

Our target case assumes that the industry will operate more sustainably across its value chain, which starts with mining and refining operations for nickel, cobalt, lithium, and other minerals. Another assumption is greater reliance on renewable energy; without it, emissions from battery manufacturing could rise to eight times today's levels by 2030.

Getting to a more sustainable operating environment will demand concerted action. In mobility, for example, it would require an orchestrated rollout of charging and grid technologies, in tandem with higher EV sales; better systems for collecting batteries for refurbishment, backed by better data tracking; harmonized recycling regulations across regions; and guidelines for the responsibilities of producers. Gearing up would also take capital: we estimate that $400 billion in new investment would be needed to generate the full economic and environmental benefits. That's a sizable bet, but it would ensure that the battery economy reaches its full potential. Q

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[5] CO_2-abatement estimates reflect today's global sales of 100 million vehicles.

[6] This analysis assumes increased use of renewable energies across the battery value chain, as well as the intensified use of batteries and raw-material components through purpose-built shared vehicles and recycling. These developments would effectively spread the initial carbon footprint of batteries over a longer lifetime and greater mobility usage.

Purpose: Shifting from why to how

What is your company's core reason for being, and where can you have a unique, positive impact on society? Now more than ever, you need good answers to these questions.

Only 7 percent of Fortune 500 CEOs believe their companies should "mainly focus on making profits and not be distracted by social goals."[1] And with good reason. While shareholder capitalism has catalyzed enormous progress, it also has struggled to address deeply vexing issues such as climate change and income inequality—or, looking forward, the employment implications of artificial intelligence.

But where do we go from here? How do we deliver a sense of purpose across a wide range of environmental, social, and governance (ESG) priorities? Doing so means moving from business as usual to a less traveled path that may feel like "painting outside the lines." Are we going too far beyond our core mandate? Does it mean we'll lose focus on bottom-line results? Will transparency expose painful tensions better left unexamined? Will our boards, management teams, employees, and stakeholders want to follow us, or will they think we have "lost the plot"? There are no easy answers to these questions; corporate engagement is messy, and pitfalls, including criticism from skeptical stakeholders, abound.

Yet when companies fully leverage their scale to benefit society, the impact can be extraordinary. The power of purpose is evident as the world fights the urgent threat of the COVID-19 pandemic, with a number of companies doubling down on their purpose, at the very time stakeholders need it the most (for more, see "Demonstrating corporate purpose in the time of coronavirus," on McKinsey.com). Business also has an opportunity, and an obligation, to engage on the urgent needs of our planet, where waiting for governments and nongovernmental organizations to act on their own through traditional means such as regulation

[1] Alan Murray, "The 2019 Fortune 500 CEO survey results are in," *Fortune*, May 16, 2019, fortune.com.

About this article

This article was a collaborative, global effort between **Arne Gast** (partner in McKinsey's Kuala Lumpur office and leader of Aberkyn, McKinsey Academy's dedicated leadership facilitation group), **Pablo Illanes** (partner in the Washington, DC, office and Public and Social Sector Practice lead for McKinsey's purpose initiative), **Nina Probst** (partner in the Geneva office and leader of the survey underpinning the article), **Bill Schaninger** (senior partner in the Philadelphia office and leader of McKinsey's Organization Practice), and **Bruce Simpson** (senior partner in the Toronto office and leader of McKinsey's purpose initiative).

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and community engagement carries risk (for more, see "Confronting climate risk," on page 9").

Fortunately, a "how to" playbook is starting to emerge as a growing number of companies lead. In this article, we try to distill some inspiring steps taken by forward-looking companies. In doing so, we don't pretend to have all the answers. What we present here is some early thinking about the road ahead from our research and engagement with clients around the world. We hope this will help you wherever you are on your journey.

