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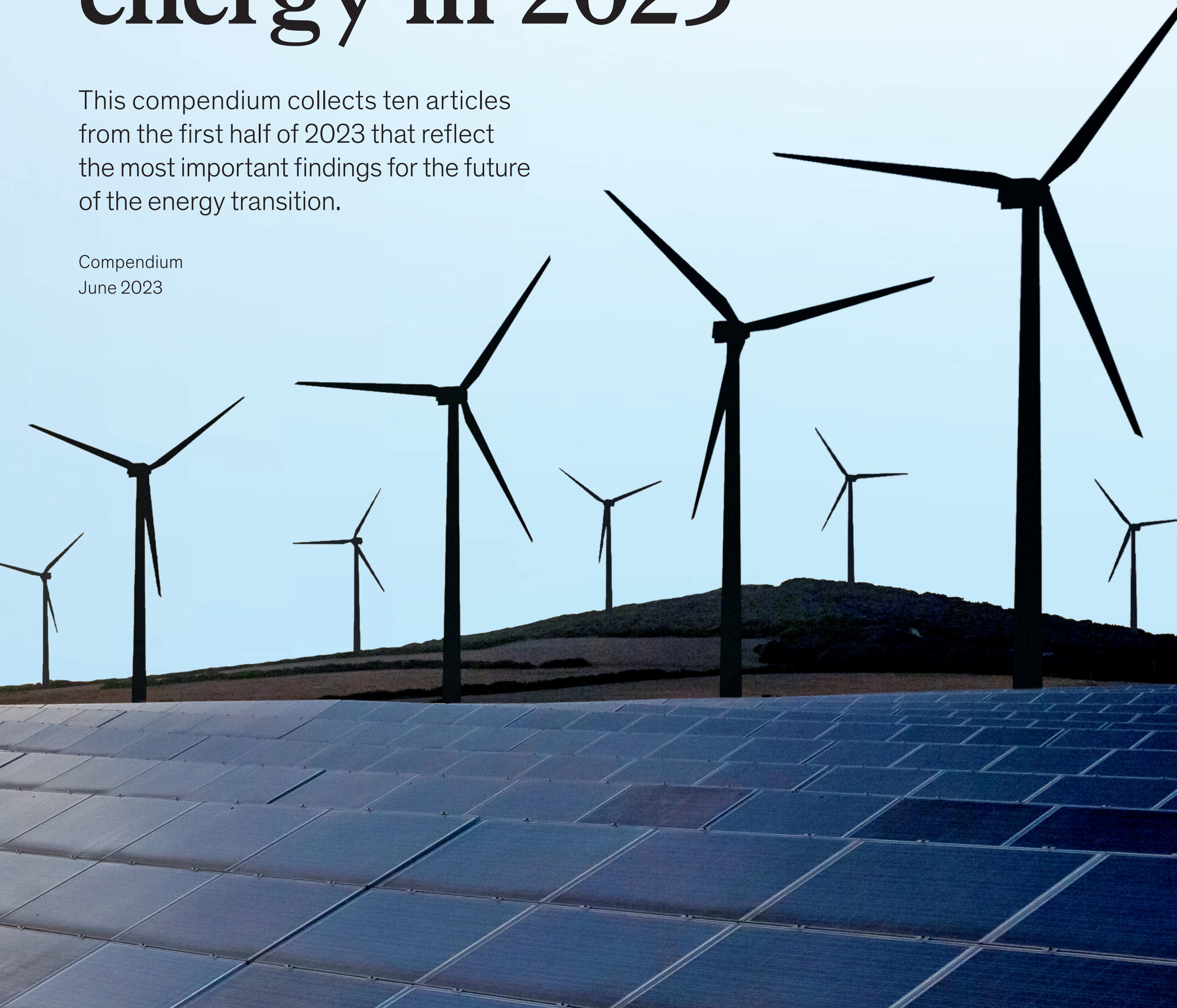
A more orderly transition: Navigating energy in 2023

This compendium collects ten articles from the first half of 2023 that reflect the most important findings for the future of the energy transition.

Compendium
June 2023



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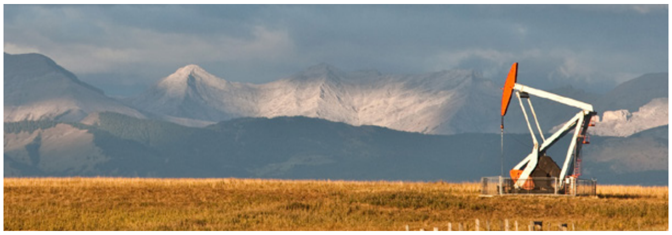

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Introduction

At the end of 2022, the energy transition was in a precarious state. The COVID-19 pandemic had disrupted global supply chains, exacerbating inflation and slowing recovery, and the invasion of Ukraine had led to increased energy prices and uncertain energy security.

Since then, the challenge for many industry leaders has been charting a course for a more orderly transition. Broadly speaking, the energy transition cuts across a number of global food, energy, and materials systems, which means that players in these spaces must contend with sometimes unexpected obstacles—from securing supplies of materials to trading commodities to merging sectors. This compendium collects ten articles published in the past six months that best reflect the findings most important to industry leaders and readers of McKinsey alike, including the following:

- *Several materials critical for the energy transition, such as copper, lithium, and cobalt, may see severe shortages in both the mid and long term.* The increased susceptibility of markets to both short- and long-term volatility and boom-and-bust cycles will likely increase the value of maintaining prompt inventory to deploy in response to a market dislocation. Given these expectations of higher volatility, flexible capacity to respond to changing market conditions will become more critical from both balancing and economic standpoints.

- *The traditional business model of oil and gas players is under pressure, and many are investing in the sustainable-power value chain.* Oil and gas companies are navigating an environment in which increasingly stringent carbon-reduction targets affect investment decisions, with strong uncertainty about where and how to support activities such as offshore generation, electric-vehicle charging, and hydrogen production and development.

- *The wind and solar sectors face a number of industry-specific challenges, many of which are compounded by COVID-19 and the invasion of Ukraine.* Prices for the materials needed to create wind turbines and solar panels have experienced significant volatility. Securing access to raw materials and rare-earth metals at stable prices is critical in the years to come.

- *Industry leaders are transforming themselves and their organizations to succeed.* Although transformation of the global energy mix is not new, the current transition is larger in scale and more complex than previous ones. Therefore, the search for sustainable, reliable, and affordable energy will be at the core of global aspirations.

We hope this compendium offers new insights that can help energy executives remain competitive as the transition continues apace.

The energy transition: A region-by-region agenda for near-term action

What practical actions could countries take now to ensure that the energy transition both accelerates and proceeds in an orderly fashion?

This article is a collaborative effort by Alex Bolano, Filippo Lodesani, Daniel Pacthod, Evan Polymeneas, Madelina Pozas Pratt, Hamid Samandari, and Humayun Tai, representing views from McKinsey's Global Energy and Materials Practice and McKinsey Sustainability.

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As 2022 comes to a close, the energy transition seems more disorderly than ever. A world economy shaken by a global pandemic and the surging inflation that has accompanied the subsequent recovery has had to contend with a tragic conflict in Ukraine and its aftermath of human suffering, rising energy costs, and declining energy security. The immediate response has meant more short-term reliance on fossil fuels and less available resources for the transition, not to mention additional challenges to regional and global coordination.

As we look forward to 2023 and COP28, the dual imperatives of ensuring energy resilience and affordability and of reducing emissions appear equally inescapable. Instead of delaying action, we believe these imperatives emphasize the importance of accelerating coordinated long-term action, at the same time as taking short-term measures.

This article, a summary of our full report of the same name, highlights a range of near-term actions that countries and regions around the world could take to ensure they transition their energy system while maintaining focus on the immediate needs of energy reliance and affordability—and thereby achieving a less disorderly, or "more orderly" transition.

The report looks at these actions through three different lenses: actions that apply on a global scale; actions that apply more specifically to regions that take into account their local needs and nuances; and finally, actions that various stakeholders including governments, financial institutions, companies, and individuals could take to find a path to a more orderly transition.

Our focus is on near-term, critical action, and we use 2030 as the time horizon. We are aiming to describe neither a longer-term path with its implications nor the implications of the current momentum. Three factors motivate this choice: the need to move from commitments to clear plans and actions; the recognition that transitioning our energy system is a slow-moving process and that actions taken now could take years to have the desired consequences; and the sense that time is running out.

Momentum toward renewables is growing but without a corresponding decrease in global emissions

The world's progress toward cleaner energy has been accelerating. Over the past decade, production of renewable energy has more than doubled globally, and its share of total primary energy consumption has grown from 9 percent in 2011 to 13 percent in 2021. While renewables broadly defined encompass a range of energies, including hydropower and geothermal energy, we focus here mainly on solar and wind energy.

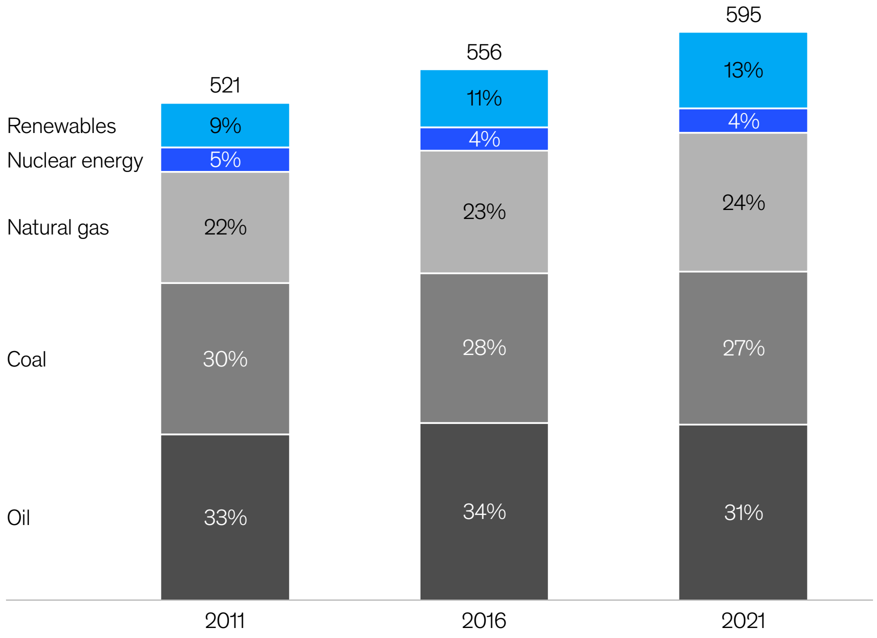
Despite growth in renewable energy, the use of fossil fuels is also expanding to meet growing demand for energy. Global energy demand grew by 14 percent from 2011 to 2021, fueled mainly by emissions-intensive sources. As a result, global energy-related emissions have increased in the past decade by about 5 percent, or 1.7 gigatons (Gt) of CO2, and the share of primary energy from fossil fuels has remained largely unchanged, at 82 percent (Exhibit 1).

Prescriptions for the role of fossil fuels cannot be simplistic, given this continued reliance. The net-zero transition requires steep and decisive declines in fossil-fuel consumption. At the same time, in one scenario of our analysis (the "achieved commitments" scenario, which implies a 1.7°C rise in global temperatures by 2100), global demand for natural gas could be higher in 2030 than 2021, while oil consumption would decline by less than 5 percent in the same time frame. Securing this supply would require investment in fossil fuels to ensure energy resilience and affordability. Achieving a more orderly transition entails balancing the accelerated decommissioning of inefficient and highly polluting assets such as coal or oil power generation facilities with incremental investments in lower-emissions fuel production. To the extent that fossil-fuel investments are made, they should be directed toward lower-emission options and flexible assets that can rapidly adjust their production as demand decreases to meet net-zero goals. Investments and actions to reduce the carbon intensity of fossil fuels, such as addressing methane emissions and electrifying oil and gas operations, will also be needed.

Exhibit 1

The share of renewables in primary energy consumption has risen, but fossil fuels still predominate.

Primary energy consumption, exajoules



Installed capacity, gigawatts

	2011	2016	2021
Total renewable[1]	**1,330**	**2,010**	**3,064**
Solar and wind	**294 (22%)**	**767 (38%)**	**1,674 (55%)**

Note: Figures may not sum to 100%, because of rounding.
[1]Includes wind, solar, hydropower, marine, bioenergy, and geothermal energy.
Source: BP Global Energy Outlook, 2022; International Renewable Energy Agency (IRENA) Renewable Capacity Statistics, 2022

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The socioeconomic context has become at once more precarious and more receptive to the energy transition. The war in Ukraine has, beyond its incalculable human cost, significantly increased energy and food costs and exacerbated the inflationary trends that were already manifest in the recovery from the COVID-19 pandemic. It has also elevated the urgency of energy resilience and affordability. In addition, the pandemic disrupted global supply chains and inflated, among others, the costs of energy-project construction. These challenges have heightened awareness and spurred new actions toward an energy transition, particularly in Europe.

The conclusion of COP27 last month has brought renewed uncertainty on the path to the energy transition. While progress was made in pursuing global cooperation through the establishment of Loss and Damage funding arrangements for particularly vulnerable countries, progress on emissions mitigation remained largely elusive.[1] According to our analysis, achieving national commitments could lead to significant progress

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[1] See “COP27 reaches breakthrough agreement on new ‘Loss and Damage’ fund for vulnerable countries,” United Nations Climate Change, November 20, 2022; “The EU and international partners launch ground-breaking Just Energy Transition Partnership with Indonesia,” European Commission, November 15, 2022.

The opportunities, challenges, and risks associated with a more orderly energy transition are not distributed evenly around the globe, and not all economies are equally equipped to address the challenge of transforming their energy mix.

toward a 1.5° pathway. However, after COP27, it is less obvious whether these critical targets will be met.

Physical climate risk and its visible manifestations are also continuing to grow. Specifically, according to the sixth assessment report of the United Nations' Intergovernmental Panel on Climate Change (IPCC), extrapolation of current policies would lead to a median global warming of 2.4°C to 3.5°C by 2100 and put limiting global warming to 1.5°C beyond reach. McKinsey analysis indicates that there could be an annual gap of 2.4 Gt carbon dioxide equivalent (CO_2e) (7 percent of 2021 energy-related emissions) between the "current trajectory" and the trajectory of an "achieved commitments" scenario.[2] To bridge this gap, annual solar and wind installed capacity would need to nearly triple, from approximately 180 gigawatts (GW) of average yearly installed capacity in 2016–21 to more than 520 GW over the coming decade, with different accelerations required across global regions (Exhibit 2).

Countries fall into five main archetypes with respect to their opportunities and priorities for a more orderly energy transition

The opportunities, challenges, and risks associated with a more orderly energy transition are not distributed evenly around the globe. Some countries can count on greater financial or natural resources, and not all economies are equally equipped to address the challenge of transforming their energy mix. It is therefore useful to identify the primary archetypes, or groupings, into which countries would fall in the context of the energy transition and the corresponding opportunities and challenges.

Considerations of affordability and resilience will shape each country's ability to achieve a more orderly transition. The following three factors are critical in understanding each country's ability to make the transition. The first two relate to energy resilience, while the third relates to energy affordability.

The country's short-term economic reliance on energy imports and emissions-intensive industries. Some countries rely on imported energy, frequently fossil fuels, for energy security. These include several European countries including Germany, which are exposed because of their high level of dependence on imported fuels, and India and China, which represent the world's largest population centers and have both high energy needs and highly polluting energy-consumption profiles.

The country's access to favorable natural resources. Some countries have limited natural domestic potential for the development of clean energy, such as the required levels of sunshine or wind, suitable land for new projects, or abundant reserves of minerals such as copper and nickel that are critical to the energy transition.

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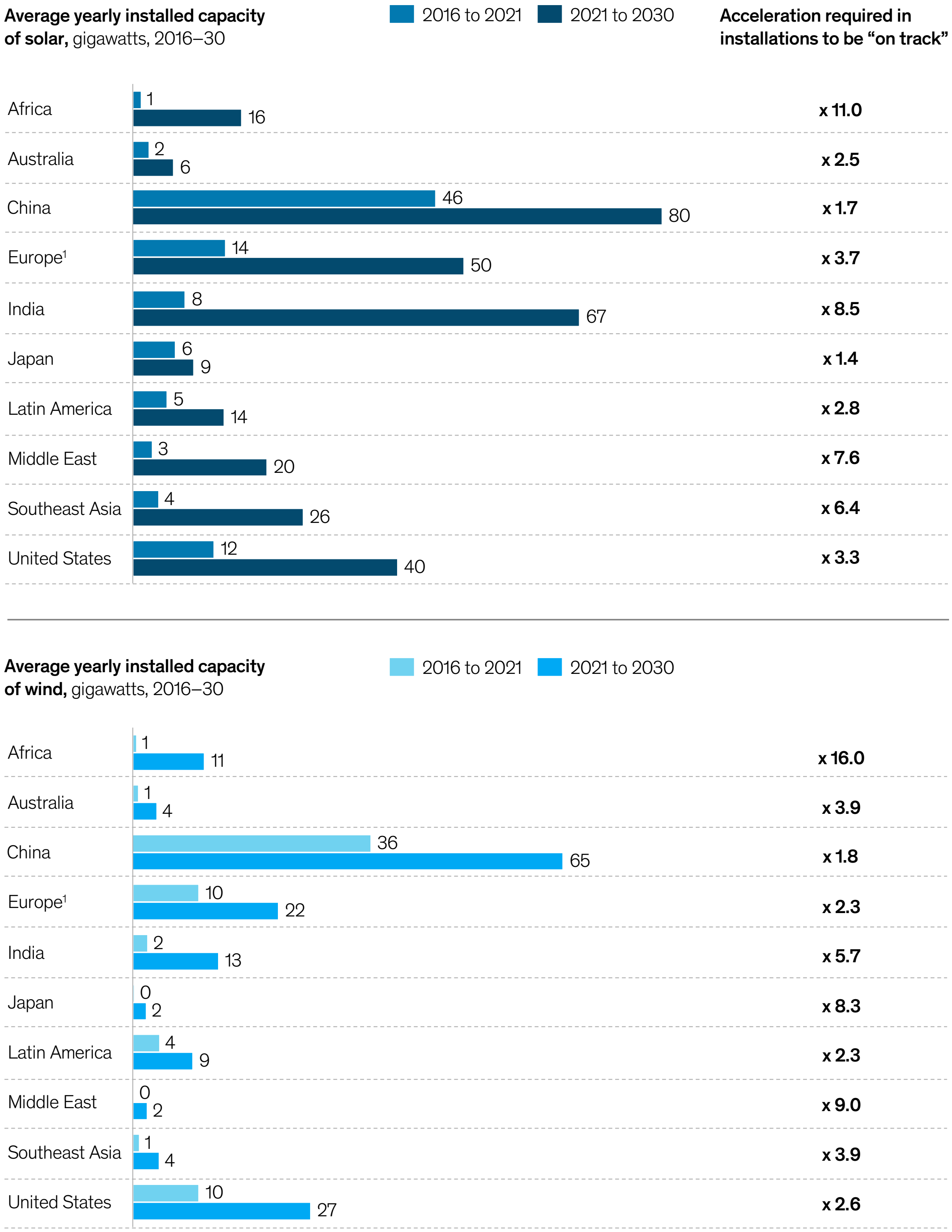
[2] The "current trajectory" scenario would imply a 2.4°C rise in global temperatures by 2100, while an "achieved commitments" scenario would lead to a rise in global temperatures of 1.7°C by 2100. See full report for details.

Exhibit 2

The acceleration in renewable-energy installations required to achieve commitments varies among regions.



[1] Includes members of the EU27 only.

Source: McKinsey *Global Energy Perspective 2022* (Achieved Commitment scenario); International Renewable Energy Agency (IRENA) Renewable Capacity Statistics, 2022

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The country's disposable financial resources and ability to leverage capital to support the energy transition. The net-zero transition would require an additional $1 trillion to $3.5 trillion in average annual capital investment globally through 2050, according to estimates in our January 2022 report on the net-zero transition. Renewable energy and grid improvements require up-front capital investment. These capital investments pay off over various time horizons in the form of reduced operating expenses and improved energy resilience and cost. The transition will also require investments to address stranded costs in fossil-fuel assets, conduct at-scale R&D, retrain the workforce, offer safety nets to vulnerable groups, and fund early-stage infrastructure deployment to initiate "learning curve" effects. Both more and less affluent countries find themselves under budget constraints these days, but the former have many more resources and face fewer trade-offs than the latter in making these investments.

