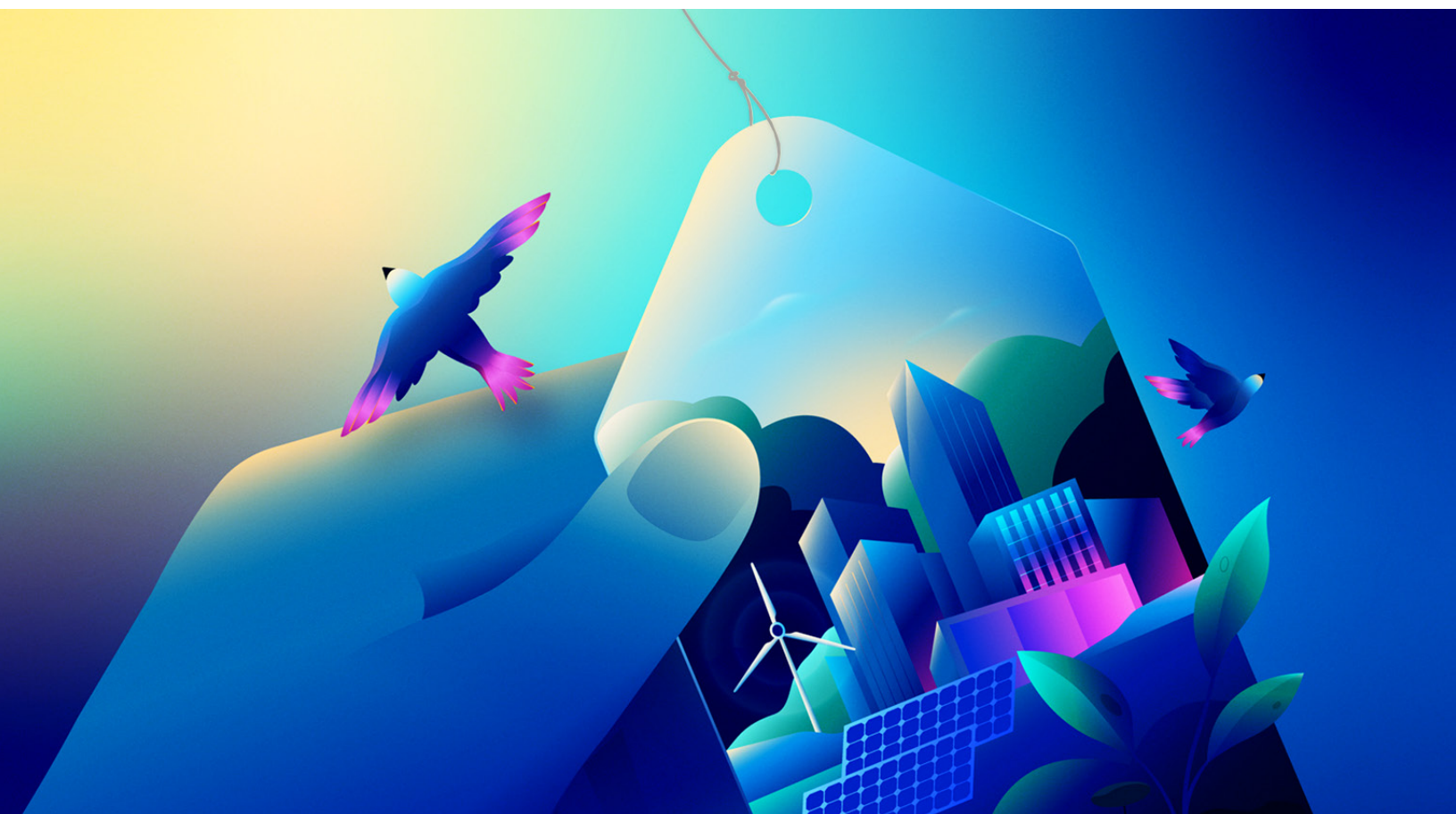


McKinsey Sustainability

Understanding the price of decarbonization

Cutting emissions is more important than ever. Marginal abatement cost curves help companies develop cost-effective strategies.