Confronting the purpose gap

The August 2019 Business Roundtable Statement, which elevated stakeholder interests to the same level as shareholders' interests, represents both a reappraisal of purpose and a reflection of tensions that have been boiling over. Customers are boycotting the products of companies whose values they view as contrary to their own. Investors are migrating to ESG funds. And the majority of employees in the corporate world feel "disengaged"; they are agitating for decisions and behaviors that they can be proud to stand behind and gravitating toward companies that have a clear, unequivocal, and positive impact on the world.

Organizations turning a blind eye will face inevitable blowback. In just the past year, companies have witnessed hundreds of thousands of employees walking out over climate issues and recurrent high-profile petitions about business practices that have raised the ire of socially conscious interest groups. Digital platforms are powerful amplifiers. As historian Niall Ferguson warns in a recent *McKinsey Quarterly* interview, "If your company has not been on the receiving end of a Twitter storm, then don't worry, it soon will be."[2]

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[2] Niall Ferguson, "'Don't be the villain': Niall Ferguson looks forward and back at capitalism in crisis," *McKinsey Quarterly*, November 2019, McKinsey.com.

Despite all this, the potential is extraordinary for business to serve as a force for good. Corporate social responsibility (CSR) initiatives remain a powerful lever. We also see burgeoning opportunities for businesses to contribute that extend beyond traditional CSR—such as deploying digital tools and advanced analytics to address global challenges, as well as mobilizing diverse ecosystems of players to pursue goals that no individual business (or government) could realize on its own. To take just one example, apparel giants such as H&M, Kering, Nike, and PVH have joined forces to create Global Fashion Agenda, a not-for-profit organization that promotes sustainable fashion, from the efficient use of resources and secure work environments to closed-loop recycling. Often, though, these opportunities feel tangential. Many executives tell us they feel their own companies do great CSR work but wish those efforts could extend into the core, adding meaning to the day-to-day experience of their employees and themselves.

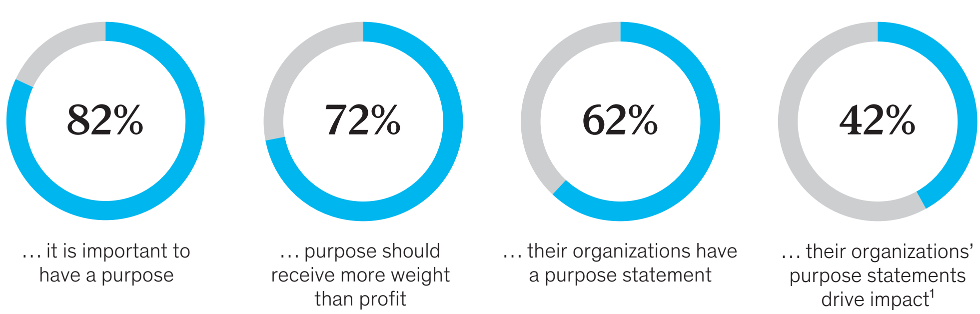
We'd suggest that the disconnects between public perceptions of business and its potential for good, or between employees' desire for meaning at work versus what they experience, reflect a purpose gap. In a recent McKinsey survey comprising a representative sample of more than 1,000 participants from US companies, 82 percent affirmed the importance of purpose, but only 42 percent reported that their company's stated "purpose" had much effect (exhibit). That shouldn't be surprising. Many companies' purpose statements are so generic that they do little to challenge business as usual, and others don't emphasize the concerns of employees. Contributing to society and creating meaningful work, the top two priorities of employees in our survey, are the focus of just 21 percent and 11 percent of purpose statements, respectively.

We'd further suggest that there is a frustratingly simple reason why business leaders have struggled to square all these circles with coherent statements and credible actions: it's difficult to solve, simultaneously, for the interests of employees, communities,

Exhibit

Employees feel that purpose is important—but many say their companies don't have one, let alone one that makes a difference.

Respondents reporting that …



Note: segments displayed in gray reflect respondents who were neutral, disagreed, or strongly disagreed.