The five archetypes

Based on the examination of these three dimensions, we have defined five main archetypes of countries that face similar challenges and opportunities in the net-zero transition (Exhibits 3 and 4). While each country is different, we believe these archetypes lend themselves to similar sets of actions and priorities for a more orderly energy transition.

This categorization of countries reveals that the burdens of the energy transition, and each region's ability to meet the challenges of adaptation and mitigation, will not be evenly distributed. Moreover, global cooperation and coordinated collective action beyond current levels will be needed: for example, while significant progress has been made in mobilizing public and private financing for developing countries, OECD analysis indicates that the $100 billion target for 2020, set at COP15 in Copenhagen, was likely not met.[3] The pathway to mobilizing global financial flows from more affluent to more at-risk countries is still unknown, but our analysis indicates that developing countries can benefit from readily available solutions such as abatement and avoidance of coal expansion or methane emissions, which increased financing flows can catalyze. Similarly, affluent countries would benefit from greater availability of critical natural resources from developing countries, which would require investment in the sustainable extraction and processing of these resources.

1. Affluent, energy-secure countries. These countries—which include Australia, Saudi Arabia, and the United States—together account for 8 percent of the global population and 22 percent of global greenhouse-gas (GHG) emissions. They have abundant domestic production of energy and high GDP per capita (as a proxy for the amount of available financial resources and capital). They are likely to remain energy exporters as the energy transition unfolds but could reconsider their energy sources to meet emissions targets.

2. Affluent, energy-exposed countries. These countries—which include Germany, Italy, and Japan—represent 7 percent of the global population and 13 percent of global emissions. They have relatively high GDP per capita but are exposed to energy security concerns. The transition could represent an opportunity for them to pivot to domestic clean-energy production; some of the more manufacturing-intensive countries could incorporate more green manufacturing practices.

3. Large, emissions-intensive economies. China, India, and South Africa are among the countries in this archetype. Together, these countries are home to 37 percent of the global population and generate 40 percent of global emissions. For these economies, a net-zero transition would naturally focus on finding a balance between meeting growing energy demand with cleaner resources and addressing reliance on the most emissions-intensive fuel, which has historically been relatively low-cost, domestically produced coal.

4. Developing, naturally endowed economies. Brazil, Indonesia, and Mexico are among the countries with developing, naturally endowed economies. Together, these countries represent 9 percent of the global population and 5 percent of global emissions. These countries have significant

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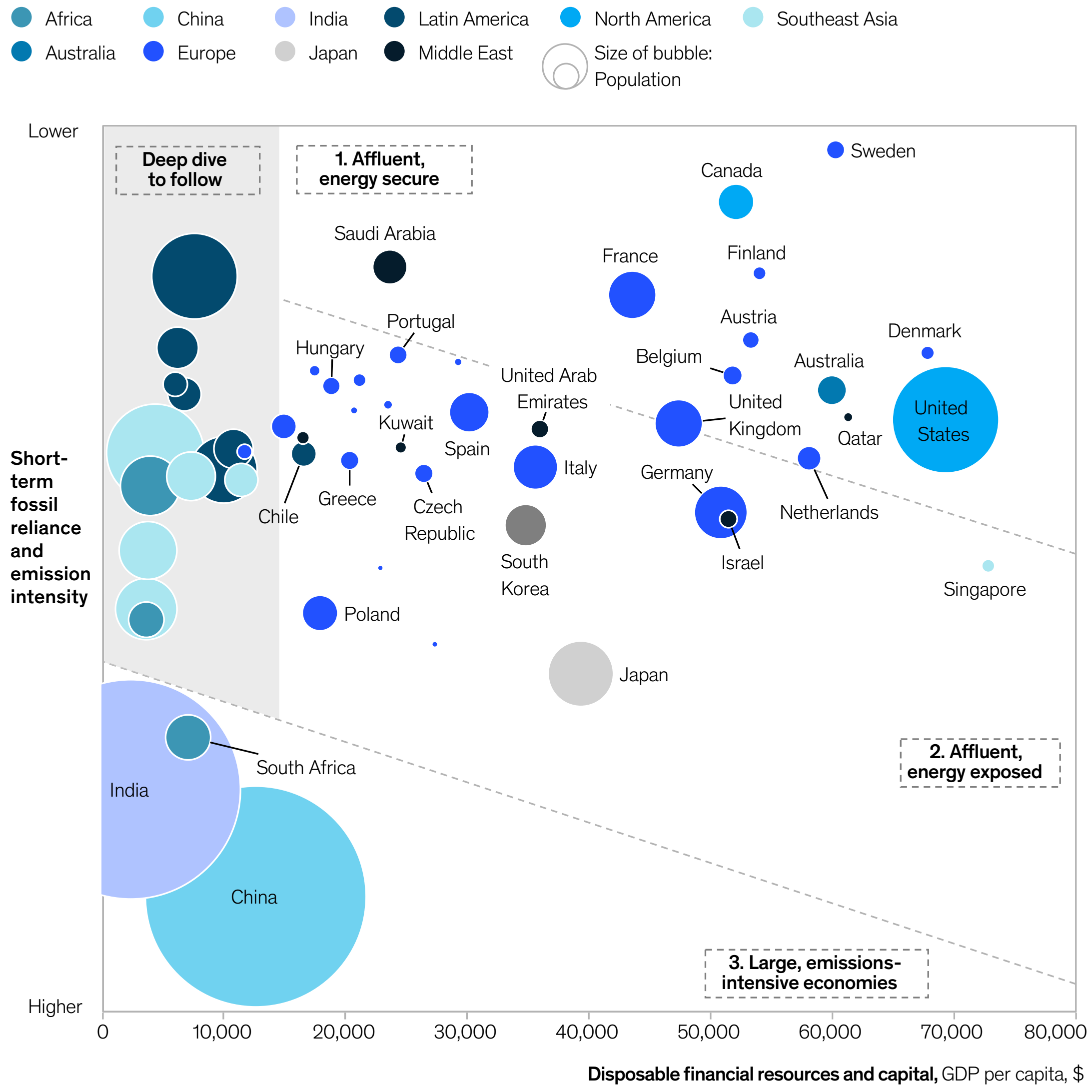
[3] *Aggregate trends of climate finance provided and mobilised by developed countries in 2013-2020*, OECD, 2022.

Exhibit 3

Countries can be divided into five main archetypes based on key energy transition characteristics.

Short-term risk: Relative energy security; CO_2 intensity



Source: McKinsey analysis

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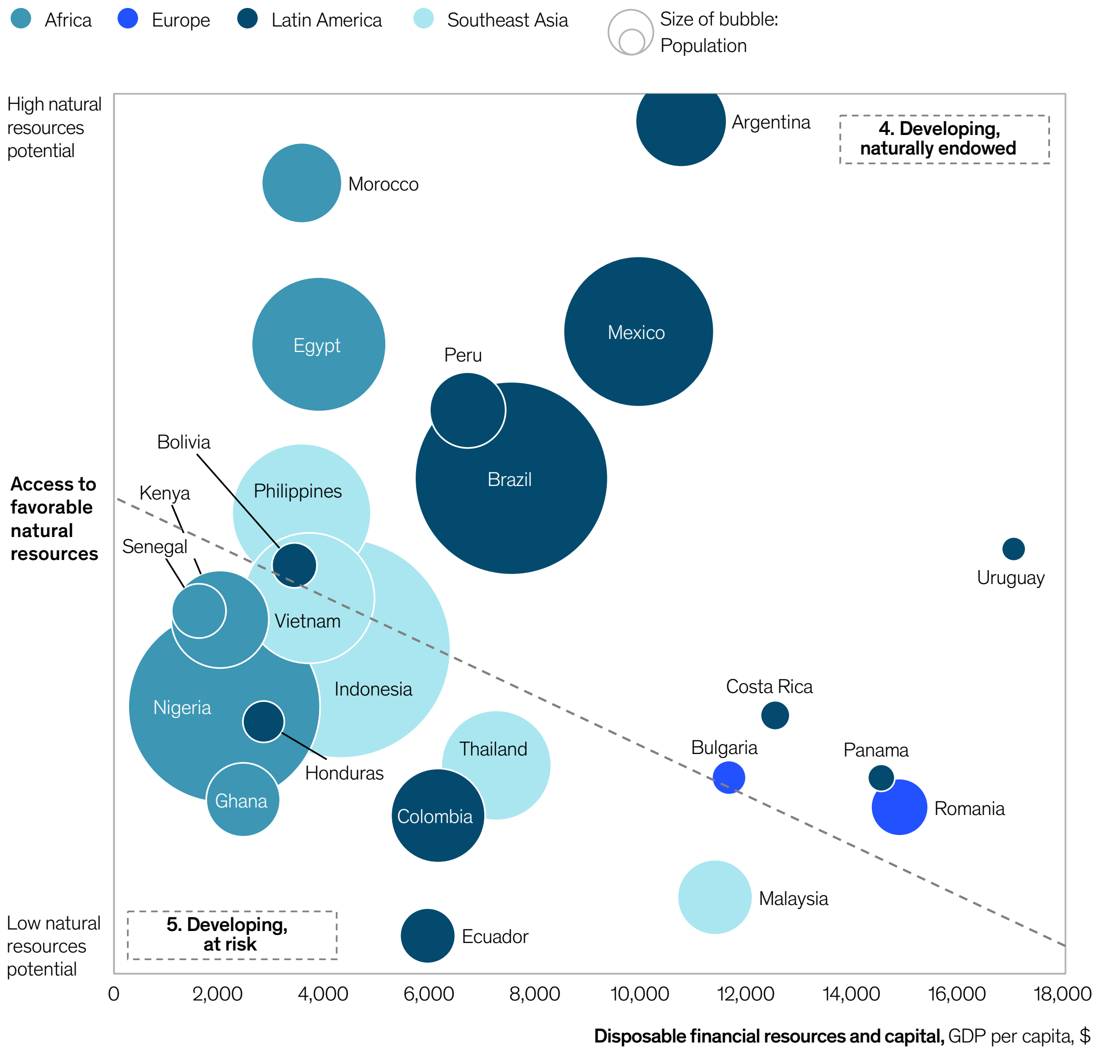
potential for power from solar or wind sources or critical natural resources, such as rare metals, to support the energy transition. A natural priority for these countries would be setting up a framework to develop these resources and move to a sustainable mode of production.

5. Developing, at-risk economies. These regions include parts of Africa and Southeast Asia, as well as some island nations. Together, they are home to 11 percent of the global population and generate 5 percent of global emissions. They are characterized largely by agricultural economies and a disproportionate exposure to climate risk. Some have limited potential for the development of renewable energy, either because of financial constraints or because of limited natural endowments. Their transition would likely be coupled with the establishment of basic infrastructure services and investment in climate

Exhibit 4

Countries can be divided into five main archetypes based on key energy transition characteristics.

Long-term opportunity: Relative potential from wind and solar; presence of critical materials



Source: McKinsey analysis

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adaptation, and it would likely be possible only with foreign support.

Globally, eight sets of common actions are needed for a more orderly transition

All countries could take eight sets of actions that are necessary in the near term to make the energy transition more orderly. The extent to which these actions are relevant to a given country, and the specifics of their implementation, would of course vary. While these actions address the entirety of the global energy system, most of them focus on energy production rather than consumption. Indeed, while promoting the adoption of green technology on the demand side will be important, we believe that many of the actions to be taken in the near term will interest the supply side, where addressing the scalability of assets and infrastructure and moving energy production toward a smaller carbon footprint will likely be key priorities.

This analysis builds on a previous article that groups the requirements for a more orderly transition into three categories: physical building blocks; economic and societal adjustments; and governance, institutions, and commitments. Many of these actions are well understood. We believe it is possible and critical to make meaningful progress on all of these actions by the end of this decade.

Physical building blocks

1. Streamlining access to land and simplifying permit processes to accelerate time to deployment for renewables and cleantech. Streamlining the permit process and limiting the number of required project-approving entities could accelerate project execution. Access to land could be simplified by advancing projects that benefit local communities and by developing land-efficient solutions such as offshore wind. The use of alternative lands—for example, wastelands, which is land degraded by human activities, or agrivoltaic land, which is used for both agriculture and solar-photovoltaic-energy generation—and out-of-the-box solutions such as floating solar photovoltaics could help expand the area suitable for installation of renewables.

2. Modernizing and repurposing legacy infrastructure and creating new assets to accelerate the integration of renewables and cleantech into the energy system. Investing in developing and modernizing the power grid will be crucial to ensuring that areas with high potential for renewables generation are integrated and connected with demand centers. Also important will be the development of new flexibility solutions such as batteries and better-matching supply and demand through demand-response programs—that is, incentives and technology solutions to adjust distributed energy demand and generation when the grid needs support. Conventional assets such as gas plants or pipelines might still be important to ensure an adequate supply, but they will need to be adjusted to reflect decreasing utilization or repurposed to use a cleaner fuel mix, such as hydrogen.

3. Strengthening global supply chains to secure critical raw materials, components, and labor competencies. Countries will need to develop resource strategies to match their needs for components and materials with the supply that's available. This could include investing in product redesign to promote the substitution of constrained or at-risk materials. Promoting recycling and reuse could help limit demand for critical resources. The selective adoption of reshoring could promote the development of local supply chains. Setting up long-term agreements and partnerships with suppliers could be a hedge against variations in critical supply.

4. Decarbonizing the industry and transportation sectors by investing in new technologies such as hydrogen solutions for energy and carbon capture, utilization, and storage (CCUS), alongside electrification and energy efficiency. Providing incentives for investments in hydrogen and CCUS solutions could help increase demand in hard-to-abate sectors and, in turn, promote the growth of a green-product industry. Investing in electrification and energy efficiency could boost the decarbonization of light industry. The transportation sector could address its carbon footprint through incentives for the uptake of light-duty transportation. Technological acceleration could reduce the cost difference between fuel cell electric vehicles and conventional internal-combustion-engine vehicles for heavy-duty transportation.

Economic and societal adjustments

5. Limiting and mitigating emissions-intensive generation to reduce the carbon footprint of fossil fuels and lower the risk of stranded assets. Measures to limit the addition of new fossil assets could be introduced to avoid the further expansion of fossil plants, particularly highly intensive assets like coal. Fossil-fuel generation would progressively shift toward balancing intermittent renewables while storage systems are brought to scale. Mechanisms to value flexibility and capacity of "firm" power generation assets—that is, sources that provide controllable and reliable energy—could be introduced, even as the utilization rates of some of these assets decline. To the extent that fossil-fuel extraction is necessary, basins with the lowest carbon intensity could be prioritized.

6. Managing economic dislocations to promote energy affordability and create fair opportunities for affected and at-risk communities. Compensation mechanisms such as subsidies will likely be required to ensure energy affordability for the most vulnerable consumers. Regions, especially those more dependent on fossil fuels, will need to accelerate diversification of their GDP and industrial footprints. Workers in at-risk industries such as fossil mining will need safety nets. Skills programs could be developed to create a new generation of competencies in response to the needs of the energy transition.

Governance, institutions, and commitments

7. Developing stable and attractive remuneration frameworks, market designs, and offtake structures to encourage investments in renewables and cleantech. Lower-risk frameworks for offtake, such as virtual power purchase agreements (which do not involve the physical delivery of energy) could be applied on a global scale to renewables and to an even broader universe of technologies. In addition, establishing and scaling capacity markets could be a way to reward flexibility and contribute to attracting investments in storage solutions such as batteries and hydrogen.

8. Scaling frameworks and standards to measure the carbon intensity of energy and final products and to develop a global, new carbon economy. Developing the right carbon standards, incentives, and markets will be important to accelerating the transition. Further, the right carbon pricing could play an essential role in driving the fossil-to-green switch and promoting the viability of business cases for low-carbon technologies. Carbon transparency could ultimately lead to the pricing of carbon contents and the creation of low-carbon or green premiums for hydrogen and other fuels and for commodities such as steel and cement.

These global actions will play out differently across regions and countries and will need to be combined with region-specific actions to enable a more orderly transition. In the full report, we identify some of these regional actions. It is important to recognize that the burdens of the transition would not be felt evenly. Developing countries face unique challenges related to transitioning their energy systems. Three challenges stand out: difficulty accessing private-capital markets; constraints on public spending (particularly if government tax revenues from emissions-intensive industries fall); and the impact of rising energy costs, given the limited safety nets and the imperative in these regions to expand energy access and enable development.

A more orderly transition will therefore need to be a just transition, one that recognizes the specific challenges that developing countries experience and that responds with collective, global, and unified action. This could take various forms, including the expansion of financial transfers to the poorest countries, measures to derisk lending to developing countries (for instance, via a greater role for multilateral development banks), and broader capital-market access.

Key stakeholders can accelerate action to promote a more orderly transition by 2030

Achieving an orderly global energy transition will require all stakeholders to take decisive, coordinated action. It will also require global coordination to ensure an equitable and affordable transition, while not compromising the need for energy security. Global stakeholders will need to consider several key priorities:

Governments and multilateral institutions have a central role to play in implementing policies and measures to encourage carbon standards and promote investment in renewables, with the objective of translating net-zero goals into an integrated energy plan that combines emissions reductions, resilience, affordability, and energy security and mitigates uneven impacts on communities at risk. Governments will need to work together with the private sector to promote measures that accelerate green technologies and mobilize key resources, such as the domestic labor force and supply chain.

Financial institutions are instrumental in rethinking investment horizons and risk/return profiles (for example, derisking lending to drive demand for net-zero technologies), disclosing and measuring their portfolio exposure in the near term, and quickly deploying capital toward clean-energy projects. Financial institutions can further contribute “beyond money," by lending their expertise and guidance to drive the success of green initiatives.

Companies would gain from focusing on developing net-zero strategies and action plans, prioritizing innovation in green business models and technologies, and securing a sustainable supply chain. For energy providers such as utilities and transmission and distribution companies, priorities will be defining a strategy for carbon intensive assets to manage stranded-asset risks without compromising energy security; derisking and securing the supply chain for raw materials, labor, and components; prioritizing innovation in business models and technologies; and developing the manufacturing footprint for clean technologies. Companies in energy-intensive industries, such as mining, cement, and oil and gas extraction, could consider setting targets for energy decarbonization, linked to specific, time-bound initiatives such as power purchase agreements and energy efficiency programs, which would also improve their resilience to commodity market fluctuations; investing in energy supply and developments, usually with partners; creating an asset transition strategy to promote a transition of portfolio and operations toward a net-zero world; and developing a procurement and energy risk management strategy to mitigate energy security and volatility risks.

Individuals can make informed trade-offs and decisions about the behavioral changes that may be required. These could include green-product-purchasing decisions, more efficient use of energy, and shifting of economic priorities. To manage a transition that combines emissions reductions with energy security and affordability, citizens will need to demand greater transparency and accountability from their leaders.

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The future of commodity trading

A new normal of commodity trading will call for new types of traders.

by Roland Rechtsteiner, Joscha Schabram, and Arun Thomas

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The commodity trading industry has enjoyed an upward trend over the past five years. While all industries go through multiyear cycles of peaks and troughs, the industry's prospects look excellent for the years ahead.

Indeed, commodity trading is on the cusp of the next normal. The energy transition now under way is an economic and physical transformation that cuts across and integrates the various global food, energy, and materials systems. From a commodity trading standpoint, this transformation will increase structural volatility, disrupt trade flows to open new arbitrages, redefine what it means to be a commodity, and fundamentally alter commercial relationships. All these developments will create unique opportunities and challenges for new and incumbent players alike.

In this article, we explore the trends underpinning commodity trading value pools, discuss five success factors and their potential implementation, and present our perspective on the three business models that could develop over time.

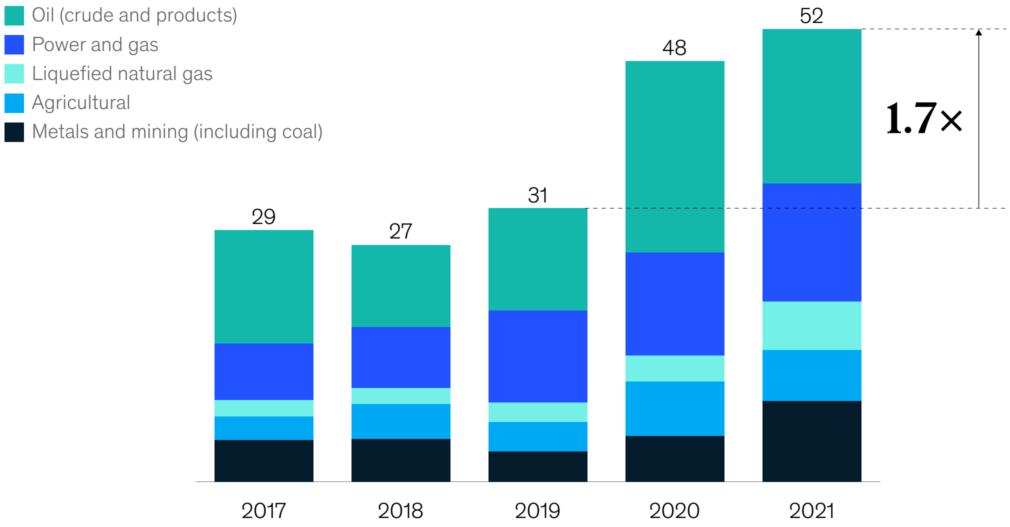
What is the status of the industry?