*by Stefan Helmcke and Tomas Nauc  r
with Scott Pendrey and Tim Vroman*



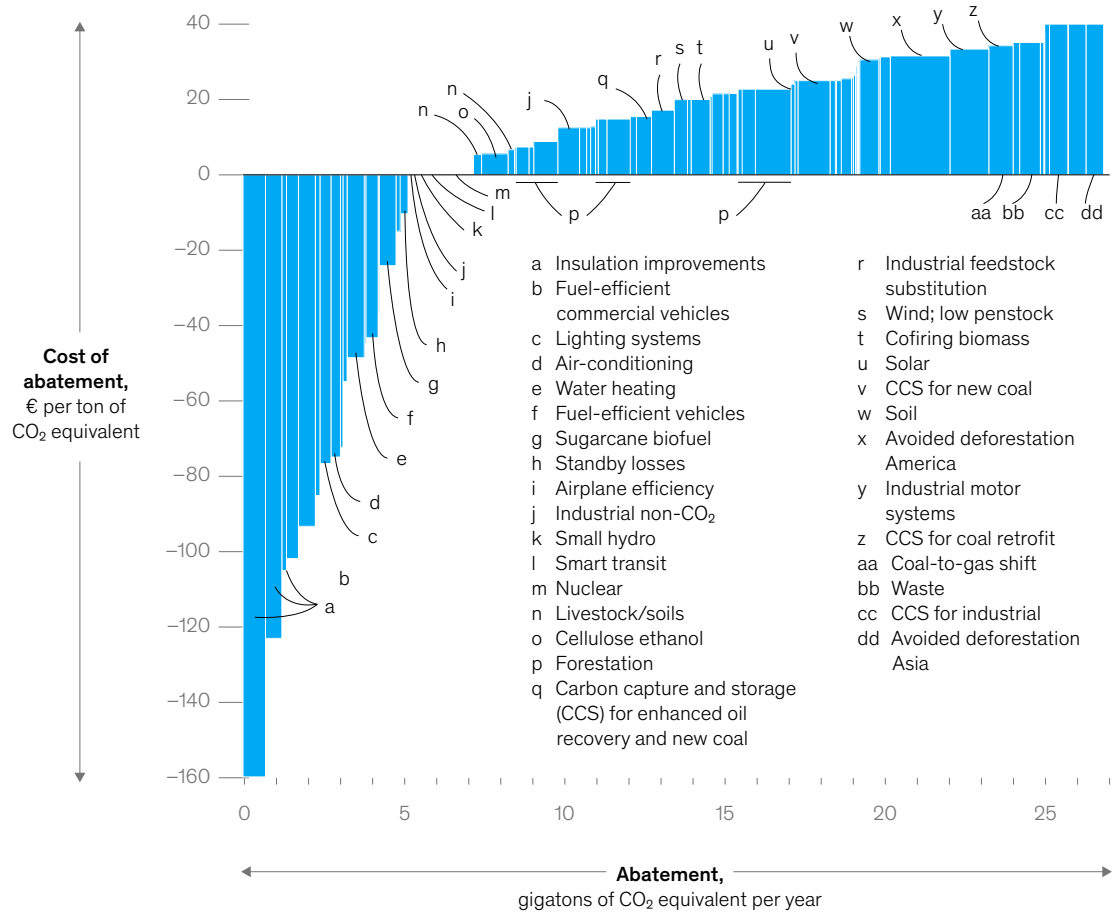
Reducing carbon emissions often requires making choices. Would it be wiser to switch to renewables, electrify a chemical process, plant forests, change a raw material, or something else? Organizations looking to make wise decisions must understand both the relative costs and the relative potential of abatement options.

In 2007, McKinsey developed—for a Swedish utility—the first marginal abatement cost curve (MACC) to provide such a framework (Exhibit 1). For each potential abatement measure, the MACC assigns a cost per ton of abated carbon and weights it by the amount of abatement that the measure could provide.

Exhibit 1

McKinsey prepared the first marginal abatement cost curve for a Swedish utility in 2007.

Global cost curve of greenhouse gas abatement opportunities beyond business as usual



McKinsey & Company

Since 2007, MACCs and their equivalents have become widely accepted. The UK Committee on Climate Change used such an analysis for its net-zero road maps. Companies including Chevron and ConocoPhillips use internal MACCs to evaluate emission reduction strategies. Now, in 2025, companies looking to reduce their emissions have many more options to consider. Our MACCs from the 2010s looked at approximately 150 levers; today's MACCs consider more than 1,400 levers across 170 value chains and incorporate hundreds of thousands of emission factors. That increase creates many more abatement opportunities for organizations; it also creates much more complexity. In this article, we look at how MACCs have developed over the years and why the kind of in-depth analysis they enable is more important than ever.