[1]Impact score, which is based on subset of respondents reporting presence of organizational purpose, derived on basis of responses to questions about achievements of purpose and positive change associated with purpose.

Source: McKinsey Organizational Purpose Survey of 1,214 managers and frontline employees at US companies, October 2019 suppliers, the environment, customers, and shareholders. Tensions and trade-offs abound as we strive to align our business and societal goals; to integrate that identity into the heart of our organizations; and to deliver on our purpose, including its measurement, management, and communication.

Placing purpose at the core

What's needed is relatively clear: it's deep reflection on your corporate identity—what you really stand for—which may well lead to material changes in your strategy and even your governance (such as your status as a public company, a private company, or a public-benefit corporation).

But how do you pull this off? What are the mechanics of getting it done and making it real? How do you embrace challenging trade-offs and uncomfortable truths that, if unaddressed, are likely to perpetuate the purpose gap and give rise to rhetoric that's not accompanied by credible action?

We don't yet have complete answers to these difficult questions. One thing we are convinced of, though, is that the only way to bridge a purpose gap is to embed your reflection, exploration, discussion, and action in the heart of your business and your organization. We describe here a necessary precondition for any of that, and then four steps for moving ahead: sizing up where you are, including your vulnerabilities; clarifying how your purpose connects with your company's "superpower"; organizing with purpose in mind; and measuring and managing purpose so that it really becomes part of your core DNA.

0. Understand that purpose is personal and emotional

The precursor to action is embracing the emotion and complexity associated with hard work on purpose. There is no simple, input/output equation, which makes it hard to address purpose in the context of prevailing shareholder models. Purpose also is deeply intertwined with the people who make up an organization and who, like all of us, are messy at times. Founder-driven companies, such as Starbucks, sometimes find it easier to put purpose at their core, because their leaders connect with and shape purpose emotionally as well as logically. The rest of us need to make this personal, too.

1. Get real: Create a baseline from your stakeholders' perspectives

Connecting purpose with the heart of your company means reappraising your core: the strategy you pursue, the operations driving you forward, and the organization itself. That's hard work, and you can't do it without deep engagement from your top team, employees, and broader stakeholders. But there's no substitute. Your stakeholders care about the concrete consequences of your lived purpose, not the new phrase at the start of your annual report.

Start by taking a hard look at the relationships among your social and environmental impact, your strategy, and your purpose, which may be misaligned. Such a reappraisal could lead you to reevaluate some of those hard-to-reverse choices about where and how to compete that represent the core of an effective strategy. The resulting friction is uncomfortable, but also extremely valuable. You can encourage it on an ongoing basis by building purpose-linked questions into your key strategy, budgeting, and capital-investment discussions. For example: "Which pillars of our strategy are most and least congruent with our purpose? How would a ranking of our products and services according to purpose compare with one based on profitability?" Questions such as these cause everyone to pause, legitimize healthy introspection, and boost the odds of spotting instances when taking a short-term revenue or margin hit is a small price to pay for being true to who you are or want to be. (For a more complete set of purpose-related questions, see sidebar, "Questioning purpose.")

Your self-assessment must go well beyond strategy. Measure your social and environmental impact, starting with a review of your supply-chain and supplier risks. Society now holds you responsible for your entire business chain, beyond your corporate walls, including what your suppliers do. If you, as a senior leader, have not been personally involved with supplier issues recently, go and see for yourself. You don't need another report; you need deep conviction—either that your supply chain is healthy and sound today or that you have a plan to make it so tomorrow. You need to recognize your vulnerabilities in the eyes of society and tackle them.

Dig deep into the makeup of your products. If you make cell phones, how much plastic in the product is recycled versus new, and how easy are your phones to repair versus replace, which carries additional environmental cost? Your impact also extends to the resources, including energy, that are required for the consumption of your products, in their entirety. Starbucks recently estimated that about 20 percent of its total carbon footprint was related to the production of dairy products consumed with its coffee.