Commodity trading value pools have grown substantially, almost doubling from $27 billion in 2018 to an estimated $52 billion of EBIT in 2021 (Exhibit 1). The majority of this growth was fueled by EBIT from oil trading, which were estimated to have increased by more than 90 percent to $18 billion during this period. Power and gas trading was just behind, rising from $7 billion to $13 billion. These value pools maintained their upward trajectory in 2022. The market will likely

Exhibit 1

Commodity trading value pools have grown rapidly in the past five years.

Total trading EBIT, $ billions



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attract new entrants that enhance competition, and our analysis suggests that its overall value will continue to grow.

We identified four developments that contributed to this rapid growth and will have an impact in the years to come.

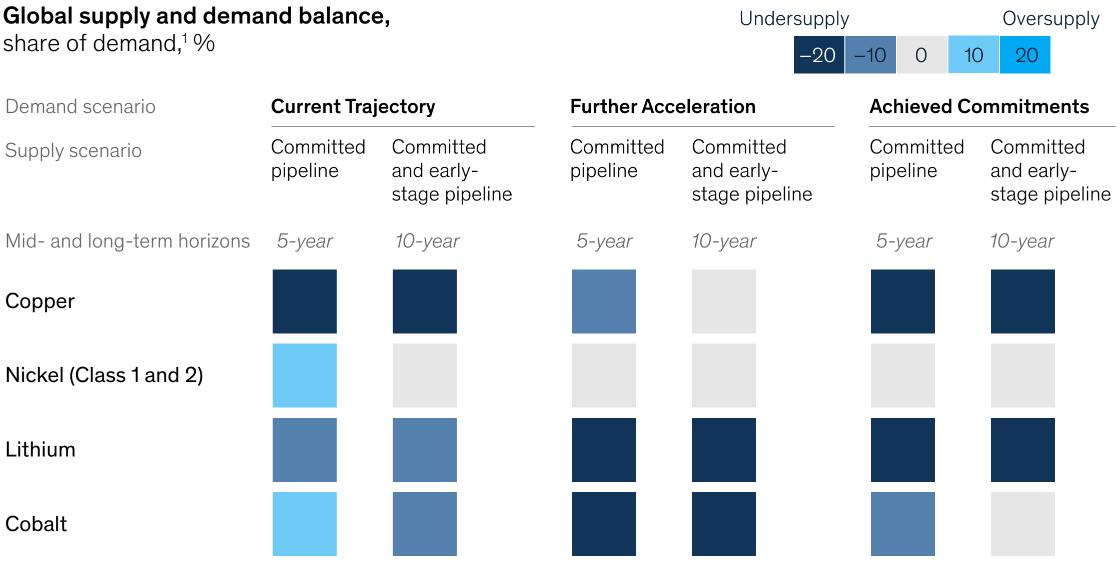
The energy transition is structurally resetting volatility and the value of flexibility across assets and demand

While significant economic and environmental benefits could be captured from decarbonization, the inconsistency of incentives, bottlenecks in the value chain, and current geopolitical turbulence have clouded the supply and demand picture. Annual investments in traditional hydrocarbons have dropped by 50 percent since 2013, but the level of funds committed to the energy transition—approximately $700 billion in 2021, about one-third the $2 trillion needed in 2022—will likely not be sufficient to prevent the emergence of sustained bottlenecks.

Without significantly building out the underlying supply chain, our analysis projects potential supply imbalances (Exhibit 2). For example, lithium and nickel have a high probability of supply constraints by 2030, particularly in the Further Acceleration and Achieved Commitments scenarios discussed

Exhibit 2

Several materials critical for the energy transition will see severe shortages in both the midterm and long term.



[1] Early-stage projects are excluded because of the low likelihood to materialize within a 10-year timeframe.
Source: McKinsey MineSpans

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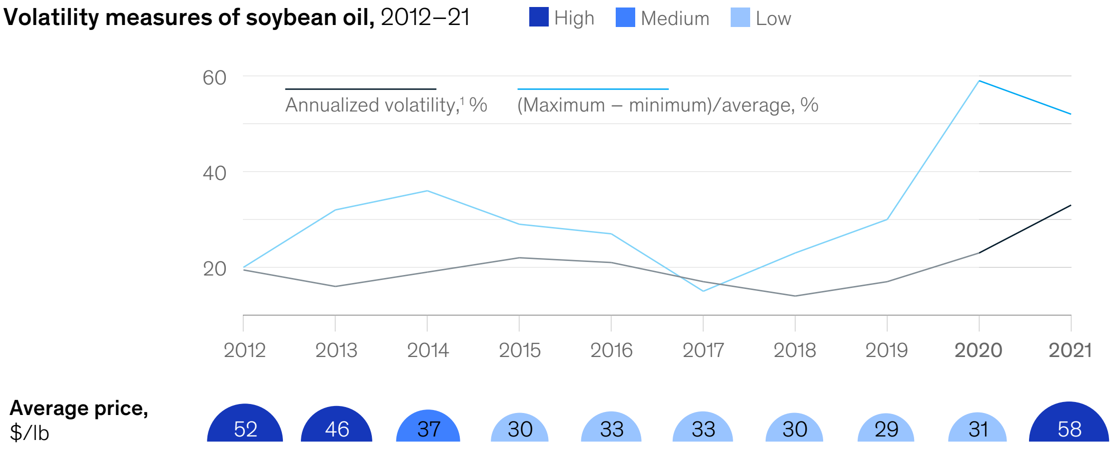
in McKinsey's *Global Energy Perspective 2022*.[1] Similarly, in Germany and Italy alone, the land space currently occupied by renewable-energy sources (RES) would need to double by 2030.[2] These supply gaps are also being observed outside the power space: continued feedstock supply constraints—combined with increasing demand from refineries on the back of regulations favorable to second-generation biofuel feedstocks—have increased used cooking oil (UCO) prices by 90 percent in the past 18 months.[3]

The increased susceptibility of markets to both short- and long-term volatility and boom-and-bust cycles will likely increase the value of maintaining prompt inventory to deploy in response to a market dislocation. Over the past two years, markets have experienced historic spikes caused by COVID-19, severe weather, geopolitical events, and macroeconomic uncertainty. These fluctuations have been most apparent in the energy sector, but other commodities have also been affected. For example, because producers of agricultural goods and metals use energy as an input, volatile prices have upended the economics of production and led to shutdowns. The historical volatility of US natural-gas prices (as measured by Henry Hub natural-gas spot prices) jumped from a low of 25 percent in the third quarter of 2021 to 179 percent just six months later. European gas prices (as measured by Dutch title transfer facility prices) increased from less than €10 per megawatt-hour (MWh) in the second quarter of 2020 to more than €330 per MWh in the second quarter of 2022. This spike has led fertilizer

Exhibit 3

The financial results of commodity traders tend to correlate more with volatility than absolute price.

Volatility measures of soybean oil, 2012–21



Approximate average year-over-year EBITDA growth, selected players, %		30	10	–15	15	–10	15	–30	100	46

[1]Annualized 25 days rolling standard deviation of log-normal returns.
Source: Bloomberg; Chicago Board of Trade; McKinsey analysis

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[1] "Global Energy Perspective 2022," McKinsey, April 26, 2022.
[2] Based on data from the Global Wind Atlas and on McKinsey analysis.
[3] Based on data from Argus Media and on McKinsey analysis.

Given these expectations of higher volatility, flexible capacity to respond to changing market conditions will become more critical from both balancing and economic standpoints.

companies to halt Europe-based production and exports. From a commodity trader's perspective, profitability is determined by a combination of price levels and price volatility (Exhibit 3).

Given these expectations of higher volatility, flexible capacity to respond to changing market conditions will become more critical from both balancing and economic standpoints. Our analysis indicates that achieving a global electrical supply based on 70 percent intermittent penetration in 2050 would require an embedded flexible capacity of 2.5 times at 25 percent penetration. Players could capture considerable economic value by optimizing flexible assets, which could account for more than 60 percent of the overall commodity trading value pool.

However, estimating the value of this flexibility based on forecasts is challenging—especially when physical assets are subject to operational, regulatory, or environmental constraints. For instance, most business cases for flexible assets do not factor in the occurrence of extreme market scenarios that are likely to occur over their 30-year lifespan, thereby underestimating the potential economic rent.

Moreover, the energy transition has priced environmental impact into the supply curve, which will have implications for market volatility. A reordering of asset values and cross-commodity relationships would more strongly intertwine the price volatility of traditional commodities with that of new green commodities—and vice versa.

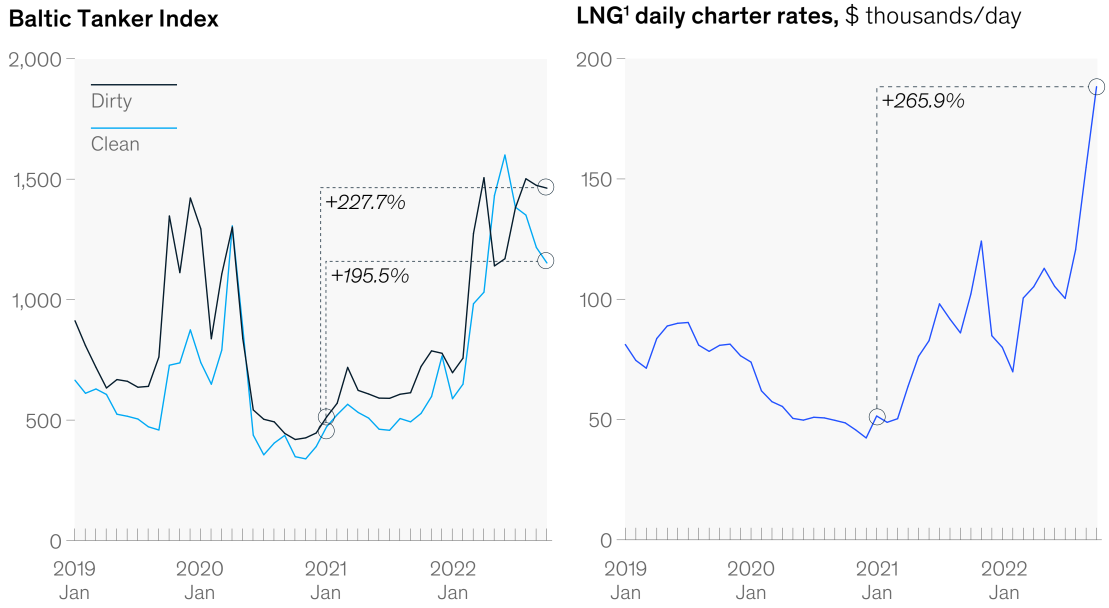
Trade flow disruptions and potentially increasing regionalization

The flow of global commodities remains vulnerable to potential disruption from one-off events. The COVID-19 pandemic is a case in point: the precipitous drop in demand for oil and the corresponding decline in seaborne crude-oil-pricing benchmarks, such as Dubai Fateh, saw charter rates for very large crude carriers (VLCCs) trade at $150,000 to $200,000 a day in the first quarter and second quarter of 2020, with tankers anchored off the coasts of major import centers to provide floating storage.

Recent events have kick-started a reordering of global flows, and the geographical distribution of relevant and competitive assets makes a reversion to pre-2021 levels unlikely in the foreseeable future. In energy, the reduction in Russian supplies to Europe and its allies has led the European Union to rely on imports sourced or rerouted from longer distances, such as Latin America, the Middle East, the United States, and West Africa. Conversely, Russia is exporting higher volumes farther afield, including to China and India. As a result, ships will likely spend more time at sea, and freight optimization could have a greater impact on margins. For example, shipping costs have risen dramatically since the first quarter of 2021: Baltic dirty, Baltic clean, and liquefied natural gas (LNG)

Exhibit 4

Rising shipping costs increase the value for traders in optimizing logistics.


Baltic Tanker Index

LNG[1] daily charter rates, $ thousands/day

[1] Liquefied natural gas.

Source: Baltic Exchange; Clarksons; McKinsey analysis

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tanker rates have increased by approximately 228 percent, 195 percent, and 266 percent, respectively (Exhibit 4).

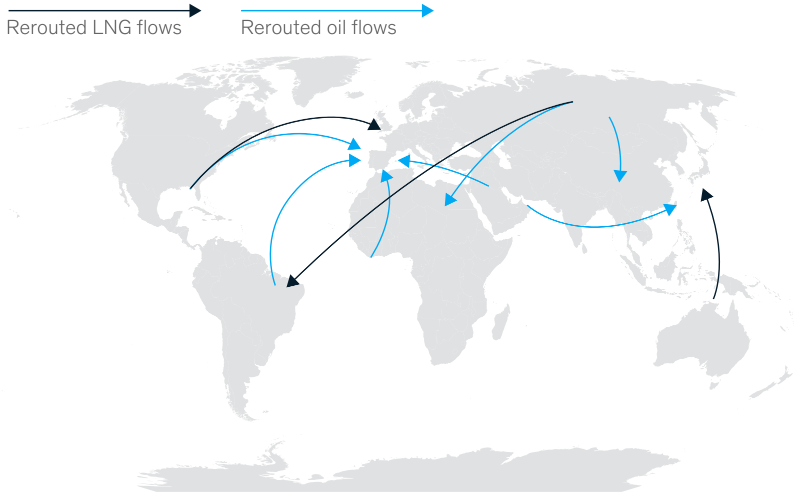
For agricultural commodities, the invasion of Ukraine has severely disrupted exports from the Black Sea, a region responsible for large shares of the global trade in wheat (25 to 30 percent), corn (around 20 percent), and sunflower oil (more than 50 percent). This disruption is having knock-on effects on other agricultural exporters that are already affected by drought and price inflation, leading them to limit flows to maintain food security. The resulting sustained volatility in commodity prices has enabled traders with access to physical alternatives to capture significant value—for example, by rerouting flows, optimizing freight, leveraging storage assets, and blending commodities to customer specifications.

More severe trade flow disruption scenarios could occur, including the potential formation of trade blocs, with the impact felt differently by each commodity class. In one scenario, for LNG, Russian exports could be wholly excluded from OECD markets, shifting instead to China, India, and Türkiye (Exhibit 5). To plug the supply gap, Australian and North American supplies would be redirected to Europe, even though some national oil companies (NOCs) have maintained that it is their obligation to deliver on supply commitments. Europe could seek to severely limit demand because projected global liquefaction capacity is insufficient to completely replace Russian volumes. Despite this “bloc building,” energy flows will adjust to balance the system, and these flows will remain strongly interlinked via fundamental pricing relationships. In the case of metals, however, it is possible that geopolitical factors could

Exhibit 5

Commodity traders will have new opportunities from shifting trade flows.

Change in oil and liquefied natural gas (LNG) in 2025



Commodity trading opportunities

Reordering of flows
Arbitrage opportunities due to higher market spreads

Higher volatility
Value chain bottlenecks[1] driving volatility—deep insights on value chain dynamics for trading are crucial

Higher logistic costs
Trading logistics optimization is critical lever to survive consolidation and to capture buyer–supplier spreads

Note: Scenario: Full curtailment of Russian and Chinese energy trade with Association of Southeast Asian Nations (ASEAN), Gulf Cooperation Council (GCC), and OECD members. The loss of Russian gas to Europe requires a reduction in European demand because of limited import and export capacity globally.

[1] Maxed-out shipping capacity and national agriculture market export capacity, maxed-out import capacity in certain markets in Europe, and demand-setting price.

Source: McKinsey analysis

McKinsey & Company

override economic relationships and significantly regionalize trade flows (for example, in the battery value chain).

This reliance on longer distances and rerouting will further constrain the shipping market. Furthermore, the changes in trade flows will require traders to reevaluate their downstream exposure—a particularly relevant consideration for those with European refining assets as the continent increases imports of diesel. Other traders would have to determine how to meet their customer commitments.

Over the long term, the energy transition could contribute to more regionalization. As the world moves to electrification and alternative fuels, underlying cost structures could create incentives for more local and regional supply networks and in turn reduce traditional large-volume, long-distance commodity flows for oil, coal, and LNG. Even with a potential move toward regionalization, global trade flows would still likely be required to balance energy systems in the foreseeable future. One example is hydrogen: a number of high-demand countries could rely on their own hydrogen production and consumption because transportation and the avoidance of converting and reconverting derivatives can be a significant contributor to overall unit economics (Exhibit 6).

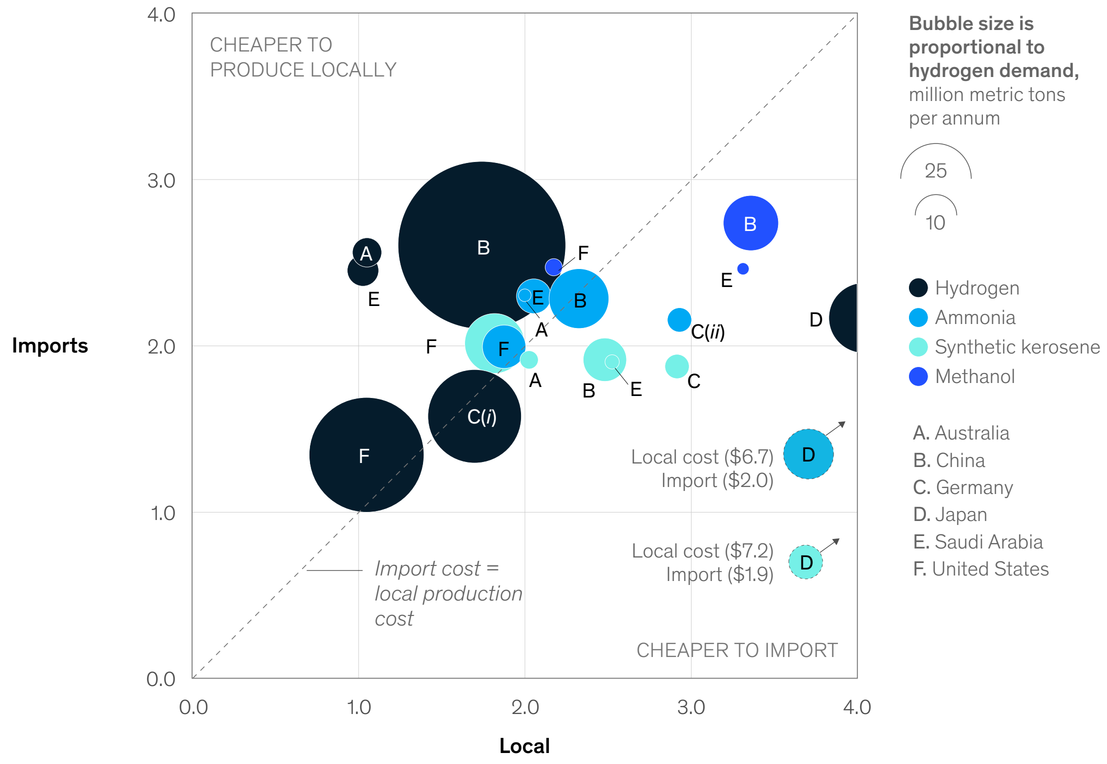
Financing as a bottleneck

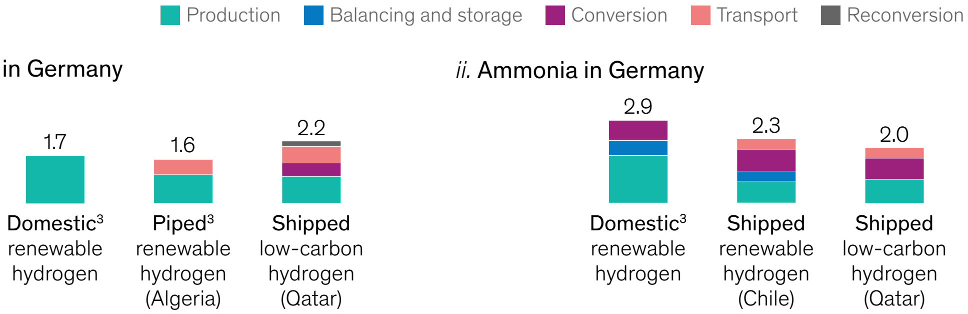
The volatility of spiking commodity price levels has significantly tightened collateral requirements and increased the size and frequency of margin calls. Working capital requirements could rise by 1.5 to 3.0 times the current levels depending on the commodity. In power and gas, for example,

Exhibit 6

In 2050, selected commodities will be cheaper to produce locally than to import.