Historical hits and misses

Over the past 15 years, the sustainability landscape has evolved, with advances in knowledge and climate technology and changes in costs, policy, and regulation. Some decarbonization levers have advanced rapidly, others have fallen short of expectations, and some new levers have emerged. The biggest factor in the uptake of abatement levers over the years is their scalability: How quickly and successfully did costs drop, allowing a clean technology to be widely adopted?

Electric vehicles (EVs), heat pumps, solar photovoltaics (PVs), and wind power scaled faster than expected in 2007 because their low system complexity, modular design, and standardized industrial processes allowed for rapid cost declines. In the initial global MACC, the abatement potential for passenger EVs by 2030 was estimated at 0.05 gigatons, but the actual abatement was already 0.08 gigatons as of 2024.

On the other hand, technologies including [carbon capture, utilization, and storage \(CCUS\)](#), [nuclear power](#), and [green hydrogen](#)—all of which have high capital costs, complex infrastructure requirements, and ongoing research and development—have advanced more slowly than anticipated. The initial MACC reported more than three gigatons of potential abatement from CCUS, but the technology has not scaled as expected; only about one-thirtieth of those three gigatons will be captured by 2030.

We have also seen transitional technologies act as interim solutions while longer-term technologies scale up and mature. Plug-in hybrid electric vehicles have served as an effective transitional technology, cutting emissions relative to gas- and diesel-powered vehicles while EV infrastructure and adoption continue to grow.¹ And natural gas emerged as a transition fuel; the shale gas boom and its scale were not anticipated in the original MACC.

Where costs are not coming down fast enough, policy, regulation, and incentives can help to unlock the abatement potential of otherwise-ready technologies—and the MACC can help visualize which technologies are on this cusp. [Circularity in building retrofits](#) (reusing materials removed during building efficiency retrofits) and many land use and agriculture-related levers are mature technologies with substantial abatement potential, but only with incentives in place because their costs remain too high.

¹ "Emissions from electric vehicles," US Department of Energy, accessed May 16, 2025.

Perhaps surprisingly, many of the cheapest solutions—even those that save companies money—can be difficult for companies to adopt. This finding underscores that low cost doesn't always mean low friction. Cost is just one piece of the puzzle, and hidden beneath these levers are potential barriers such as policy gaps, stakeholder misalignment, politics, culture, and complexity.

Today's MACCs are finer grained and use AI

Since the first MACC, in 2007, thousands of new decarbonization levers have emerged. Some of the most important levers in today's MACCs are efficiency levers such as route optimization, using advanced analytics to optimize routes based on real-time conditions to minimize fuel consumption over time; and predictive scheduling using AI to align production schedules with availability of low-carbon energy. The increasingly fine-grained view into decarbonization allows companies or governments to identify potentially easy-to-adopt wins and even money-saving opportunities that can add up. For example, a company might be able to achieve the same decarbonization via waste reduction or circularity—which can reduce emissions and save costs—as by adopting new technologies such as CCUS, which requires a larger change to operations and can come at a higher cost.

One key insight from MACCs is that nature is the greatest lever of all. Some nature-based solutions (NBS), such as avoiding deforestation, are low-cost and high-impact. Others, including reforestation and new agricultural practices, have great promise for the future but can be costly. Over the past few years, NBS have been increasingly incorporated into policy frameworks and financial mechanisms. Yet they have their share of critics, who note (among other remonstrances) that vague definitions can lead to NBS being co-opted by entities that may not prioritize genuine ecological benefits.