Engage a wide range of stakeholders early as a key input into the process. A basic-materials company we know interviewed 150 external stakeholders, including investors who had chosen not to invest in its industry, as well as CEOs in other industries, all with an eye toward understanding their posture and process related to purpose. Such engagement brings out new perspectives, mitigates risk, and avoids surprises later on. What would an activist discover by digging deeply? Where are you most vulnerable? What is the central thing that critical stakeholders believe society expects from you, and are you doing enough about that? Are you focusing on only a couple of the United Nations' Sustainable Development Goals, while critics would emphasize others at the bottom of your to-do list? Or are you "doing good" in some areas of your business, while hoping this makes up for negatives in others? All these can be calibrated and assessed, to some degree. At times, doing so may demand the courage to let your stakeholders' perceptions of where you are trump your own views.

2. Connect purpose with your company's 'superpower'

As you take stock and tackle your company's vulnerabilities, you also need to set bold aspirations and push for specificity on the alignment between purpose and value. It's often present. Research by author and professor Raj Sisodia suggests that purpose-led companies significantly outperformed the S&P 500 between 1996 and 2011.[3] More than 2,000 academic studies have examined the impact of environmental, social,

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[3] Rajendra Sisodia, Jagdish N. Sheth, and David Wolfe, *Firms of Endearment: How World-Class Companies Profit from Passion and Purpose*, second edition, Upper Saddle River, NJ: Pearson Education, 2014.

Questioning purpose

Purpose defines our core reason for being and the positive impact we have on the world. It shapes our strategy, inspires our people, engages our customers and community, steers choices at moments of truth, and is fully embedded in our culture. Living purpose authentically should feel uncomfortable and new. It may mean surfacing fresh questions in meetings, engaging in difficult conversations about some of our businesses, and reevaluating our partners based on a clear-eyed view of their practices.

Whether we are reappraising an existing purpose or designing one for the first time, we need to wrestle with challenging questions such as the ones below. These questions can help test whether we are acting with the necessary authenticity and boldness. In exploring such questions, some companies we know have found it helpful to use the accompanying framework to help them assess how far they've gone and how much room there is left to run.

The purpose of a company leads to strategic choices and builds on cultural strengths to drive impact.

Purpose

Questions

- What is our purpose as a company and how does it link with our "superpower"—our capacity to make a distinctive contribution to the world?
- Who benefits from our success, and what are our responsibilities—to shareholders, yes, but also to our workforce, suppliers, ecosystem participants, communities, and the environment in which we operate?

Proof points

- Declaring a purpose statement that is clear enough to help middle management make trade-offs in daily decisions, and credible in the eyes of stakeholders
- Defining specific, short-term (for example, "2021") impact goals

Strategy

Questions

- When trade-offs arise, how should various stakeholder interests be balanced and reconciled? Who needs to be involved, and how will we make decisions?
- How willing are we to change our philosophy and economic model to reflect our purpose and enhance our social and environmental impact?

Proof points

- Incorporating purpose screens and criteria into budget and investment decisions
- Changing governance and sources of capital (such as becoming a public-benefit corporation)
- Sticking to bold purpose goals during times of economic turbulence

Culture

Questions

- What is our heritage? Why have we been successful in the past? How does this foundation enable our purpose going forward?
- How will our purpose strategy enrich and strengthen our culture and values?
- How do we make purpose personal to employees, unlocking additional engagement?

Proof points

- Heavy, early investment in listening to stakeholders and understanding the current corporate culture—both weaknesses and strengths
- Candid, transparent assessment of corporate identity

Operations

Questions

- What are the biggest externalities across our value chain (including the impact of our products' use) that have not been considered, mitigated, or both?
- How can we align our supply-chain partners to our purpose?
- Where can we work with peers and other partners to diminish any negative societal impact caused by our sector—through, for example, collaborative circular-economy initiatives?