Cost of imports vs local production[1] in 2050, $/kg hydrogen[2]





i. Hydrogen in Germany

ii. Ammonia in Germany

[1] Includes hydrogen produced, but not derivatives.

[2] This perspective is based on a detailed cost analysis across production, conversion, transportation, and reconversion. We assume a flat weighted average cost of capital (WACC) capital-expenditures compensation for all value chain components across time and differentiated by geography for country risk. In reality, in the early stage of market developments, we expect investors to require a higher margin for an internal rate of return (IRR) that is both attractive and covers early market-entry development and commercial risk. As the market matures in the 2030s, we expect pricing to increasingly be set by the marginal production cost—just as in mature commodity markets—which would see required IRRs and margins progressively come down.

[3] Only if domestic production or piped imports are available. If there are no other sources, there is a chance that the only available option is to ship imports.

Source: Hydrogen Council

McKinsey & Company

price volatility has limited the scope of positions for market participants. According to estimates, energy margin calls could total $1.5 trillion.

In other commodities, the stance of central banks has resulted in a rapid increase in the cost of trade financing for various commodity traders and created a massive challenge for players, especially small and medium-size commodity traders. In the past six months, financial intermediaries have significantly reduced credit to Asia-based metal traders, which have responded by restricting trading activities, exploring selective asset sales, and shoring up balance sheets to maintain access to working capital and to avoid financial distress. Traders with large portfolios and healthy balance sheets have taken advantage of these restrictions to increase their margins considerably. The added working capital requirements combined with the longer shipping times could further increase the competitive advantage of large traders (Exhibit 7). However, it also creates a potential opportunity for larger traders to emerge as "financiers of last resort" for smaller players. For instance, in energy transition commodities such as copper, merchant traders have engaged junior miners on long-term origination contracts linked to prefinancing.

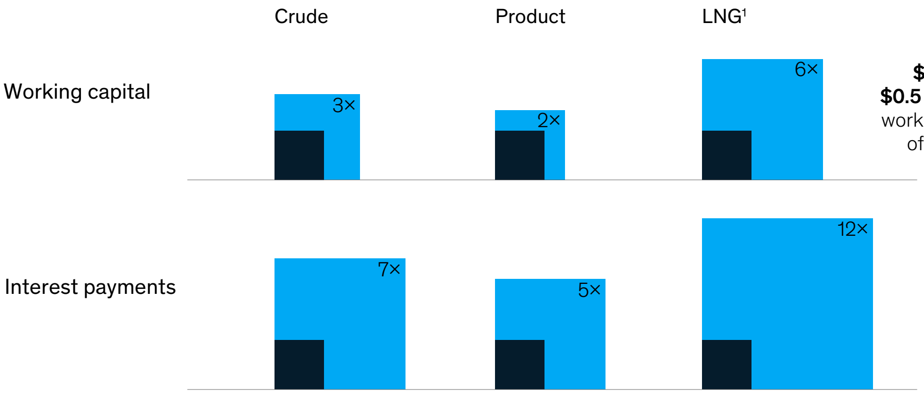
Increase in liquidity and financially tradable products

In the past five to ten years, commodity markets have experienced a dramatic rise in the overall level of liquidity. While the past two years saw events such as the drop in liquidity in European power and gas trading, any repercussions are unlikely to affect the overall trend. One major factor

Exhibit 7

An additional $300 billion to $500 billion could be required to finance global commodity trading.

8% increase in shipping time	3× increase in price of energy	7× interest rate payments	2.5× increase in volatility



$0.3 trillion to $0.5 trillion additional working capital (~10% of German GDP)

[1] Liquefied natural gas.

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has been large producers that moved from direct-to-consumer (D2C) sales into trading to capture more value from their global logistics, systems, and inventories. Similarly, some large customers could shift away from long-term contracts (LTCs) to capture benefits from the spot market. For example, Middle Eastern NOCs have increased margins by bringing their product into the traded markets. Commodity players have also enhanced their participation in one another's value chains, such as energy traders taking part in the value chains of agricultural traders and vice versa.

Recent market developments include increased price transparency, greater access to structured and unstructured data (such as satellite imagery and infrared detection), contract standardization, new exchanges and platforms, and regulations. The resulting lower barriers created a virtuous circle, with higher market participation, transaction volumes and costs, and speed to market. An example is the LNG market, in which spot transactions account for more than 38 percent of annual volumes today (approximately 140 million metric tons) compared with 27 percent (approximately 60 million metric tons) in 2010. The monthly Japan/Korea Marker (JKM)[4] futures open interest on the Intercontinental Exchange (ICE) has grown from 1,500 lots six years ago to more than 120,000 lots today, reflecting the increased liquidity of benchmark indices. And while the recent volatility has created incentives for customers to revisit LTCs, the growth in overall volumes will likely ensure that absolute short-term volumes increase as well. In iron ore, for example, the market is developing forward curves to help better manage flat-price and basis risks; the open interest in Singapore Exchange iron ore futures expiring up to three months out has more than doubled in the past five years.[5] The net effect of these changes: the addressable market for all commodity flows continues to rise.

Five factors to achieve success in the coming years

To capture opportunities, commodity traders will likely need to invest in new capabilities. Our analysis has identified five factors that could be critical to success in the years ahead.

1. Prioritize customer centricity as the energy transition reshapes commodities

The energy transition is redefining the commodity asset class with the arrival of new offerings being differentiated by geography, production methods, regulatory treatment, and environmental impact—and therefore being valued differently by customers. The development path of these new commodities will be determined by customer needs, willingness to pay, and the improving economics of new technologies that will enable differentiation for each commodity to a varying degree. Traders that have access to customer short positions and the accompanying customer-backed perspective could capture an advantage in originating and tailoring high-quality products (a clear differentiator in the metals space); anticipating and locking in demand; gaining insight into product differentials (specifically green-product price discovery); understanding value chain bottlenecks; and strategically shaping customer behavior.

Customer centricity is particularly relevant for new commodities such as sustainable aviation fuel, for which the lack of a wholesale market in the near term will make the D2C model (in which a single customer or a few large ones purchase a producer's whole supply) the only model able to off-load exposure. Since customer centricity can be successfully developed independent of asset intensity, companies that have not historically focused on end customers would have to adopt a significantly different operating model, culture, and set of capabilities. Failure to adapt could leave margins for big commodity trading players, severely undermine the economic viability of asset investments, or both. Players must pay attention to their counterparty risk because larger customer exposures could create risks.

For example, demand for corporate power purchase agreements (PPAs), which has grown considerably in the past five years, will be spurred by the evolution of customer groups whose decarbonization needs cannot be met solely by

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[4] JKM is the price index for LNG delivered to Japan and South Korea.
[5] Based on data from S&P Global Platts.

pay-as-produced PPAs.[6] This trend has created a need for 24/7 PPAs that can contractually specify the level of clean supply–demand matching, time and geographical granularity, the addition of renewables, and clean dispatchable capacity based on customer needs.

2. Embrace the industry's shift toward short-term markets, especially on new commodities

The current market environment has heightened how customers perceive risk. Many are pursuing LTCs. Even though these products don't reduce risk significantly, they enable customers to lock in a price mechanism and secure supply. Producers will revert to short-term markets because their shareholders will not accept the negative impact from the loss of flexibility, the neglect of arbitrage opportunities created by short-term volatility, and the high costs of hedging illiquid long-term positions. Conversely, the high premiums commanded by producers and potential large mark-to-market write-downs will also steer customers back to short-term markets. That said, no model can accommodate all customer needs, and regional or commodity-specific nuances could slow the move to short-term markets. The LNG market is an example of regional nuances: European buyers are leaning toward short-term contracts, while those in Asia and Latin America are likely to prefer LTCs with some degree of flexibility. Moreover, producers may still rely on LTCs to make projects bankable and take final investment decisions (FIDs). A potential outcome could be a world in which short-term volumes remain robust and price indexes are recalibrated to more liquid and stable benchmarks.

With respect to new commodities, producers will likely need to maintain the ability to ramp up and down—a responsiveness that will be challenging if they are constrained by offtake agreements. For example, our evaluation of Power-to-X (for example, Power-to-Hydrogen) projects finds that fully merchant projects can offer a superior risk/return trade-off compared with fully contracted ones. The better result, which derives from the ability to switch between producing and selling power and hydrogen based on short-term market conditions, will, over time, encourage commodity players to return to short-term markets.

Therefore, to avoid impeding the energy transition, producers of new commodities could likely move faster to short-term markets compared with those of commodities such as LNG and power. The large, global players are well positioned to benefit from this trend, given that their diversified portfolios and balance sheets enable them to take on the long-term merchant risk associated with asset investments while participating in the short-term markets.

3. Invest in decarbonization as an asset class to harness the 'green premium' as a potential source of first-mover advantage

End customers that want to mitigate the environmental impact of their consumption could increasingly demand green products in various forms. Commodity players with an understanding of the green premium will be able to unlock arbitrage opportunities—for example, through adjustments to their product blending and logistics processes or through cost optimization. The green premium's evolution and the opportunities it creates for players will be closely linked to how voluntary and compliance carbon markets evolve in the future. Although these markets will expand massively (coverage is expected to more than double to 52 percent of global emissions by 2030), they will remain fragmented, illiquid, and subject to moments of significant dislocation due to regulations and the technological and economic drivers of decarbonization.[7]

A detailed quantitative, transaction-linked understanding would enable better-informed investment decisions and a potential avenue to access competitive green-financing options. To capture these advantages and opportunities, players must accurately track the carbon exposure of their products and cargoes and connect it with their customers' willingness to pay while also setting up the necessary physical processes and accounting protocols for compliance. In the future, this tracking could extend past carbon to a holistic view of multiple environmental, social, and

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[6] *A path towards full grid decarbonization with 24/7 clean Power Purchase Agreements*, LDES Council, May 2022.
[7] Based on Vivid Economics' VCM Model.

governance (ESG) elements. First movers could also accumulate strategic volumes and scale to benefit from the price differentials that accompany the rapid expansion and uptake of green commodities and carbon markets. On a related note, as the green premium becomes more mainstream, it will provide traction to technologies (such as commodity tokenization) that enable more bespoke price discovery mechanisms and low-latency traceability.

For example, metals with different ESG and carbon footprint ratings, such as zero-carbon steel, have become considerably more popular. In the past 12 to 18 months, nine colors of hydrogen and ammonia have been introduced to the market, each with a differentiated production methodology.[8]

4. Rapidly ramp up trading capabilities, because scale is a critical factor

The combination of growing value pools and lower barriers to entry may lead existing players to pursue growth—particularly incumbent asset players that have yet to unlock their full potential. New entrants may also have added incentives to enter this space. While the competitive landscape can initially expand, scale could still be critical for success (especially at times of higher volatility and rapidly changing trade flows) for three reasons: it enables players to achieve better risk-adjusted returns (especially for new energies that need to be kick-started by large illiquid deals), to ensure global access to customers and optionality, and to secure more competitive financing.

Accordingly, scale will spur further industry consolidation. Large merchant traders and asset players will grow organically by taking away “flows” from smaller players and by growing in new asset classes. Asset players would increasingly be expected to acquire smaller players and, in the process, provide the risk capital and flows to supercharge growth. Meanwhile, smaller players would focus on “niches” that are less capital-intensive or more local. However, preparing for this phase of consolidation requires a rapid buildup of “smart scale”—in essence, focusing on scaling up a portfolio of alternatives in positions and products. In some cases, traders would have to make bold moves beyond the typical trading mandates. This pursuit of scale also has implications for business models: moving from a capital expenditure–based model to a more operating expenditure–based one would force traders to critically assess the trade-off between making one’s system more flexible and adding operating expenditures.

5. Ensure that the trading platform and operating model balance efficiency and agility to enable growth, especially in light of talent shortages

A number of players have been ramping up their trading businesses to capture their share of the growth in commodity trading, but their ambitions have been potentially limited by their trading platforms and operating models. This is mainly due to three reasons:

1. Trading platforms are not currently designed to capitalize on economies of scale. To grow, players need to increase their head counts at a time when talent is at a premium.

2. Growth from increased customer centricity can be constrained by the platform and the operating model’s inability to capture, process, and report on new customized and complex transactions.

3. The increased use of more granular data (both structured and unstructured) in trading analytics has generated margin growth. However, poor data governance and outdated IT infrastructure can hinder players from capturing this growth and impede their attraction of commercial talent with experience in data-driven methodologies.

To develop a trading platform and an operating model that facilitate growth, players must first define their strategic ambitions and then make targeted investments to achieve the right mix of efficiency and agility to enable data-driven trading. For example, if a player’s strategic focus is on short-term trading, efficiency is critical. For the origination of customized and complex PPAs, a

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[8] “The hydrogen color spectrum,” National Grid, accessed January 25, 2023.

trading platform must be agile. And in prop trading, the increased integration of data into decision making will require both solid data governance and a best-in-class tech stack.

A successful trading platform requires several factors: an organization and operating model that incorporates agile principles where needed; the migration of technology applications to the cloud to unlock efficiency and reduce demand for talent; and a competitive employee value proposition to attract the in-demand technical specialists required for platform support.

Implications for commodity traders

The five success factors raise strategic questions for all classes of commodity trading players to consider. The following list of questions is not exhaustive but highlights some of the most pressing challenges for various sectors.

— *Oil and gas.* What is the role of M&A in achieving portfolio scale and optionality, as well as in gaining trading capabilities? Are you prepared to make the necessary adjustments to the operating model? Should you expand into new commodities (such as green ammonia and hydrogen), and should you set up new trading activities to be integrated with oil and gas or to be separate?

— *Utilities and renewable-asset players.* Do you want to embrace short-term markets in renewables (such as hydrogen) or derisk assets through a customer-centric approach? What is the required level of scale and diversification in your portfolio and in your deep market insights to successfully employ a merchant or customer-centric strategy?

— *Mining and metals.* To what degree will customer centricity be a key value driver in the future, especially with increasing demand for green products and the need to build associated commercial and trading capabilities? What is the outlook at the product level on whether a market remains truly global or becomes more regional, and what does that imply for your portfolio and for your commercial and trading capabilities?

— *Agriculture.* How do you expect the convergence of food and energy (for example, biofuels) to evolve, and what does this imply for the need to develop portfolio and trading capabilities (for example, cross-commodity activities)? Given trading's potential to generate value from embedded flexibility (optionality), how can you smartly scale up assets and positions to capture above-average returns?

— *Large industrial consumers.* To what degree should you pursue long-term contracts to lock in green supply versus taking a short-term approach to avoid being stuck with potentially high prices in the event of a market depression? How can you achieve the right share of low-carbon products and brands in your product portfolio to capture the green premium?

Three potential models

While the duration of this combination of cyclical bottlenecks, price transparency, and redefinition of commodity classes is uncertain, its effects will likely be felt beyond the short term and to different degrees in different commodities. In addition, many players will gravitate to one of three possible models, each with a different mix of the five success factors.

The global smart-scale trader

The digital enablement and convergence of markets, the prevalence of automation, and the migration of trading and optimization activity to short-term markets mean more players will be pursuing thinner margins. These developments will not only spur the addition of new at-scale players but also compel traders to ensure that their portfolios and customer access are more global and extend well beyond their legacy commodities. Players will explore both organic and inorganic options to achieve this growth. Incumbents of this model will use their access to competitive financing to attract flows from smaller players. The move toward third-party volumes in the portfolio will also enable a model that shifts from capital expenditures to operating expenditures. Integrated players will consider acquiring smaller trading units as an option to accelerate the buildup of trading capabilities.

The niche trader mastering 'complexity'

In markets where scale is less relevant, lower barriers to entry are expected to attract multiple niche traders that target either regional or commodity-specific relationships. Specialists that enable new components of the carbon and ESG economy are one variation of this model. In the absence of barriers to entry, these players will need to develop and sustain a competitive edge based on either their customer centricity or their distinct technology and analytical capabilities. For example, in the biofuels feedstock market, players have carved out a niche by applying hard-to-replicate business models based on local insights, strong origination relationships, and acceptance of custom risks (such as those from innovative prefinancing agreements). As some of these fragmented markets become increasingly lucrative, niche traders could be viewed as acquisition targets by global smart-scale traders looking to add further scale and capabilities.

The tactical trader–investor

The cyclical nature of investment in commodity-based industries will result in supply and demand imbalances. Traders can capture value by taking positions that solve these imbalances. However, these types of positions (for example, battery storage leases) are not typically achievable through standard market access and therefore will create incentives for a breed of players willing to go outside traditional trading mandates. These tactical investors will possess a private equity mindset and use the strength of their balance sheets to take equity in illiquid physical positions aligned with their long-term views. In addition, they will possess a trading mindset that helps them better appreciate the nuances of the value of optionality associated with flexible assets, which in turn enables their capital allocation strategy.

Our analysis highlights the considerable impact possible through commodity trading in recent years and the underlying developments responsible. In the coming years, the effect of these developments and trends could be magnified, resulting in even more value at stake, which will then attract new players. An element of uncertainty surrounds these trends, especially with respect to timing. The combination of new players and uncertainty means winners need to think about both the size of their investment in these five success factors and their ability to move quickly.

Roland Rechtsteiner and **Joscha Schabram** are partners in McKinsey's Zurich office, and **Arun Thomas** is a consultant in the Calgary office.

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Beyond G&A: Maximizing synergy from oil and gas mergers

In the coming consolidation wave, exploration and production companies can raise the aspiration on deal synergy and move beyond G&A.

by Jeremy Brown, Tom Grace, and Steve Miller

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Mergers and acquisitions (M&A) are a key tool in a company's value creation toolbox. Despite a highly turbulent macroeconomic environment over the past decade, M&A activity in the oil and gas sector has continued, albeit at lower levels than prior years.[1] Now, a new M&A wave is expected, driven by record cash flow in the exploration and production (E&P) sector, among other factors.[2]

In this next wave, differentiated value creation will likely underpin M&A success, and set M&A winners apart. Many upstream firms view acquisitions as a "bread and butter" activity that they do well. However, more than 50 percent of deals in the E&P sector don't create value for shareholders.[3] Many deals are limited to a focus on reducing general and administrative (G&A) expenses and ignore any operational synergies that may exist. There is a lost opportunity here for firms to raise their synergy aspirations and look beyond G&A, as M&A deals pursued for operational synergies typically outperform those based on G&A savings. In addition, the choice to publicly announce synergy targets can impact the total return to shareholders (TRS). By making clever decisions, companies can reap the most from their deals.

In this article, we explore two steps that upstream companies could take to maximize value from their deals and build resiliency ahead of the next cycle.

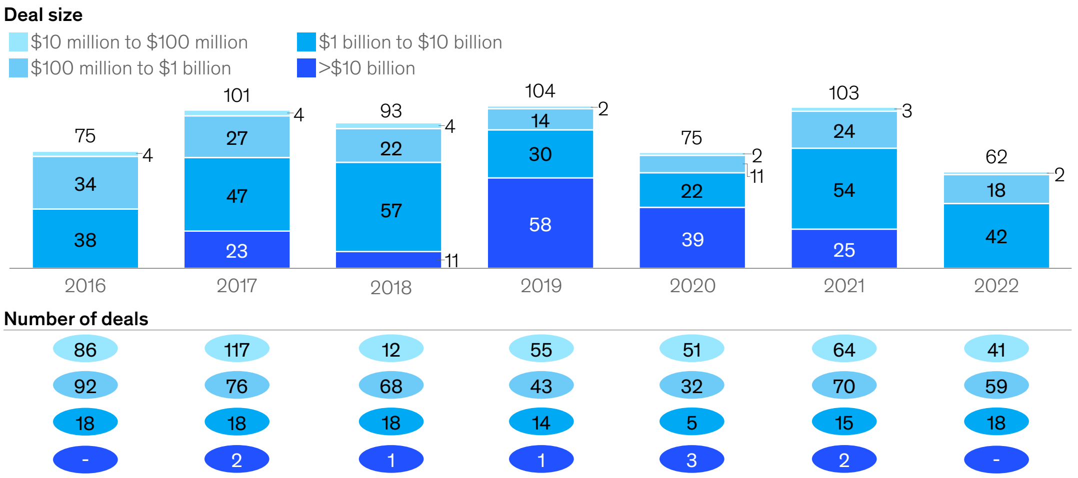
Most deals don't create value

Over the past 12 years, there have been roughly 750 upstream deals with a transaction value of at least $100 million.[4] Although most deals were less than $1 billion in size, deals greater than $1 billion have contributed the largest portion of transaction value since 2016 (Exhibit 1).