A major technological development for decarbonization is the rise of AI and advanced analytics. These technologies enable companies to achieve cost savings and accelerate their decarbonization through digital and cloud solutions, such as streamlining the understanding of their Scope 3 emissions, identifying efficiencies in operations through the use of [digital twins](#), and reducing emissions via machine learning that helps to optimize product design and material use. [While AI data centers require significant energy](#), McKinsey estimates that [cloud-powered technologies](#) can accelerate 47 percent of the initiatives required to achieve the global 1.5° pathway by 2050 under the Paris Agreement.²

The latest versions of the MACC make use of AI and automation. Incorporating more than 300,000 emission factors from across sectors, today's MACCs use extensive data sets to rapidly create automated, dynamic MACCs for companies. This automation allows rapid testing of the effectiveness of potential decarbonization strategies. In one case, AI-driven MACCs were able to [identify a set of levers](#) that could reduce the cost of achieving the company's decarbonization target by 10 percent relative to its plan without this tool. This analysis also required 90 percent less time and expense than traditional MACC generation.³

² "Cloud-powered technologies for sustainability," McKinsey, November 9, 2023.

³ "Accelerating decarbonization across the farming supply chain," McKinsey, February 4, 2025.

Can MACCs help us catch up on cutting emissions?

The world is currently not on track to achieve greenhouse gas emission reductions in line with the Paris Agreement's goals, so there is an urgent need to scale new ideas faster. Our work with MACCs has led us to several insights that could help stakeholders devise strategies to decarbonize faster.

Regional plans for decarbonization are increasingly important

The past century has seen the rise of global value chains, with many goods and services manufactured and assembled across multiple countries. In Europe and elsewhere, cross-border regulations are emerging that account for a product's emissions in other countries. The result may be that countries with weak environmental regulations and minimal decarbonization efforts could see costs increase because of their role in global value chains.

This has led to the need for research on regional abatement levers and emission factors that incorporates differences in technological maturity, the power generation mix, and information from specific regional suppliers. More granular data allows decarbonization practitioners to shift to a more nuanced regional focus.

There can be significant regional variance in cost and abatement potential. Exhibit 2 illustrates this variance for a key decarbonization lever—green electricity for smelting in aluminum production—across four countries.

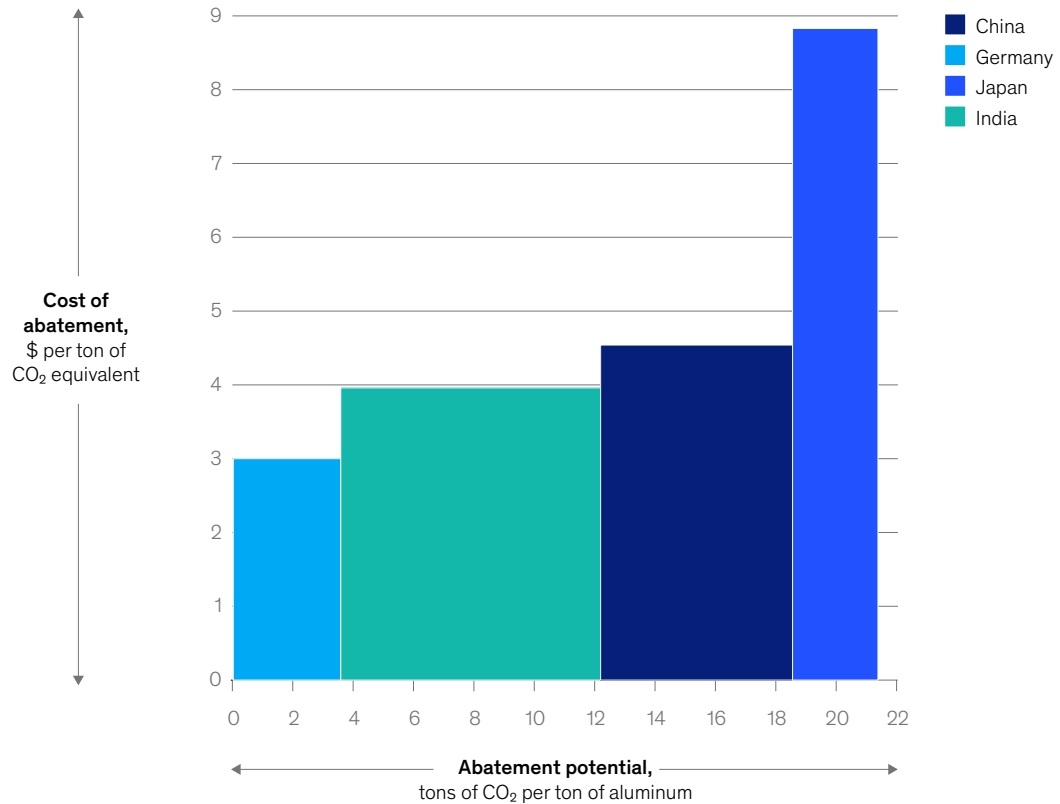
These regional views give stakeholders more transparency on their supply chain's carbon footprint, helping them implement more effective and context-specific decarbonization strategies.