Proof points

- Creating end-to-end value-chain accountability from sourcing to recycling, including sustainability metrics and other environmental, social, and governance (ESG) disclosures, and comparing with stated goals
- Investing to help suppliers achieve ESG goals and exiting relationships with those that can't or won't

Marketing & sales

Questions

- How would our products and services rank in terms of social and environmental impact, compared with a ranking on profitability?
- What products and markets should be exited, and how will those decisions be made?
- How will purpose affect future decisions to invest in new product and market opportunities?

Proof points

- Exiting products/markets with significant, adverse social impact—even if it results in short-term revenue loss
- Entering new products/markets or making changes to existing products that enhance their societal value
- Making company-wide branding decisions that integrate purpose

Organization

Questions

- To what extent does organizational structure and governance enable employees to make trade-offs that prioritize purpose?
- What are the most powerful levers to pull around incentives, policies, and processes to ensure purpose is lived?
- How are employees able to engage on purpose today (including specific platforms and opportunities for dialogue)?

Proof points

- Making clear changes to recruitment and capability-building processes to embed purpose
- Incorporating purpose-driven metrics into compensation and performance decisions
- Developing mechanisms to constantly measure the link between employee and corporate purpose

Engagement

Questions

- How does our company talk about purpose with the board and investors?
- Who are the external stakeholders and partners who must be engaged? How and when should we engage them to ensure an open and authentic dialogue?
- What kind of public engagement enables us to project our purpose authentically?

Proof points

- Creating mechanisms to engage stakeholders early
- Engaging in purpose-driven public influence where appropriate
- Withholding nonpurposeful use of public influence (such as deciding to forgo a lobbying opportunity whose implications include identifiable, negative externalities)

Measurement

Questions

- What data and evidence are critical to measuring the total social and financial impact of our purpose, and what gaps exist today?
- What is not being measured or reported today that society will expect and hold us accountable for in the future?

Proof points

- Accounting for externalities in monetary terms
- Tracking and reporting progress against purpose goals

and governance propositions on equity returns, and 63 percent of them found positive results (versus only 8 percent that were negative).

Such outcomes don't arise magically because a company decides to be purpose-driven. They take shape most effectively when purpose connects with a company's "superpower"—its unique ability to create value and drive progress across ESG themes. For example, the multinational retailer H&M, whose CEO was previously its chief sustainability officer, has embraced the superpower of its supply chain by opening it up to rival brands that can use it to accelerate their own sustainability efforts.

Identifying and building around unique assets, capabilities, or points of leverage with the potential for outsize impact on social challenges can create value in a variety of ways:

- Purpose can generate topline growth (or serve as an insurance policy against revenue slippage) by creating more loyal customers, fostering trust, and preserving your customer base at a time when 47 percent of consumers disappointed with a brand's stance on a social issue stop buying its products—and 17 percent will never return.

- Purpose-driven environmental stewardship can reduce costs—for example, by improving energy or water efficiency.

- Purpose can unleash employee potential—helping you win the war for talent, retain your best people, and boost employee motivation. Today, about two-thirds of millennials take a company's social and environmental commitments into account when deciding where to work.

- Purpose can make you more aware of shifting external expectations, policy directions, and industry standards—thereby helping you identify risks you might otherwise miss. If a crisis does strike, preexisting alignment on the organization's core reason for being will enable a coordinated, values-driven response that is authentic to your people and compelling to stakeholders. "Trusted" brands bounce back faster after product mishaps and economic shocks, particularly when they respond effectively. This remains as powerful a truth as it was in 1982, when Johnson & Johnson recalled and repackaged Tylenol following a tampering tragedy.

- Purpose can improve your balance sheet. Danone, the French food multinational, has achieved materially lower capital costs by meeting a set of ESG criteria, including the registration of certain brands as B Corps over time. This move is backed by a syndicate of banks that have committed to rewarding purposeful business with cheaper capital.