Exhibit 1

Although most deals were less than $1 billion in size, deals greater than $1 billion accounted for the largest portion of transaction value since 2016.

Global total upstream transaction value by deal size,[1] $ billion



[1] Includes global upstream transactions involving 100 percent ownership stake. Includes only exploration and production company transactions; excludes oil field service and equipment, drilling, midstream, or downstream transactions. Data as of January 2023.
Source: Capital IQ

McKinsey & Company

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[1] Robert Belanger, Jeremy Brown, and Tom Grace, "Success in the M&A rebound: Riding the coming wave of upstream deals," McKinsey, February 24, 2023.
[2] Ibid.
[3] McKinsey analysis based on global upstream transactions involving 100 percent ownership stake. Includes only exploration and production company transactions; excludes oil field service and equipment, drilling, midstream, or downstream transactions. Data from Capital IQ as of January 2023.
[4] Ibid.

Taking a closer look, most deals greater than $1 billion in size haven't created value—but the best deals have created outsized returns for their shareholders (Exhibit 2).[5]

What could be the make-or-break factor determining deal success? Multiple components are at play, such as pre-deal diligence, asset-performance uncertainties, outlooks for oil and gas prices, and transaction management.[6] But in all cases, the ability to accrue differentiated value creation is a key factor determining merger success and may determine the winners in the next cycle.

One plus one equals three: Maximize value by moving beyond G&A

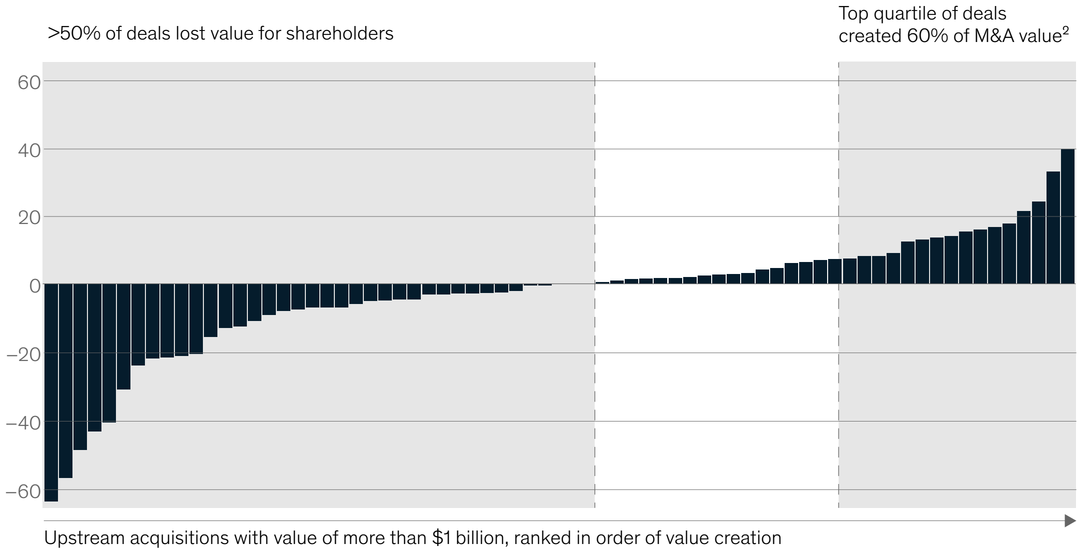
All too often, upstream deals have limited their synergy goals to the low-hanging fruit of G&A reductions. Our experience shows, however, that operational synergies are almost always larger than G&A savings—often by a factor of three or more.

The most successful mergers are usually those that adopt a transformative approach to value capture, systematically pursuing synergies across financial categories and functions, including operations. Upstream companies can open the

Exhibit 2

Establishing a plan for capturing synergies can ensure a deal creates value, which most transactions fail to do.

Excess TRS by deal from 2011 to present,[1] %



[1] Analysis of excess total returns to shareholders (TRS) post-deal, based on trend versus index. Includes 71 upstream E&P transactions (excludes OFSE, mid-stream, other upstream sub-sectors) worldwide with value of more than $1 billion and 100 percent change in ownership. Calculated as the post-transaction difference between buyer share-price performance and S&P 500 oil and gas index over a period of two years.
[2] The top 25 percent of deals created $44 billion of excess returns to shareholders in two years, out of net $75 billion created in the data set of $269 billion of transactions.
Source: Capital IQ; McKinsey M&A insights

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[5] McKinsey's Merger Integration Practice analyzes value creation through M&A deals across sectors using the metric of excess total return to shareholders.

[6] Jeremy Brown, Tom Grace, and Zach Kimball, "The dos and don'ts of M&A in shale," McKinsey, November 2, 2020; Pat Graham, Maximilian Mahringer, and Andy Thain "Ten principles for successful oil and gas operator transitions," McKinsey, January 31, 2020; *Global oil supply-and-demand outlook to 2040,* McKinsey, February 26, 2021.

aperture across revenue and production, operating costs, and capital efficiency in addition to G&A, using the merger as a "moment in time" to catalyze performance improvement across both entities.

Pursuing operational and production synergies with rigor equal to (or greater than) G&A cost synergies also has an important change-management dynamic. While reducing headcount and other expenses is usually viewed as a necessary evil that often generates negative emotion, developing additional revenue through operational excellence can drive energy and excitement and offer teams a point of pride to rally around. Operational synergies have the added benefit of being a buffer in case G&A synergies are harder to obtain than expected.

Our work has highlighted that successful mergers approach operational synergies from three main angles, with examples by function included in Exhibit 3.[7]

Leading companies often ask the following questions when considering M&A:

1. What are the direct operational synergies to be extracted, either from an overlap (or adjacency in footprint) or from an expanded size and scale?

2. How can we leverage the best-of-the-best capabilities from each organization, using both data and capabilities to scale opportunities across portfolios?

3. How can new opportunities be catalyzed in this unique moment to realize step changes in performance?

Firms that strive to become world-class serial dealmakers may engineer answers to these questions into a repeatable "deal machine," which they continually improve while proactively strengthening the muscle memory of how to run it.

Publicly announce synergy goals

To announce, or not to announce, that is the question. Once synergies have been planned

Exhibit 3

Successful M&A drives operational synergy in three levels of ambition.

	Direct operational synergy	**Best-of-the-best**	**New opportunities**
Synergy examples by function	Leverage operating proximity or size-and-scale, or both, to drive efficiencies	Combine capabilities and data to scale opportunities across larger portfolio	Capture the unique moment of the merger to catalyze step change in performance
Development planning	Accelerate best inventory across combined portfolio	Optimize timing and orientation of stacked-pay development based on total program net present value (NPV)	Embed frac-interference mitigation into combined development plans with supporting data collection
Production operations	Combine and optimize well surveillance, workover campaigns, and water management	Maximize uptime of wells or facilities based on combined data and learnings, including design and vendor	Expand digital capabilities in surveillance and pilot new artificial lift technologies
Drilling and completion (D&C)	Increase equipment and infrastructure sharing across more rigs and frac spreads	Standardize execution based on combined data and expertise, accelerating spud-to-sales and minimizing cost	Increase piloting of new techniques, as a smaller share c larger total D&C budget
Supply chain and procurement	Institute integrated contracts with larger volume and lower unit costs	Leverage combined data and expertise to simplify designs and build supply-chain resiliency	Empower and integrate procurement teams to proactive combat inflationary pressures

Level of synergy ambition

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[7] McKinsey analysis based on synergy planning processes used during recent client work in M&A.

and targeted, they can be announced—internally or externally. At a minimum, targets, or goals, can be clearly communicated internally, with discreet goals set for each part of the combined business. This mobilizes the entire organization to drive performance, while offering a clear rationale for decision makers to anchor the many tough calls that will likely be required during the integration process.

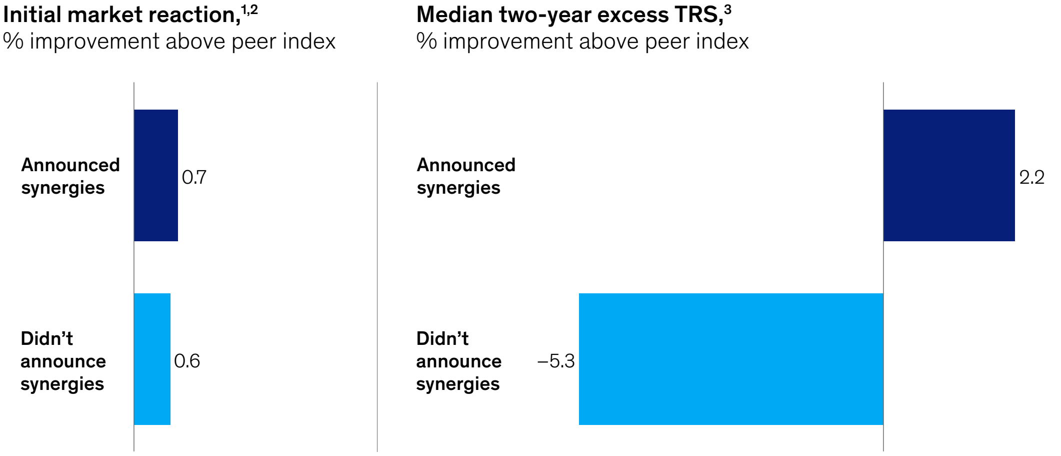
But announcing targets externally can increase the chance that deals create value (Exhibit 4). While there is a negligible link between communicating additional information about the deal and the initial market reaction, announcing cost-synergy expectations may be tied to significant long-term outperformance over peers. Our analysis of 776 deals across sectors showed that companies that announced synergy targets outperformed those that did not by an incremental 7 percent TRS over a median of two years.

Publicly announcing targets can contribute to putting healthy pressure on the executives and support teams who will have their compensation linked to meeting targets. As the onus is on the company to deliver, this can encourage executive teams to tackle the difficult decisions included in initial synergy estimates instead of opting for an easier route. To ensure delivery, publicly announced targets are typically supported by internal targets that are up to 200 percent higher, even in the case of value leakage.[8] Public announcements also allow investors to understand where the synergies are coming from, instead of the deal being a black box.

After the deal, some organizations may be tempted to adjust the synergy goals used in approval to better match the actual delivery. To counter this behavior, top CEOs may require their teams to place a record of synergy objectives in a figurative time-locked safe with the initial opening

Exhibit 4

Deals that announce synergies tend to outperform those that don't.



[1] Excludes non-strategic deals (for example, acquirer is a real estate investment trust or investment bank). Includes transactions of companies acquired with a market cap representing 30 to 500 percent of the acquiring company market cap, and a total acquired market cap larger than $500 million, for announced and completed deals between 2010 and 2019.
[2] Median acquirer short term TRS in excess of industry sector TRS (MSCI) for two days pre-deal versus two days post deal. N=973.
[3] Two-year excess TRS involves the median acquirer long-term TRS in excess of industry sector TRS (MSCI) for one month pre-deal versus two years post deal. N=776.
Source: Synergy Lab

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[8] Ibid.

set for the first executive lookback on deal success. There will likely be both positive and negative variances against the goal, but only by knowing where gaps exist can teams fine-tune estimation and delivery methods to continually improve.

In the next wave of upstream M&A, differentiated value creation may be a key factor underpinning merger success. By pursuing operational synergies beyond G&A and publicly announcing synergy targets, companies can maximize the value from their mergers—and accelerate their growth and performance.

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The authors wish to thank Robert Belanger, Joaquin Cancino, and Luca Sivers for their contributions to this article.

How oil and gas companies can be successful in renewable power

The traditional business model of oil and gas players is under pressure. Investing in the sustainable-power value chain can provide an opportunity to diversify and play a leading role as the industry transitions.

by Clemens Kienzler, Alexandre Lichy, Humayun Tai, and Fransje van der Marel

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Climate change is here, and humanity is already grappling with its effects and taking action in all parts of the economy. As part of these efforts, the transition to a lower-carbon energy system requires urgent and fundamental shifts in how energy is produced and used the world over. Such shifts, in turn, require strategic responses from businesses.

Oil and gas companies, whose fossil-based products have long been integral to the energy-supply landscape, are no exception. They need to navigate an environment in which increasingly stringent carbon-reduction targets affect investment decisions, with strong uncertainty about where and how to support activities such as offshore generation, electric-vehicle (EV) charging, and hydrogen production and development. As a consequence, operating models for new and legacy businesses are changing fast.

According to McKinsey's *Global Energy Perspective 2022,* fossil fuels such as oil and natural gas will continue to make up a significant share of the energy mix by 2050, partly because of how they combine affordability and security of supply.[1] Nonetheless, we believe that oil and gas companies are well positioned to play a meaningful role in the energy transition. Reasons for this include their global scale, the risk appetite of their investors, their large balance sheets and cash positions, and their long-standing relationships with energy customers and stakeholders.

We have analyzed how strategic choices can help build a sustainable-power value chain and have outlined four ways oil and gas companies can lead in the energy transition. These include developing business models with customer centricity at the core, improving energy management and risk-exposure practices, diversifying energy portfolios, and pursuing capital excellence and project capabilities.

A global shift in how energy is produced and used

Shifting toward net-zero emissions requires replacing fossil-based electricity and heat with renewable energy and hydrogen power while balancing the demand for affordable energy as the world transitions (Exhibit 1). Projections to 2030 and 2050 illustrate how this shift could also further the electrification of industry, transportation, and construction while adding new sustainable fuel and hydrogen to industrial processes and transport.

The shift of oil and gas companies into the power industry is not new. In fact, private international oil companies (IOCs) and state-owned national oil companies (NOCs) started investing in cleaner energies decades ago. In the early 1980s, the first major oil company invested in renewables generation by supporting solar-component manufacturing as well as solar and wind project development. Nearly 40 years later, it bought a stake in one of Europe's largest solar developers. Another major oil company made several investments in the 2000s; in the past decade, it has established a renewables and energy solutions arm and invested more than $5 billion in a variety of business models, including renewables generation, power retail, distributed generation, energy services, and EV charging.

One of the largest NOCs in the world recently announced a target of net-zero emissions by 2050 as well as significant investments in renewable energy. Others have committed to investing billions over the next few years to building a renewable-energy business and launching a fund of approximately $500 million to invest in energy efficiency and renewable-energy solutions.

The success of these investments has been mixed, but there is evidence that momentum will not falter as customer demand for cleaner energy

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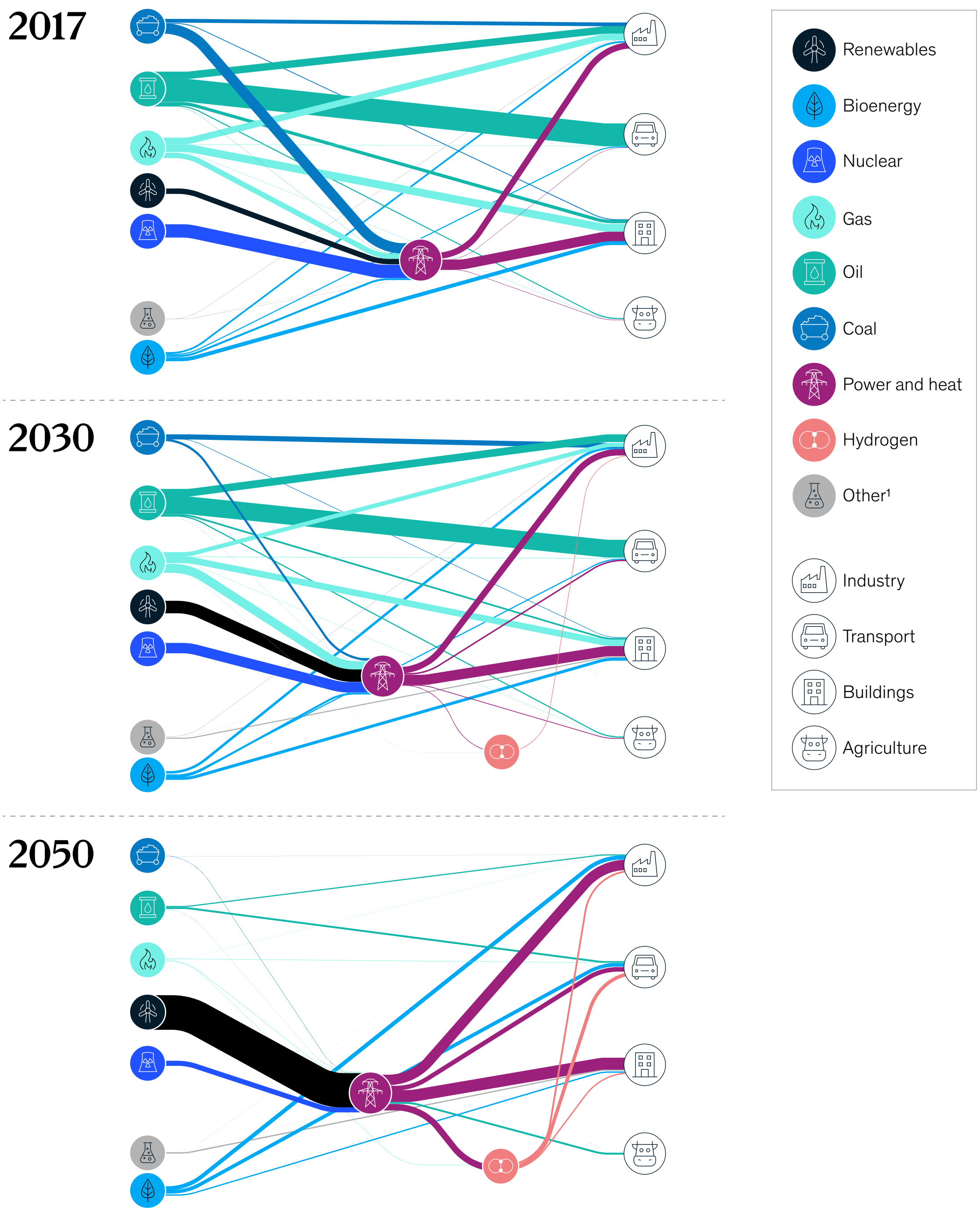
[1] For more, see "Global Energy Perspective 2022," McKinsey, April 26, 2022.

Exhibit 1

The path to net-zero emissions requires a fundamental and global shift in how energy is produced and used.

Net-zero Europe decarbonization pathway, renewables and hydrogen, total primary energy demand



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[1] Other miscellaneous sources (eg, nonrenewable waste).
Source: *Net-Zero Europe: Decarbonization pathways and socioeconomic implications,* McKinsey, November 2020

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grows and regulatory incentives to decarbonize strengthen. Capital markets are placing higher value on firms that are structurally aligned with the energy transition across sectors such as liquid fuels, power, and equipment manufacturers. By contrast, the major oil and gas companies that are most invested in low-carbon markets have not yet benefited from material uplifts in company valuation. In fact, our research shows that the upside for some leading firms starts to materialize when more than 40 percent of total portfolios are low carbon, while leading oil and gas majors typically allocate less than 25 percent of their new investments into new energies.

Many oil and gas companies are well positioned to become leaders in the energy transition. This is not only because of their global scale, the risk appetite of their investors, their large balance sheet and cash positions, and their long-standing relationships with energy customers and stakeholders, but also because of their unique capabilities related to offshore projects and hydrogen and sustainable-fuel production and transport.

On these points, oil and gas players can offer distinctive value propositions in the following four areas of the energy transition:

- *Offshore project development.* Oil and gas players with extensive experience in large-scale projects can develop and build integrated projects, including renewables generation and hydrogen and heat production. In addition, some bidders for projects provide offers that include heat and hydrogen investments.
- *Hydrogen production and transportation.* Oil and gas companies often have long histories with hydrogen production in their refining and chemical processes. In addition, existing capabilities in gas storage and transportation are relevant for hydrogen production and transportation because of their chemical similarities; both gas and hydrogen are flammable gases that need to be kept under pressure and carefully managed.
- *EV charging.* Players across the value chain, including retailers, refiners, and producers, can leverage their brands, customer relationships, real estate, and fuel stations near roads and highways to deliver fast-charging services for EVs.[2]
- *Decarbonization solutions.* Pressure on oil and gas companies to decarbonize has pushed them to develop technical solutions and know-how that can be relevant to other industries. Oil and gas companies can leverage these to offer decarbonization solutions, including renewables generation, energy retail, batteries, and carbon capture, utilization, and storage (CCUS). And because the industry currently relies on fossil fuels and has long-standing relationships with suppliers, its representatives also belong at the table when designing the transition pathway.