The world is currently not on track to achieve greenhouse gas emission reductions in line with the Paris Agreement's goals, so there is an urgent need to scale new ideas faster.

Exhibit 2

Marginal abatement cost curves illustrate that decarbonization levers can vary across geographies.

Green electricity for smelting as an example lever



Source: McKinsey Catalyst Zero

McKinsey & Company

Dynamic MACCs offer better insights

Initially, the MACC presented static costs and abatement potentials without considering how technologies interacted. Today's MACC platform can be updated in real time and reflects the interdependence of levers and changes in costs and abatement potentials over time.

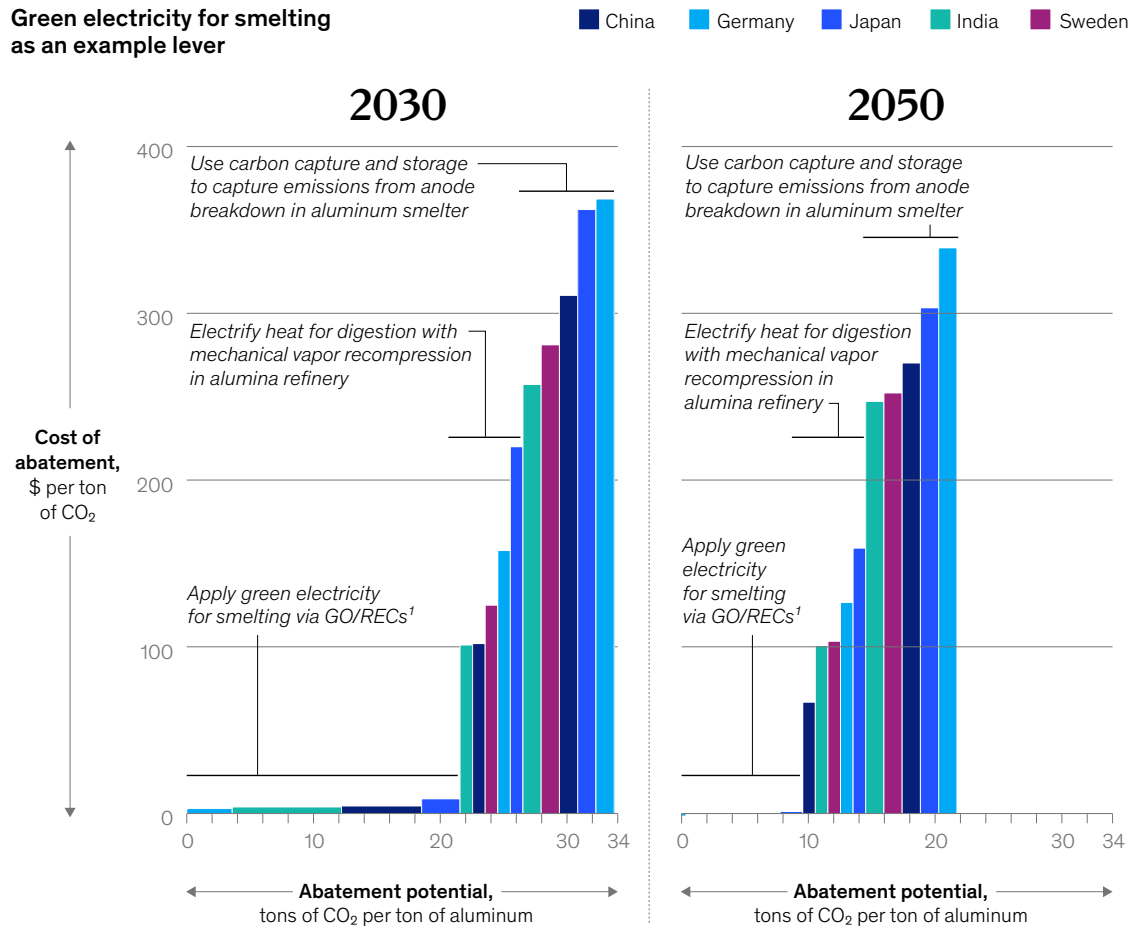
For example, Exhibit 3 illustrates how, between 2030 and 2050, MACCs for aluminum decarbonization will change over time for different countries. Across the board, the potential for green electricity used in smelting will be less by 2050 than in 2030 because of the increased traction of the technology.