The role of the leader is first to inspire creative thinking about what makes you unique, how it links to purpose, and why it could be valuable—and then to encourage rigor in embedding it in your company's core. As you strive to connect the superpower of your business with its impact on society, you're likely to identify a rich constellation of potential purpose initiatives. Some are near-term win–wins, delivering immediate societal and financial benefits. Others clearly help society now but take longer to yield bottom-line results. There also are bigger, "moon shot" bets, whose potential benefit to society is enormous but, for shareholders, perhaps unclear. If you have already built momentum with initiatives in the first two categories, it's easier to stretch for moon shots—which are the most meaningful, generate the most internal satisfaction, and also capture external attention (including motivating others to act). For example, Patagonia's commitment to repairing jackets, to encourage reusing them, has been emulated by other makers of outdoor wear.

3. Organize to keep purpose at the top of everyone's mind, every day

Then there's the organization itself. Do your people routinely reflect on purpose? Do your critical organizational building blocks—whether they are business units, agile squads, or pockets of functional expertise—have the autonomy and incentives to do their work with purpose? Are your purpose-driven functions (such as philanthropy) self-contained silos, or are they connected with the core of your business?

What about your culture? That, too, is part of your social impact. Just because you deliver good service to customers doesn't legitimize a toxic culture in your organization that excludes people. Dig deep to assess your own culture, the level of engagement of your own people, and the degree to which they feel empowered to bring their best selves to work.

Above all, do you understand what your employees care about—their sources of meaning, aspirations, and anxieties around social issues? Many CEOs are concerned that the majority of their employees are not actively engaged. What would it take for employees to bring enthusiasm, creativity, and collaboration to work, in addition to discipline? Connecting your people's individual purpose with organizational purpose is the critical link. An Asian insurer provides explicit space in its leadership programs to reflect on this connection. Meanwhile, a US-based healthcare company has prototyped an app with which people can explore their values and purpose and make workplace connections to enable the pursuit of those aims.

Making that link—in other words, achieving a truly purpose-driven culture—requires listening and being very open to what you hear. According to the leader of a recent effort to reexamine purpose at Nordea, a large bank in Scandinavia, it was indispensable to spend time "listening to more than 7,000 people in and around our organization over a period of six months . . . in workshops . . . online with surveys . . . [and] in more than 1,500 coffee-corner discussions. . . . We discussed deeply why people had joined us, why they stayed, and what they see as impact for a financial institution." That's what it looks like when organizations move purpose past slogans and buzzwords.

4. Measure what you can, and learn from what you measure

We all know that what gets measured gets done. But when it comes to purpose, what metrics best reflect impact across the ESG playing field? For complex, far-flung organizations, it can be easy to feel overwhelmed by the seemingly endless array of conflicting reporting standards. Different geographies demand different levels of rigor, and keeping up with the range of voluntary reporting initiatives can be taxing. Popular frameworks such as the United Nations' Sustainable Development Goals or the Global Reporting Initiative framework are useful touchstones, but they cannot serve as the sole basis of measurement efforts.

Instead, you should ask yourself and your peers questions like the following: What data and evidence are critical to understanding your organization's total social, environmental, and financial impact? How much insight are your current reporting outputs generating about your efforts to deliver on purpose? When was the last time you took action in response to a metric about your purpose? Perhaps even more important: What is *not* currently being measured or reported that society will hold you accountable for in the future—such as the greenhouse-gas emissions associated with your industry? And what metrics do your performance-management systems take into account? Seventh Generation, a maker of cleaning and personal-care products, recently built sustainability targets into the incentive system for its entire workforce, in service of its goal of being a zero-waste company by 2025.

Changing how you incentivize people, including the integration of societal-impact goals into compensation, is a "proof point" taken seriously by stakeholders. What other proof points can you build in? Measuring and reducing your carbon footprint and making substantial, measurable investments in reskilling are good examples. Ideally, such proof points become mutually reinforcing. Shell, for example, has plans to set short-term carbon-emissions targets and link executive compensation to performance against them.