Many oil and gas companies are well positioned to become leaders in the energy transition.

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[2] For more on fast charging, see Sean Kane, Florian Manz, Florian Nägele, and Felix Richter, “EV fast charging: How to build and sustain competitive differentiation,” McKinsey, June 4, 2021.

When, where, and how: Making strategic choices

Oil and gas companies aspiring to lead the energy transition need to take a stance on at least three strategic questions.

To begin, players need to time investments in sustainable offerings in a way that meets carbon emissions goals (current and projected) while delivering on shareholder expectations. Investing early requires confidence that demand will follow—otherwise, it risks subpar returns for capital expenditures. On the other hand, playing "catch-up" in new energy markets could affect players' abilities to maintain a competitive advantage against those that invested "on time"—which would subsequently create risk exposure as CO_2-intensive sources of energy are increasingly regulated.

Players also need to choose the value chains and segments in which they'd like to operate. Within power, potential areas for investment by oil and gas players include offshore generation, EV charging, and hydrogen production and development. Each of these has different risk/return profiles, capital requirements, and needed capabilities.

Last, there are ideal operating models for both new and legacy businesses. To unlock value, an "arm's length" setup can enable the new business to be independent. This in turn can lead to potentially higher valuations; maximize attractiveness for capital markets; allow greater access to environmental, social, and governance (ESG) capital; and enable different cost of capital and financing structures.

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Building a sustainable-power value chain

Oil and gas players can help create value in the integrated energy value chain by getting four things right (Exhibit 2). The upside can be substantial, leading to material improvements on the base rate of return for specific portfolios.

Customer centricity at the core

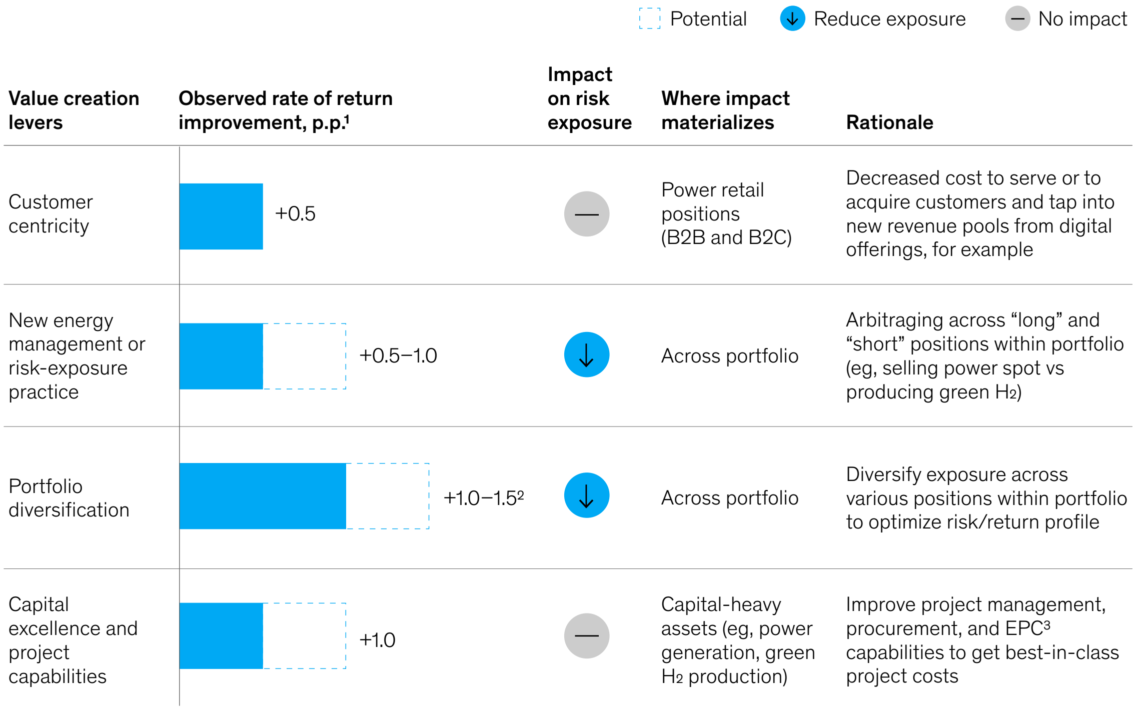
Business models are constantly evolving as innovation shapes the technology and services landscape. As technology changes, so do customer expectations. That said, winners in both B2B and B2C retail have shown that downstream power should be customer-centric. A deep understanding of product and service offerings can provide customers with the right support as they transition to renewable energy.

Because of their existing business and deep technical capabilities, oil and gas players can help create value in key segments of the energy transition. For instance, "dual fuel" offerings already show promising synergies between oil and natural gas. And trading services can provide additional returns, offering "around the clock" green power (the delivery of zero-carbon electricity that meets demand at all times).

The art lies in the construction of specific and integrated customer offerings that are tailored to individual needs. For example, mining companies

Exhibit 2

Portfolio diversification will likely have the largest impact on risk exposure for companies entering the sustainable-power value chain.



⬚ Potential ↓ Reduce exposure — No impact

Value creation levers	Observed rate of return improvement, p.p.[1]	Impact on risk exposure	Where impact materializes	Rationale
Customer centricity	+0.5	—	Power retail positions (B2B and B2C)	Decreased cost to serve or to acquire customers and tap into new revenue pools from digital offerings, for example
New energy management or risk-exposure practice	+0.5–1.0	↓	Across portfolio	Arbitraging across "long" and "short" positions within portfolio (eg, selling power spot vs producing green H_2)
Portfolio diversification	+1.0–1.5[2]	↓	Across portfolio	Diversify exposure across various positions within portfolio to optimize risk/return profile
Capital excellence and project capabilities	+1.0	—	Capital-heavy assets (eg, power generation, green H_2 production)	Improve project management, procurement, and EPC[3] capabilities to get best-in-class project costs

Note: Rate-of-return improvements are not additive.

[1] Percentage points.

[2] Risk adjusted; takes into account increased capital consumption to manage through cycles.

[3] Engineering, procurement, and construction.

Source: McKinsey analysis

McKinsey & Company

may require electrified trucks and machinery as well as operations powered by renewable electricity, whereas steel players may shift toward producing green steel using hydrogen.[3]

The customer-centric approach is also fundamental to answering the three strategic questions of when, where, and how—ensuring that oil players enter production when demand is rising (when), invest available capital in the projects that best fit customers' needs (where), and help define the operating model (how). Answering these questions and accounting for the needs of customers could help players partner with green companies according to public commitments.

Energy management and risk-exposure practices

The oil and gas sector contends with fluctuating prices as well as unpredictable geopolitical events and demand shocks. As a result, oil and gas companies have developed an adaptable "risk culture" for investment decisions. In particular, the unique characteristics of the power value chain—including constraints to geographic arbitrage, high price and volume volatility, risks that covary between different investment positions, and different regulatory frameworks—make players more aware of risk. Generally speaking, returns in the power industry can be lower than those of fossil fuels, while market volatility can be higher and of a different nature.

Investors in renewables have already experienced the risks and benefits of exposure to power markets: in February 2021, winter storm Uri in the United States caused significant investment risk for power producers with firm commitments. More recently, rising gas prices have pushed wholesale power prices past €300 per megawatt-hour (MWh) over extended periods of time in many European countries (to the benefit of some renewables players).

Diversified portfolios and optimized risk returns

Oil and gas players that enter new energy markets typically have a competitive advantage because risk exposures across oil and gas and power can offset each other. When energy consumption remains fairly stable, reduced consumption of fossil fuels translates into increased consumption of power or hydrogen, and vice versa.[4]

Balancing risk exposures across the portfolio can improve the risk/return profile, compared with nondiversified portfolios. In other words, players that invested in only one source of energy are typically exposed to higher levels of risk (because 100 percent of the portfolio may be affected by a market event). Those with diversified portfolios, however, not only can reduce their overall risk exposure but also tend to be able to improve project returns through higher leverage. Achieving diversified risk/return profiles in a controlled manner, however, requires advanced portfolio and risk-management capabilities.

- *Geographic diversification.* Energy prices do not move in the same way across geographies. The sun in California does not shine at the same time the wind blows in the North Sea. With renewables increasingly setting the price of power, prices across geographies are increasingly uncorrelated.

- *Portfolio diversification.* Different types of assets and financial positions offset one another's commercial risks. Our research on global portfolios of energy companies shows that these portfolio effects can eliminate 50 to 80 percent of risk. This means that building a smart, diversified portfolio across geographies can reduce market risks to minimal levels.

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[3] For more on green steel, see Steven Vercammen, "Steel," *McKinsey Quarterly,* August 1, 2022.
[4] For more on energy consumption in the years to come, see "Global Energy Perspective 2022," April 26, 2022.

Capital excellence and project capabilities

Significant investments are needed in the years to come, which means it’s crucial that capital is strategically deployed to the right projects at the right times. Especially challenging is the sequencing of investments. Technologies are progressing at a fast pace, and assets can become obsolete without ever being operated profitably.

The risk of sunk capital is high if investments are made too early or during an immature market state. An example of this is the recent repowering of wind farms; operators are replacing older, smaller turbines with larger and more efficient ones. By contrast, investing capital too late could result in entering a market when competitors have already forged partnerships with customers, developed proprietary expertise, or established their brands and market positions.

History has shown that early investment in renewables often pays off. Yet the sheer size of these investments requires players to ensure that projects stay on time and deliver at optimized project costs. That said, the lack of materials and pressured supply chains can create an additional challenge to project development.

Developing business capabilities and reskilling the workforce can help capture the full potential of returns. More power engineers will need to be trained to work with new technologies, and so will a workforce that understands power markets, regulatory frameworks, and customer needs in the energy transition. And new comprehensive reporting frameworks can be developed that cover profitability as well as environmental impact across Scopes 1, 2, and 3 emissions.

The rise in investments in clean and renewable technologies provides compelling evidence that power markets will continue to change rapidly. To stay ahead of the curve in the power value chain, oil and gas players will need to be thoughtful, strategic, and intentional in playing to their strengths. There is no time to waste; the industry cannot afford to wait to see what happens.

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The world needs to capture, use, and store gigatons of CO_2: Where and how?

Strategically building carbon capture, utilization, and storage hubs near clusters of large emitters can lower costs and accelerate scale-up.

This article is a collaborative effort by Phil De Luna, Luciano Di Fiori, Yinsheng Li, Alastair Nojek, and Brandon Stackhouse representing views from McKinsey's Oil & Gas Practice.

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Countries and companies around the globe are committing to net zero by 2050. One suite of technologies—collectively called carbon capture, utilization, and storage (CCUS)—offers solutions for many hard-to-abate sectors such as aviation, cement, and hydrogen production from fossil fuels. However, global CCUS uptake needs to expand 120 times from current levels by 2050, rising to at least 4.2 gigatons per annum (GTPA) of CO_2 captured, for countries to achieve their net-zero commitments.[1]

There are two routes for captured CO_2: permanent storage (CCS) or utilization by converting into products (CCU). The potential for CCUS is highly dependent on factors including the emissions source, industry, capture technology, transportation, as well as location and type of storage. Thousands of CO_2 point source facilities exist that could be suited to carbon capture and storage (CCS), with varying concentrations of CO_2 in the flue gas and differing proximity to storage sites, which can affect the viability for CCS for these facilities. Future emission sources may exist near facilities that use captured CO_2 to create products such as fuels, chemicals, and building materials, and near oil and gas wells where they can be used for enhanced oil and gas recovery (EOR/EGR). Utilization has the added benefit over CCS of generating revenue to offset the cost of capture and transport.

However, many, if not most, CCUS projects are economically challenged today, with high costs of capture for dilute point sources and a limited number of revenue streams available.[2] For CCUS to reach levels needed to achieve net-zero commitments, lowering costs may be vital. Developing cross-industry hubs that share CCUS infrastructure and resources across multiple companies could reduce the risks associated with the upfront investment capital that individual emitters may be unable to burden alone.

This article explores potential CCUS hubs, five emerging hub archetypes, and three key steps to accelerate the development of CCUS hubs.

Creating CCUS hubs can accelerate development

A CCUS hub is a cluster of emission facilities that share the same CO_2 transportation and storage or utilization infrastructure. There have been several recent government funding calls for hub developments in Canada, Europe, and the United States to address industrial emissions and accelerate the development of both carbon-removal technology and infrastructure.[3] There are approximately 15 CCUS hubs globally under various stages of development, with many more being planned.[4]

In the United States, CCUS has recently been boosted by the Inflation Reduction Act, which offers an increased tax credit for captured point source CO_2 from $50 to $85 per ton.[5] Many industrial use cases such as ammonia production, ethanol plants, and natural gas processing facilities are now economically “in the money” in the United States with the increased 45Q tax subsidy.[6] This subsidy provides $85 per ton for sequestered industrial or power emissions, and $180 per ton for emissions captured directly from the atmosphere and sequestered.

Shared transportation, utilization, or storage infrastructure could lower costs, increase savings through economies-of-scale, provide additional options for managing or sharing risks, and strengthen regional visibility for support by governmental entities. Hubs may, however, bring companies together from different sectors that do not normally work together, which can introduce project complexity as there are multiple collaborators across different industries, all with different timelines and objectives.

We developed a macro-model to assess the viability of future CCUS hubs (see sidebar, “Our methodology”). This model considers a range of factors, including point source industries and purity of the emissions streams (which determines their potential for utilization or storage, or both), the

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[1] “Scaling the CCUS industry to achieve net-zero emissions,” McKinsey, October 28, 2022.

[2] Ibid.

[3] “Safely reducing emissions in the industrial heartland,” Government of Alberta, March 31, 2022; “Integration of CCUS in hubs and clusters, including knowledge sharing activities,” European Commission, April 8, 2022; “Notice of Intent No.: DE-FOA-0002746,” US Department of Energy, May 13, 2022.

[4] McKinsey Energy Insights Global Emissions and Storage Database; McKinsey analysis.

[5] Alejandro de la Garza, “The Inflation Reduction Act includes a bonanza for the carbon capture industry,” *Time*, August 11, 2022.

[6] Matt Bright, “The Inflation Reduction Act creates a whole new market for carbon capture,” Clean Air Task Force, August 22, 2022.

Our methodology

We developed a perspective on optimal locations for CCUS hubs that match global storage potential with CO_2-emitting facilities across countries. Our cross-industry global database of CO_2 point source emissions spans 11 sectors, covers over 25,000 individual facilities, and accounts for 19.5 gigatons (GT) of CO_2 emitted per year. Analysis of this data allowed us to identify potential locations for approximately 700 CCUS hubs globally.

The analysis is based on an optimized view with direct links between the CO_2 source and the closest sink location with enough storage capacity. Actual storage and access will depend on geological assessments and geographical or political boundaries (for example, mountains and cities) and drilling feasibility, among others. This model does not explicitly account for external drivers such as local regulations and cross-border limitations.

Our global database of potential CO_2 storage reservoirs consolidates over 1,100 saline aquifers and 16,000 oil and gas fields, representing up to 20,000 GT of global capacity. Utilization of all this capacity could represent over 700 years' worth of global annual emissions at today's emissions rate. Utilization opportunities, apart from EOR/EGR, were not considered explicitly in the model, which could lead to an underestimation of overall CCUS potential. According to McKinsey analysis, utilization is projected to account for approximately 5 percent of the captured CO_2 volume in 2050, compared to approximately 95 percent for storage. Further, the model did not account for transport and storage savings in hubs that focus on utilization rather than storage, which may lead to more conservative results for emissions savings in the different cost buckets.

physical proximity of the emitters to potential storage sites, and the potential for shared infrastructure costs, operating costs, and other commercial synergies within a cluster.

Our analysis suggests that approximately 700 CCUS hubs could be established globally. Most of these hubs are located on, or close to, potential storage locations and EOR/EGR sites, with more than 60 percent located within 50 miles from potential storage sites (Exhibit 1). East Asia could become a hub hotspot since the region's high emission volume could be covered by its high storage capacity (Exhibit 2).

For each potential hub consisting of five nearby emitters or more, we have calculated a total carbon-abatement cost, which includes the cost of capture, compression, transportation, and storage. Additional variable costs such as financing, vendor margins, and contingency are project specific and not included here, but need to be factored in to understand real-world cost of abatement.

Capture costs are typically the largest cost in the CCUS value chain and vary considerably between technologies and industries.[7] One of the key factors here is the concentration of CO_2 in the emissions stream. High concentration streams, such as those from ethanol and ammonia processes, where CO_2 is 50 to 90 percent of the emissions, are the cheapest to capture.[8] However, such sources represent less than 5 percent of the worldwide emissions volume. Low-concentration sources, such as power generation, cement, and petrochemical production, with CO_2 concentrations in emissions streams of between 5 and 15 percent, represent the greatest share of emissions and are also the costliest to capture.[9]

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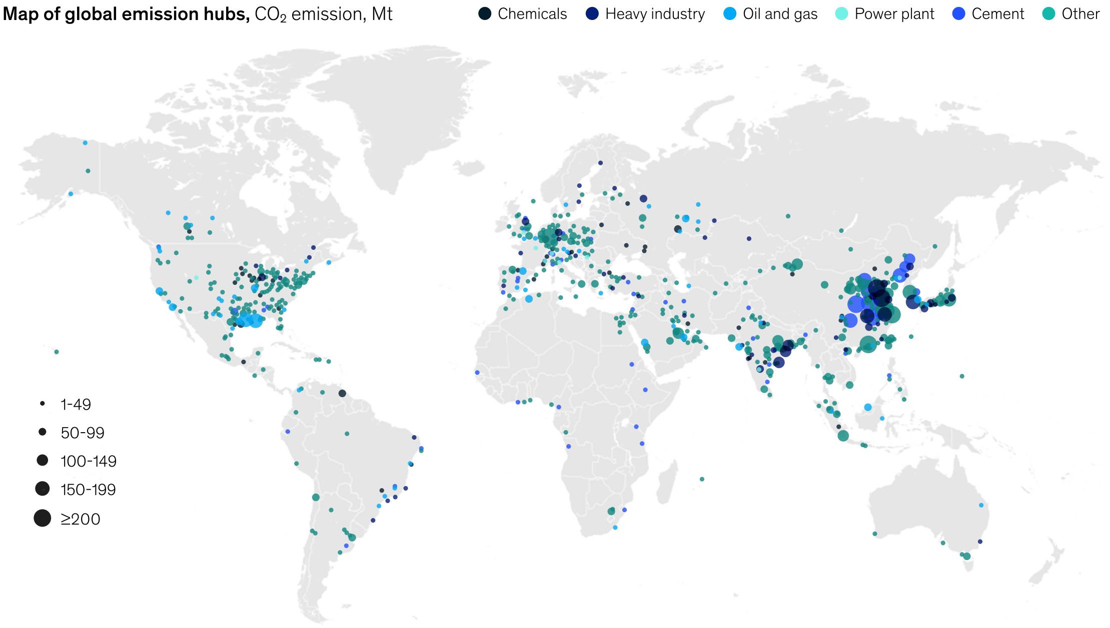
[7] Adam Baylin-Stern and Niels Berghout, "Is carbon capture too expensive?" IEA, February 27, 2021.
[8] Ibid.
[9] Ibid.

Exhibit 1

There is a potential to establish approximately 700 CCUS hubs globally, most of which are located on, or close to, potential storage locations.