This interconnection and time dependence leads to complexities around the prioritization and sequencing of initiatives, creating the need to monitor progress and routinely revise

Exhibit 3

Marginal abatement cost curves illustrate that decarbonization levers can vary across time.

Green electricity for smelting as an example lever



¹Guarantees of origin/renewable energy certificates.
Source: McKinsey Catalyst Zero

McKinsey & Company

plans. Implementation plans that incorporate this fluctuation ensure better sequencing and prioritization of initiatives for the stakeholder.

Commodity prices are strong influencers of what levers are adopted

Over the years, we have seen the crucial role that commodity prices play in the adoption of decarbonization levers across various industries. Fluctuating prices of critical materials can make clean-technology solutions more or less attractive than higher-emission alternatives, affecting investment decisions and the scaling of decarbonization technologies. Automated, dynamic MACCs help reveal these potential fluctuations.

Find more content like this on the
McKinsey Insights App



Scan • Download • Personalize



The availability of key materials is expected to be the biggest bottleneck to the scale-up of five crucial low-carbon technologies: solar PV, wind energy, EVs, heat pumps, and green hydrogen. These materials include lithium for EVs, iridium for green hydrogen electrolyzers, and rare earth elements, including dysprosium and terbium, for wind turbines.⁴

Another crucial commodity for the energy transition is steel. As a critical material for renewable-energy infrastructure (for example, wind turbines, solar panels, and EVs), the price of steel can affect the cost of building and deploying these technologies.

Some levers matter more at city, regional, and national levels

The feasibility and impact of certain levers depend on whether they are applied at the city, regional, or national level. For example, the adoption of EVs requires grid infrastructure typically deployed at a regional or national level, relying on economies of scale, centralized planning, and long-term investment frameworks. Meanwhile, efficiency improvements in buildings are often best accelerated through regional policies that standardize codes, incentivize retrofits, and align supply chains. Finally, smaller-scale levers such as building retrofits or installing more efficient household appliances are suited to the individual or facility level. This last category often relies on consumer behavior, incentives, and decentralized action. Understanding and aligning scale and boundaries is essential to ensure decarbonization strategies are both technically sound and practically implementable.

MACCs are merely tools. The solutions they analyze won't implement themselves. But countries and companies that want to accelerate their efforts to drive decarbonization can make good use of them. MACCs can be instrumental in providing a framework for evidence-based emission-reduction policy setting and in helping companies make informed decisions on cost-effective abatement measures and decarbonization strategies. Over the years, some decarbonization levers have been quickly adopted, while others have stalled. By incorporating new levers, applying AI approaches, and developing dynamic MACCs, we have highlighted the importance of stakeholders' developing strategies that are regionally optimized, time dependent, and that incorporate commodity pricing. These insights can help companies determine how to think about their role in decarbonization.

We are celebrating the 60th birthday of the McKinsey Quarterly with a yearlong campaign featuring four issues on major themes related to the future of business and society, as well as related interactives, collections from the magazine's archives, and more. This article will appear in the fourth themed issue, which will launch in August. Sign up for the McKinsey Quarterly alert list to be notified as soon as other new Quarterly articles are published.

⁴ "Global Energy Perspective 2023: Transition bottlenecks and unlocks," McKinsey, January 10, 2024.

Stefan Helmcke is a senior partner in McKinsey's Vienna office, **Tomas Naclér** is a senior partner in the Stockholm office, **Scott Pendrey** is a practice specialist in the Bay Area office, and **Tim Vroman** is a senior asset leader in the Brussels office.

The authors wish to thank Apoorva Bajpai and Shengle Huang for their contributions to this article.

This article was edited by Jessica Marshall, a senior editor in the Seattle office.