You may need to create new metrics that more precisely reflect the tensions you are seeking to reconcile for you and your stakeholders. At PayPal, CEO Dan Schulman and his leadership team became concerned when they realized that a significant portion of their nearly 25,000 employees, particularly at the entry level and in hourly positions, were struggling to make ends meet despite the fact that the company was paying wages at or above market rate. To Schulman, this "seemed ridiculous" for a company whose purpose focuses on improving the financial health of its customers. As he put it, the "market wasn't working" for these employees—or for many others similarly situated.

PayPal surveyed its employees to assess their financial wellness, developed and began tracking metrics such as a new "net disposable income" calculation for its employees, and took immediate action to improve these metrics and provide its employees with financial security. By significantly lowering the cost of medical benefits, making every employee a shareholder, raising wages in certain instances, and delivering financial-wellness training, PayPal set a target to raise the net disposable income of its employees and improve their financial health. In a world where, as McKinsey Global Institute research has shown, a majority of the next generation in advanced economies is "poorer than their parents," the impact of such initiatives cannot be overstated.[4]

Leading from the front

Purpose puts a premium on leadership. Move too fast, and you will be criticized for swinging too far. Move too slowly, and you will be viewed as a corporate ostrich. Most dangerous of all, if you claim to be delivering on purpose but are ultimately viewed as inauthentic, you will lose credibility in front of your employees and society alike. For example, will you stick to your purpose during economic turbulence, or only when times are good?

[4] See "Poorer than their parents? A new perspective on income inequality," McKinsey Global Institute, July 2016, McKinsey.com.

To be authentic, you must be unrelenting in elevating and stimulating debate about uncomfortable truths and tensions you may be tempted to sweep under the rug. You also need your own genuine way of talking about the symbiotic relationship between corporate purpose and corporate performance. Aetna CEO Mark Bertolini has a simple mantra: “No margin, no mission.” Feike Sijbesma, former CEO of life-sciences company DSM, simply says, “You cannot be successful, nor call yourself successful, in a society that fails.”

Our recent survey indicated that 33 percent of managers experienced trade-offs between purpose and profit, and 72 percent of all employees hoped that purpose would receive more weight than profit. These findings underscore both the top team’s role in mediating tensions, and the point we made earlier that some purpose initiatives require a leap of faith. At times, senior leaders will need to embolden their managers to take that leap, which is likely to be easier if some purpose-driven priorities are self-funding, setting the stage for subsequent, bolder bets. Pixar director Brad Bird describes these dynamics eloquently in a *Quarterly* interview: “[M]oney is just fuel for the rocket. What I really want to do is go somewhere.”[5]

In pushing your company to define and live its purpose consistently, you will be challenging the status quo in ways that may be unsettling for your people, and even for you. Championing such change requires leading with empathy—which, according to McKinsey research, means developing a broad future vision that extends beyond the problem at hand, inspiring and building trust with others by finding common ground, and leading by example. These findings suggest that a reset of leadership norms may be important as you strive to define and live your organization’s purpose, which must feel congruent and fit the style and actions of you, your senior team, and your employees. Remember, purpose is personal. By embracing that reality, you can create alignment between people and the organization that enables and ennobles everyone.

Decisions about purpose may be some of the more difficult decisions of your career. There will be a cacophony of opinions; adjudicating them will take discipline and conviction. There may be thinner evidence to guide your actions than you would like. Don’t let yourself be rushed. Establish a fact base to help you weigh trade-offs and mitigate risks.

Above all, don’t settle for “generic” on purpose. You do have a superpower to discover, and unique impact to deliver. Your company’s role stretches far beyond the confines of your employees and customers. Your suppliers will look to you for guidance. Your peers will look to you for inspiration. And society will hold you accountable for leaving the world a better place than it was when you started. Q

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[5] Hayagreeva Rao, Robert Sutton, and Allen P. Webb, “Innovation lessons from Pixar: An interview with Oscar-winning director Brad Bird,” *McKinsey Quarterly*, April 2008, McKinsey.com.

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