Emissions | Storage capacity

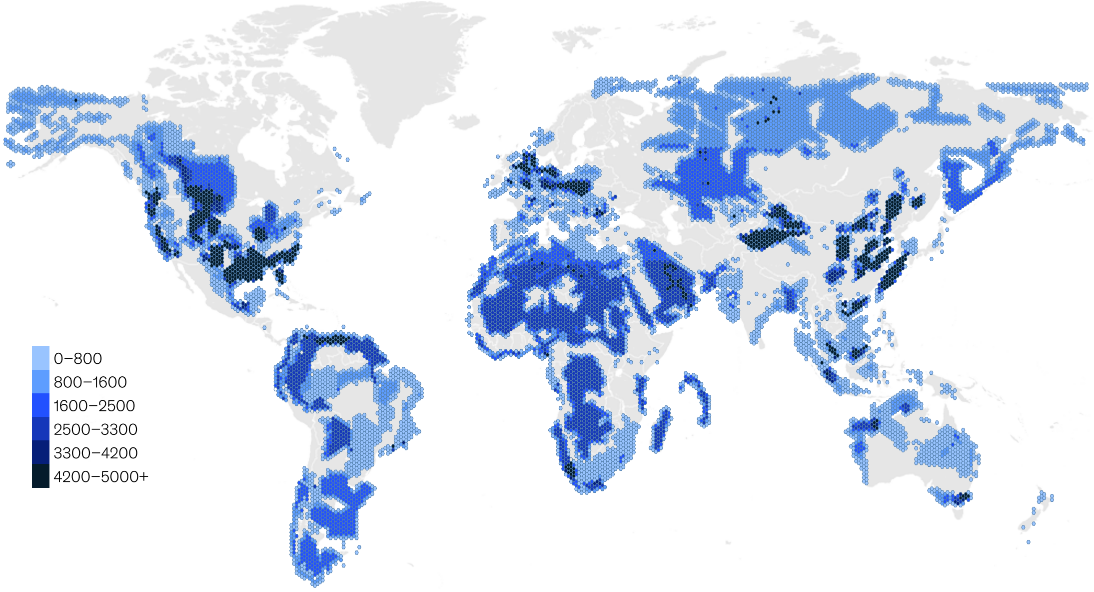
Map of global emission hubs, CO_2 emission, Mt



Disclaimer: The boundaries and names shown on maps do not imply official endorsement or acceptance by McKinsey & Company.
Source: McKinsey Energy Insights Global Emission and Storage Database, Energy Insights Carbon Hub Explorer

Emissions | **Storage capacity**

Map of potential sink locations, CO_2 storage capacity, Mt



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Source: McKinsey Energy Insights Global Emission and Storage Database, Energy Insights Carbon Hub Explorer

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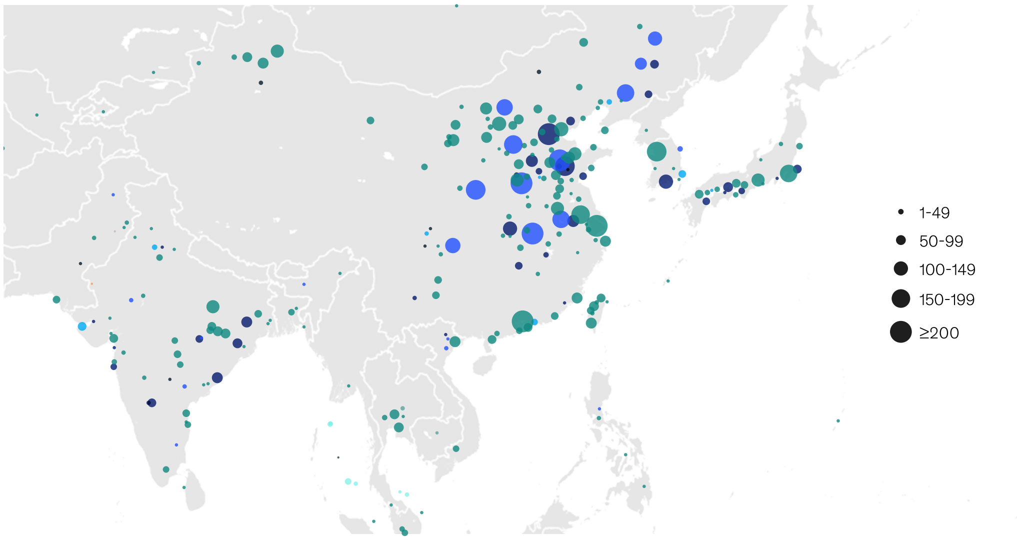
Exhibit 2

East Asia could become a hub hotspot, as the region's high emissions could be covered by its high storage capacity.

Emissions | Storage capacity

Map of East Asia emission hubs, CO_2 emission, Mt

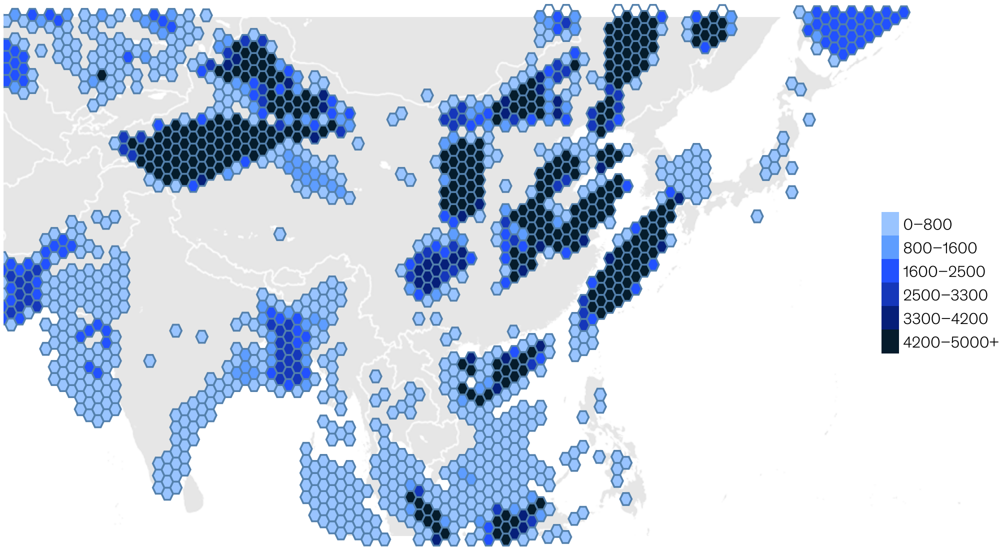
● Chemicals ● Heavy industry ● Oil and gas ● Power plant ● Cement



Disclaimer: The boundaries and names shown on maps do not imply official endorsement or acceptance by McKinsey & Company.
Source: McKinsey Energy Insights Global Emission and Storage Database, Energy Insights Carbon Hub Explorer

Emissions | Storage capacity

Map of potential East Asia sink locations, CO_2 storage capacity, Mt



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Source: McKinsey Energy Insights Global Emission and Storage Database, Energy Insights Carbon Hub Explorer

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As compression is a mature and well-established process, this cost element is typically well-understood and less variable between operations. Transportation cost is highly dependent on proximity to storage sites, transport mode, terrain, and whether sites are located on land or offshore. Finally, storage cost is dependent on the type of storage used (onshore, offshore, reservoir, geologic, etcetera).

The resulting emission-abatement cost curve shows that if 440 hubs are developed, 9 GTPA to 10 GTPA of existing emissions could be abated at a cost of less than \$100 per ton CO_2 (Exhibit 3). Furthermore, the world could reach its 4.2 GTPA net-zero goal by 2050 through the development of approximately 160 CCUS hubs at costs of less than \$85 per ton CO_2.

While the total addressable CO_2 abatement from CCUS is based on clusters of emission point sources, we should note that much of the decarbonization may come from other levers (for example, increased energy efficiency, fuel switching, or electrification) prior to CCUS being adopted. Some of the high-emitting facilities included in the model may be nearing their end of life and will simply be decommissioned, or there is a potential for disruptive new technologies to decarbonize their supply chain, such as electric arc furnaces for steel production. In many situations and use cases, CCUS serves as a backstop for emissions that are difficult or impossible to decarbonize using other means.

Five emerging hub archetypes

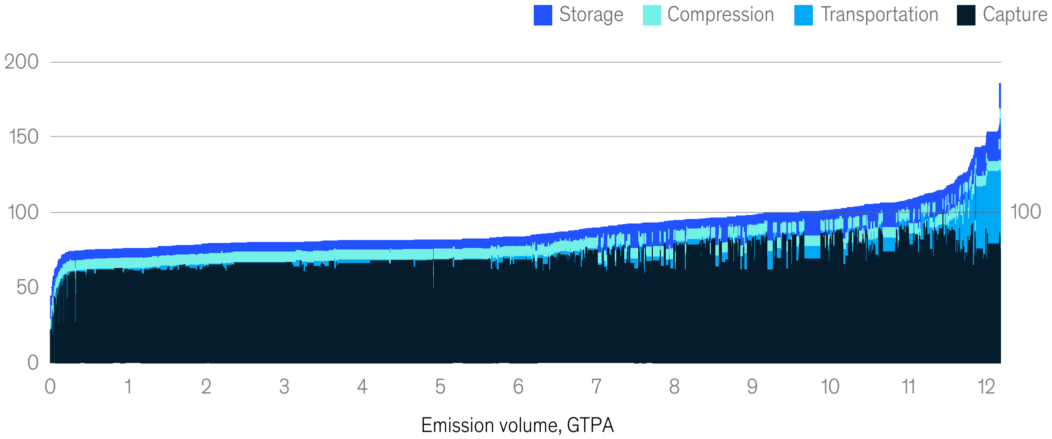
Five hub archetypes sharing common features across regions and sectors emerge when the industrial make-up of an emissions cluster drives the formation of these hubs. These archetypes each have unique characteristics that will likely shape their business case, operating model, governance, and potential impact.

1. *Large emitter-dominated hubs* are characterized by the presence of multiple emission point sources greater than 1 million tons per annum (MTPA). Sometimes these facilities may be so large that they require their own dedicated CCUS infrastructure and can afford the capital expenditures to deploy CCUS. They may still be open to partnering with other

Exhibit 3

With the development of 440 hubs, 9–10 GTPA of existing emissions could be abated at a cost of less than \$100 per ton CO_2.

Global CO_2 emission-abatement cost curves across selected CCUS hubs,[1] \$/tons



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[1] Based on current emission profiles; assumes midpoints of cost estimates across capture and storage, excludes hubs or facilities with CCS cost above \$200/ton; based on an optimized view with approximately 50 percent additional transportation cost to account for actual pipeline routes; actual storage (and access) will depend on geology, and geographical and political boundaries (such as mountains, cities, regulations, and drilling feasibility). Does not include cost of financing, project execution, or margins from vendors. Selected hubs based on emission size of more than 1 MTPA and facility count no less than five.
Source: McKinsey Energy Insights Global Emission and Storage Database; McKinsey Energy Insights Carbon Hub Explorer

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smaller emitters to create a hub. These facilities are primarily power plants, but may also be large iron, steel, or cement facilities. Point sources are typically lower purity with higher costs, making them better suited to storage than utilization, but lower project complexity due to the reduced number of players may lead to faster execution. Smaller emitters that would not be able to afford the build-out of CCUS infrastructure may benefit from proximity to a large emitter as a bolt-on. While there are large CCUS facilities in operation today, there have yet to be hubs that have formed around existing infrastructure.

2. *Cross-industry hubs* are built around industrial parks with a mixture of high and low-emission facilities with varying costs across different sectors and industries (for example, a cement facility located near an ammonia production plant and a refinery). These industry-balanced hubs are typically centered around common CCUS infrastructure, such as a transport pipeline that collects CO_2 from various sources. A combination of utilization and storage may work at such hubs, with different purity streams used for different purposes. Cross-sectoral collaboration between industries not accustomed to working together may lead to higher project complexity. An example of a cross-industry hub is the Alberta Carbon Trunk Line (ACTL), which captures CO_2 emissions from an oil refinery and fertilizer facility that shares a pipeline to storage for EOR. The ACTL was designed with a larger capacity to accommodate future emitters.

3. *Storage-led hubs* are strategically located near ports for shipping or near geological storage to reduce the need for onshore and offshore pipeline transportation. Creating hubs that are located close to storage can reduce costly transportation infrastructure. In locations where onshore geological storage may be limited due to regulation or public acceptance, such as in Europe, offshore storage-led hubs are more likely to emerge. An example of a storage-led hub is the Porthos CCUS project, which captures CO_2 emissions from facilities in the Port of Rotterdam and then stores them in gas fields under the North Sea.

4. *Smaller, higher-purity emitter hubs* consist of a higher number of facilities with relatively high-purity CO_2 streams (such as ethanol production plants) and therefore typically lower capture costs. However, aggregation across multiple facilities is required to achieve economies of scale and share the capital burden to build transport, storage, and utilization infrastructure. Such hubs may be better suited to utilization than storage, to take advantage of high-quality streams of CO_2. Due to the larger number of smaller facilities, there is likely to be increased project complexity, which may slow progress or complicate operations. An example of a smaller, higher-purity emitter hub is the CCUS pipeline network in the Midwest that will capture emissions from ethanol biorefineries and is being developed by companies like Summit Carbon Solutions, Navigator, Wolf Carbon Solutions, and ADM.

5. *Carbon-removal-led hubs* are built around direct air capture (DAC) or bioenergy carbon capture and storage facilities. Since a DAC facility could theoretically be deployed directly around carbon removal-driven hubs, and could also overlap with a storage-driven hub, the infrastructure built for carbon-removal technology (such as pipelines, CO_2 compression, and monitoring and measurement subsurface technologies) could be shared by other nearby emitters. The CO_2 captured from the atmosphere by these hubs is also well suited for utilization to produce synfuels such as sustainable aviation fuels. The US Department of Energy's Office of Clean Energy Demonstration announced $2.5 billion for the development of regional DAC hubs, with applications due in March 2023.[10] An example of carbon-removal-led hubs is the recent announcement from Occidental Petroleum and King Ranch to remove and store up to 30 MTPA of CO_2 using DAC.[11]

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[10] "Biden-Harris Administration announces $2.5 billion to cut pollution and deliver economic benefits to communities across the nation," US Department of Energy, February 23, 2023.

[11] "Occidental and 1PointFive, King Ranch reach lease agreement to support up to 30 direct air capture plants on leased acreage," Oxy, October 31, 2022.

Large emitter-dominated hubs may have improved deployment speed due to organizational simplicity with one dominant stakeholder. However, cross-industry or storage-led hubs may be more resilient as the success of the hub is diversified across multiple organizations and the fate of the entire hub is not dependent on one facility. Hubs that have some form of utilization may also emerge faster than those focused on storage alone, as utilization provides a stream of revenue to offset the costs.

Ultimately, proximity to storage, availability of renewable energy for powering carbon removals, opportunities for utilization, and willingness of parties to cooperate will likely drive the business cases for the formation of many of these hubs. Integration with other emerging climate technologies, such as hydrogen production and sustainable aviation fuels, may also drive adoption.

How can we accelerate the development of CCUS hubs?

Our recent research shows that an annual global investment in CCUS technology of $120 billion to $150 billion by 2035 is required to achieve net zero.[12] To scale CCUS effectively, greater coordination across the value chain may be needed. The following three key actions could speed up CCUS-hub development worldwide:

1. **Identify no-regrets activation projects within regions that are feasible under existing economic conditions and around which hubs can begin to form**. Building hubs around high-purity sources with lower CO_2 capture costs may allow for quicker learning that can be applied to larger-scale sources of CO_2 emissions that are more expensive to capture. These initial hubs can be designed to accommodate modularity and flexibility for expansion to take advantage of potential future economies of scale or cost compression from technological advances.

2. **Build market mechanisms to ensure value and risk are apportioned appropriately across the hub.** It is important to understand the value and risk across capture, transportation, storage, and utilization in different regions and situations. Sharing learnings and best practices from the development of hubs can facilitate risk sharing, improve safety, standardize storage monitoring, and ensure governance and business models follow best practices. Creating standards around the capture, utilization, monitoring, and measurement of CO_2, and end-of-life liability management, could give investors confidence in capitalizing on CCUS hubs.

3. **Design hub networks to be resilient and adaptable to change.** Developing a CCUS hub is a multistep process that can require significant collaboration between industry players that are often not accustomed to working together. The network between capture and storage may need to be carefully designed. For example, a hub may choose a trunk line model that aggregates many emissions into one pipeline with one storage location, or it may choose a network approach with multiple sequestration and transportation options and flexibility across sinks and sources.

Carbon capture, utilization, and storage offers a way to reduce the emissions of our existing infrastructure, especially for hard-to-abate sectors, while we continue to improve renewables and electrification. By working together, pooling resources, and sharing critical infrastructure, CCUS hubs could lower the costs associated with capturing, transporting, utilizing, and storing CO_2. Considerable volumes of CO_2 remain to be captured, and we can accomplish significantly more by working together than laboring alone.

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The authors wish to thank Krysta Biniek, Alastair Hamilton, and Clint Wood for their contributions to this article.

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[12] "Scaling the CCUS industry to achieve net-zero emissions," McKinsey, October 28, 2022; *Global Energy Perspective 2022*, McKinsey, April 26, 2022; McKinsey Energy Insights.

A balancing act: Securing European gas and power markets

The invasion of Ukraine has shocked the European energy market. Europe may need to intensify efforts to reduce gas demand to balance the market and ensure security of supply while avoiding price spikes.

This article is a collaborative effort by Gillian Boccara, Diego Hernandez Diaz, Berend Heringa, Ole Rolser, Namit Sharma, Thomas Vahlenkamp, and Cindy Xue, representing views from McKinsey's Oil & Gas and Electric Power & Natural Gas practices.

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This is a challenging time for European energy markets. The war in Ukraine, while foremost a humanitarian crisis, has shaken the European energy market more than any other event in recent history as shocks to gas supply have led to surging natural gas and power prices, high volatility, and supply security risks (see sidebar, “Disclaimer on Ukraine”).[1] Europe has so far managed to avoid a sharp slowdown of economic activity by balancing its gas market through increased liquefied natural gas (LNG) imports, reduced household demand, and industrial efficiencies and plant closures.[2]

In the coming years, Europe may need to sustain and intensify efforts to reduce gas demand to manage the supply shock from the ongoing war in Ukraine, which may require a difficult, but doable, set of actions.[3] However, while Europe’s energy supply and demand are expected to balance, there is still uncertainty as volatile prices and supply disruptions pose a risk to all sectors of the economy—and Europe may need to prepare to navigate these risks.

In this article, we explore trends in Europe’s energy market over the past year and present key signposts to watch for in the future supply-demand balance. Further, we outline what could help to ensure a balanced and stable European energy market through 2023 and put forward three ways in which businesses can help navigate risk in the energy market.

Year in review: European energy markets in crisis

Prior to the invasion of Ukraine, Russia supplied nearly one-third of European natural gas.[4] After the invasion, Russian piped gas flow decreased by more than half from 140 billion cubic meters (bcm) in 2021 to 65 bcm in 2022.[5] As Europe lost this volume of piped gas supply from Russia, liquefied natural gas (LNG) was purchased as a substitute—increasing LNG imports to Europe by 64 bcm from 2021 levels.[6]

This shake in the European energy market caused energy prices to spike in 2022: gas prices peaked at $100 per million metric British thermal units (MMBtu), Brent crude oil prices reached $130 per barrel, and coal prices peaked at $441 per ton.[7] As a result, Europe spent over €1 trillion more on oil, gas, and coal in 2022 than in 2021—more than doubling the share of GDP spent on energy (Exhibit 1). Although energy prices started to decline in the last quarter of 2022, the tight balance may continue, resulting in higher prices which may in turn cause Europe’s energy spend to remain above pre-war

Disclaimer on Ukraine

Russia’s invasion of Ukraine in February 2022 is having deep human, social, and economic impact across countries and sectors. The implications of the invasion are rapidly evolving and are inherently uncertain. As a result, this article, and the data and analysis it sets out, should be treated as a best-efforts perspective at a specific point in time, which seeks to help inform discussion and decisions taken by leaders of relevant organizations. This article does not set out economic or geopolitical forecasts and should not be treated as doing so. It also does not provide legal analysis, including but not limited to legal advice on sanctions or export control issues.

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[1] “Infographic—A market mechanism to limit excessive gas price spikes,” Council of the European Union, February 15, 2023.

[2] “GDP and employment flash estimates for the fourth quarter of 2022,” Eurostat, February 14, 2023; “How have higher energy prices affected industrial production and imports?,” European Central Bank; European natural gas demand tracker, Bruegel, January 23, 2023; Supply, transformation, and consumption of gas monthly data, Eurostat, January 23, 2023; *Energy Efficiency 2022*; International Energy Agency, November 2022; McKinsey EU PipeFlow and LNGFlow models.

[3] Europe includes the EU27, Norway, Switzerland, and the United Kingdom.

[4] *BP Statistical Review of World Energy 2022*, BP, June 2022; Supply, transformation, and consumption of gas monthly data, Eurostat, January 23, 2023; *Global Energy Perspective 2022*, McKinsey, April 26, 2022; McKinsey EU PipeFlow model.

[5] Ibid.

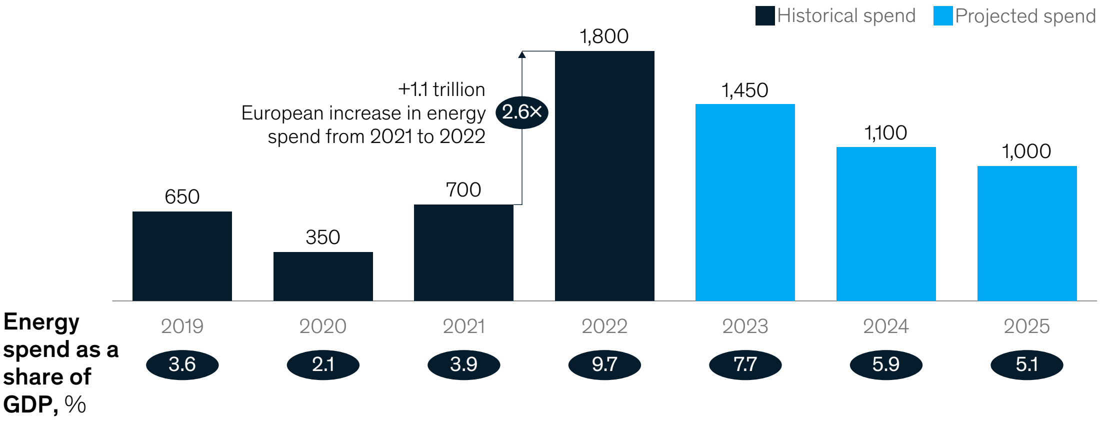
[6] Supply, transformation, and consumption of gas monthly data, Eurostat, January 23, 2023.

[7] Petroleum and other liquids spot prices, International Energy Agency, January 15, 2023; Market data, Montel, January 15, 2023; World Bank Commodities Price Data, World Bank, January 15, 2023.

Exhibit 1

European energy spend on oil, gas, and coal increased from four to ten percent of GDP last year and will likely remain high through 2025.

Europe energy spending on oil, gas, and coal,[1] billion Euros



[1] Europe includes the EU27 and the UK. Calculated as Energy consumption in EU27 and UK multiplied by the wholesale price outlook for each energy source: coal (ARA future prices), natural gas (Dutch TTF future prices), crude oil (McKinsey Energy Insights Oil Desk). Not including retail, infrastructure, or transport costs. Including thermal coal, excluding metallurgical coal and lignite. Assumed forward prices for 2023–25: coal (2023: $329/ton; 2025: $197/ton); gas (2023: 2$4/MMBtu; 2025: 22$/MMBtu); oil (2023: $96/barrel; 2025: $80/barrel). Excludes taxes and royalties. Based on publicly available data as of mid-January 2023.

Source: Coal futures, CME Group; Crude oil futures and prices, CME Group; Petroleum and other liquids spot prices, IEA; Market data, Montel; World Bank Commodities Price Data, World Bank; McKinsey EU PipeFlow, LNGFlow, and OilDesk models

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levels until at least 2025—placing further pressure on Europe's energy market.[8]

In response to the spike in prices in 2022, Europe observed a 57 bcm drop in gas demand, an 11 percent decrease from 2021, which balanced the market.[9] This reduction was driven mainly by a drop in demand in gas for buildings (15 percent) and in industry (18 percent) compared to 2021 levels.[10] Meanwhile, in the power sector, gas demand remained relatively stable in 2022, with little impact on overall European gas demand.[11]

Gas consumption in buildings dropped due to behavioral change

In buildings, the observed household reduction in gas demand throughout the 2022 winter suggests a behavioral change in response to the spike in gas prices. Many European countries saw gas demand decline by 15 to 20 percent, even after controlling for the milder-than-usual temperatures (Exhibit 2).

Energy efficiency and production shutdowns drove gas demand reduction in industry

Industry saw two main drivers of gas demand reduction in 2022: energy efficiency and production shutdowns. For example, according to the ifo Institute, three-quarters of surveyed German industrial companies were able to reduce gas consumption in the last six months of 2022 without cutting production by leveraging energy-efficiency measures.[12] Meanwhile, energy-intensive industries, such as fertilizer, chemicals, and steel, saw significant production curtailment in 2022. European aluminum and zinc production stalled at around 70 to 80 percent of total production capacity in the second half of 2022, down from the pre-war baseline of 90 to 95 percent.[13] Additionally, fertilizer production

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[8] Ibid.

[9] European natural gas demand tracker, Bruegel, January 23, 2023; Supply, transformation, and consumption of gas monthly data, Eurostat, January 23, 2023.

[10] Ibid.

[11] McKinsey analysis based on publicly available data of power generation in Europe.

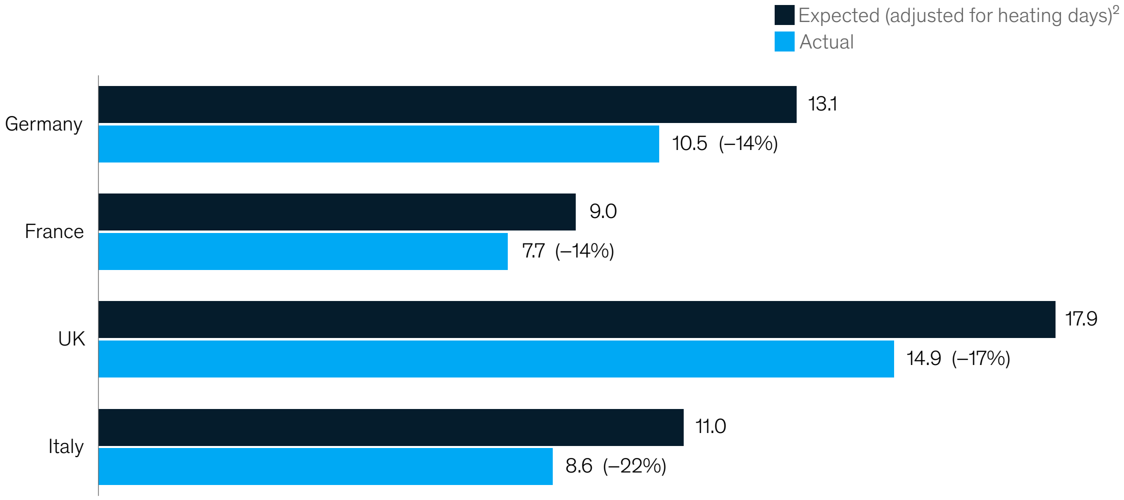
[12] Only 14 percent of companies surveyed reported necessary production cuts, 7 percent did not take measures to reduce gas consumption, and 3 percent did not know; "Many industrial companies in Germany cut gas consumption without curbing production," ifo Institute, November 22, 2022.

[13] McKinsey MineSpans.

Exhibit 2

Robust household behavior change seems a key driver for demand reduction post summer, even after adjusting for milder winter.

European household natural gas demand expected vs actual,[1] bcm



[1] Buildings deep-dive. For the period of September 2022 to December 2022. Based on publicly available data as of mid-January 2023.
[2] Demand reduction attributed to behavioral change estimated as difference between expected gas usage corrected for the warmer weather minus the actual 2022 gas consumption.
Source: Gas supply in 2022, Bundesnetzagentur; Degree Days; Platts Supply and Demand Daily, Platts

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dropped to 30 percent of total production capacity in the third quarter, down from the pre-war baseline of 80 percent.[14]

The reduction in gas consumption did not result in a reduction in overall manufacturing output in Germany in 2022, and Germany (Europe's largest economy) managed to grow in terms of real GDP over the course of the year.[15] However, McKinsey Energy Insights European Gas Buyers Survey found that 57 percent of manufacturers will not be able to continue reducing gas consumption while still maintaining output over the next two years.[16] These findings indicate that the energy efficiency levers are increasingly exhausted and that further reduction of gas supply to Europe could substantially impact economic activity.

A milder winter in the fourth quarter of 2022 reduced demand for gas-fired power generation

Europe's total power generation saw a drop in 2022 from 2021, driven by a milder winter and reduction in demand (Exhibit 3). Annual gas demand for power generation remained relatively stable in 2022, as greater gas usage during the warmer summer was offset by lower gas usage during the milder winter.[17] In addition, Europe was not able to reduce gas-fired power generation due to the lower availability of nuclear power and hydropower in 2022.

Zooming in on the fourth quarter of 2022, gas demand in the power sector decreased by 7 percent from the fourth quarter of 2021, helping Europe to balance gas supply and demand during the winter months (Exhibit 4). The lower consumption in this

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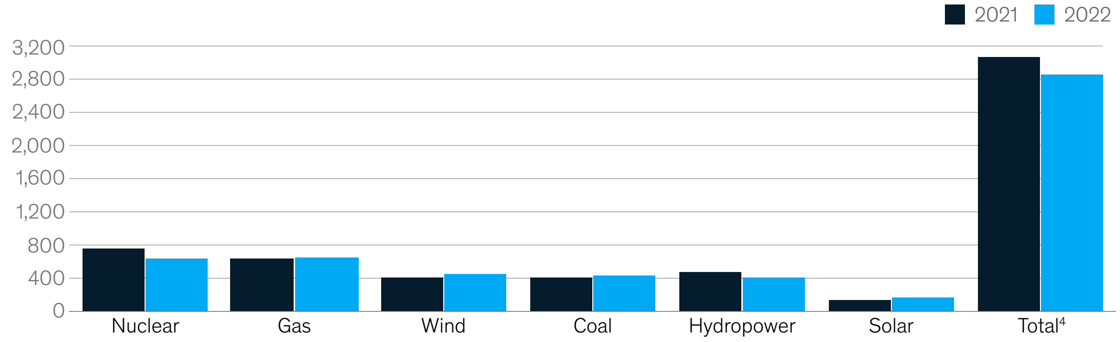
[14] Ibid.
[15] *Quarterly gas review:* short- and medium-term outlook for gas markets, The Oxford Institute for Energy Studies, December 2022; GDP and employment flash estimates for the fourth quarter of 2022, Eurostat, February 14, 2023.
[16] McKinsey Energy Insights European Gas Buyers Survey (conducted in December 2022 with 73 participants).
[17] Gas usage was greater than expected in the warmer-than-average summer and lower than expected in the milder-than-average winter.

Exhibit 3

Looking at the full year in 2022, Europe was not able to reduce gas-fired generation given low nuclear availability and hydropower.

Power generation in Europe 2021 vs 2022,[1] terawatt hours



Year-on-year change, %

–15	+2	+11	+6	–16	+22	–3[2]
Lower, due to large part of the French fleet under maintenance (~59%)	Higher, despite high gas price driven by lower nuclear and hydro generation	Higher, due to increased installed capacity and favorable weather vs 2021	Higher, due to increased utilization of existing coal power plants and LTEs[3]	Lower, primarily driven by a drought in Southern Europe	Higher, due to increased installed capacity and favorable weather vs 2021	Lower, driven by mild winter and demand reduction (mostly in Q4 2022)

[1] Preliminary statistics: Does not include all distributed generation. Europe includes the EU19, CH, NO, and the UK (Austria, Belgium, Bulgaria, the Czech republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom). Based on publicly available data as of mid-January 2023.

[2] Does not include all distributed generation. Overall decrease estimated at around –3.5%.

[3] Long-term energy scenarios.

[4] Also includes biomass, geothermal, waste, oil, and others. Does not include all distributed generation from small thermal power plants and distributed solar capacity, which is covered in the EU Power Model.

Source: Electricity Data Explorer, Ember; Energy Charts; Day Ahead Prices, ENTSO-E; Fraunhofer; Renewable Energy Statistics 2022, IRENA; National Grid; Smard; Zenodo

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quarter can be largely attributed to a milder winter, the accelerated expansion of renewable energy sources (RES), the recovery of hydropower following summer droughts in Southern Europe, and recently announced lifetime extensions of coal power generation capacity.

While Europe's energy markets balanced in 2022, several factors may still impact the supply-demand equilibrium in the coming years. To avoid price spikes, Europe may need to watch for key signposts that could upset the balance.

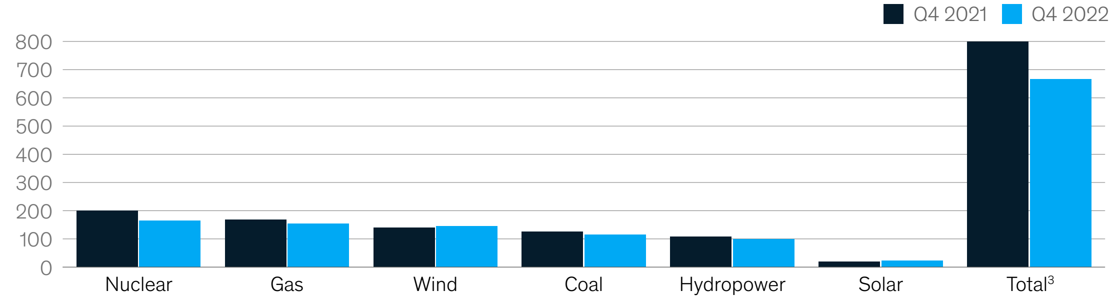
Year ahead: Key signposts to watch in 2023 and beyond

Throughout this decade, Europe may need to carefully walk the tightrope of balancing natural gas supply and demand to prevent rising prices and economic repercussions. Europe countered the reduced supply in 2022 by lowering natural gas consumption by 57 bcm, and with further demand reductions and new sources of natural gas supply, Europe may be able to maintain the balance over the next several years (Exhibit 5). However, multiple drivers could create a low-supply scenario and

Exhibit 4

In the fourth quarter of 2022, gas-fired power generation dropped by 7 percent, driven by power demand reductions and RES expansion.

Power generation in Europe Q4 2021 vs Q4 2022,[1] terawatt hours



Year-on-year change, %

–17	–7	+4	–7	–6	–17	–7
Lower, due to large part of the French fleet under maintenance (~50% in Q4 2022)	Lower, as pressure on gas generation alleviated by mild winter and RES expansion	Higher, due to increased installed capacity (236 GW in 2022 vs 213 GW in 2021) and favorable weather vs 2021[2]	Lower, as pressure on coal generation alleviated by mild winter and RES contribution	Lower, primarily driven by a drought in Southern Europe that left reservoirs empty	Higher, due to increased installed capacity (215 GW in 2022 vs 172 GW in 2021) and favorable weather vs 2021	Lower, driven by mild winter and demand reduction that decreased power demand

[1] Preliminary statistics: Does not include all distributed generation. Europe includes the EU19, CH, NO, and the UK (Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom). Based on publicly available data as of mid-January 2023.
[2] Gigawatts.
[3] Also includes biomass, geothermal, waste, oil, and others. Does not include all distributed generation from small thermal power plants and distributed solar capacity, which is covered in EU Power Model.
Source: Electricity Data Explorer, Ember; Energy Charts; Day Ahead Prices, ENTSO-E; Fraunhofer; Renewable Energy Statistics 2022, IRENA; National Grid; Smard; Zenodo

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Europe would need to reduce its consumption from 2022 levels by another 55 bcm in 2023 to stabilize the market.[18]

To stabilize gas prices, Europe may need to achieve further reductions in gas demand across buildings, industry, and power generation, with no further decline in Russian pipe flows and sustained high LNG imports amid higher competition from Asian gas demand recovery. Even after assuming a 55 bcm gas-demand reduction in 2023, the supply-demand balance for 2023 will ultimately depend on a series of drivers (Exhibit 6). Watching for signposts linked to these drivers may be critical to responding to the many complex factors that can interact to influence the equilibrium and gas prices, including the following:

— *Asian LNG demand development.* An Asian LNG demand rebound could create further competition for LNG cargoes, leading to higher prices and potentially reducing European gas supply by up to 35 bcm.

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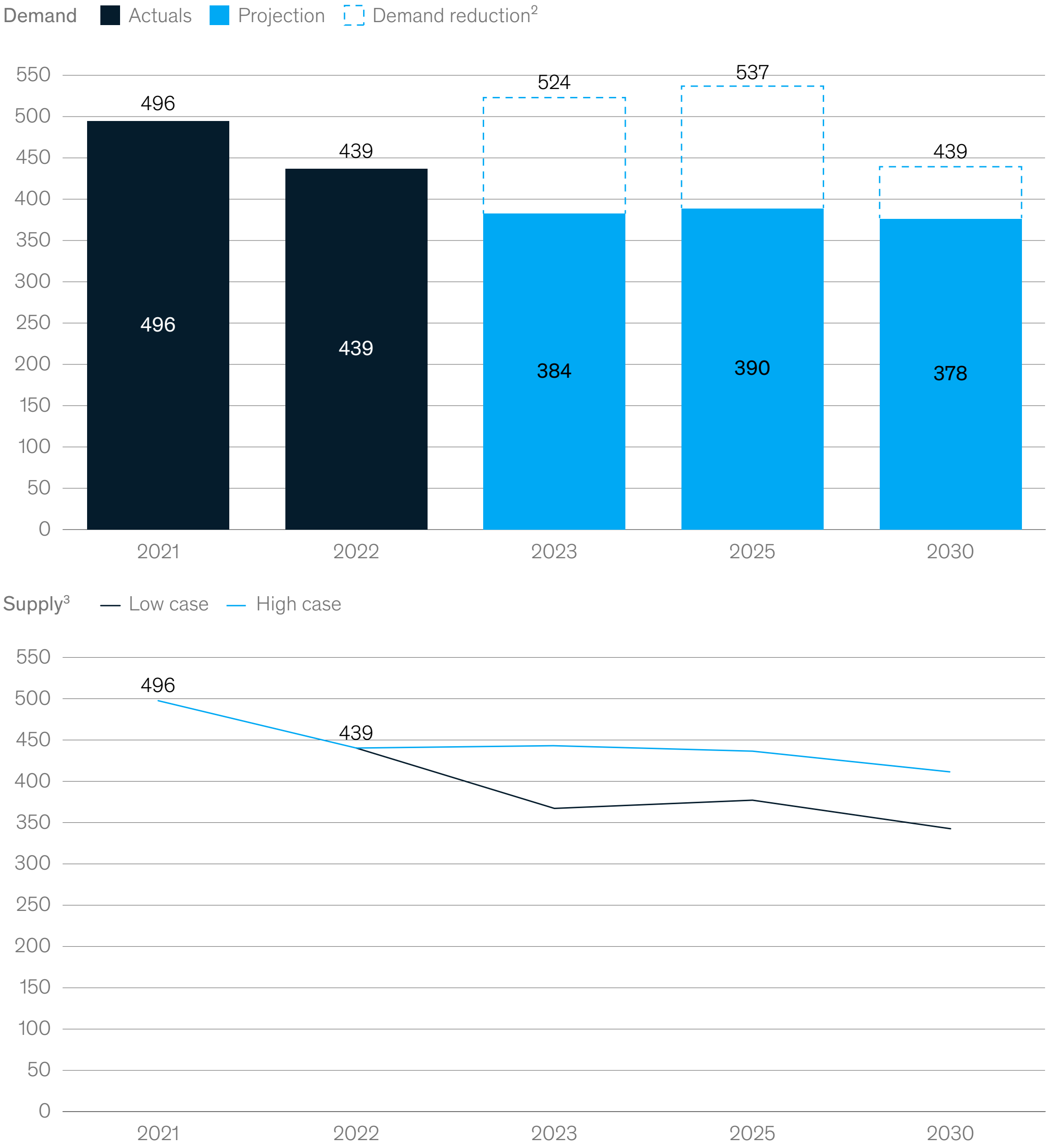
[18] European natural gas demand tracker, Bruegel, January 23, 2023; Daily power statistics, ENTSO-E, January 23, 2023; Supply, transformation, and consumption of gas monthly data, Eurostat, January 23, 2023; McKinsey Energy Insights *Global Energy Perspective 2022.*

Exhibit 5

In the near term, expected demand reductions and new sources of supply should be sufficient to balance the market.

European natural gas supply and demand,[1] bcm



[1] Post-conflict response scenario. Europe includes the EU27, Norway, Switzerland, and the United Kingdom. Based on publicly available data as of mid-January 2023. Numbers may not tally exactly due to rounding.
[2] Demand reduction represents the difference between the pre-conflict projection and post-conflict response scenario.
[3] The high and low supply cases differentiate between low and high LNG import scenarios for Europe. For 2023, supply scenarios for LNG range between 20 bcm and 95 bcm on top of the pre-conflict projection. Analysis assumes non-Russian flows as per 2022 levels and sustained Russian flows as in Q4 2022.
Source: McKinsey Energy Insights *Global Energy Perspective 2022*

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- *Russian piped gas flows to Europe.* If Russian piped gas stopped completely, Europe could see a sustained supply reduction of 25 bcm from the 2022 fourth-quarter average.
- *Winter weather.* Although Europe's gas supply-demand balance benefited greatly from the milder-than-average winter weather in the fourth quarter of 2022, a return to colder winter weather in 2023 may add another 15 bcm to gas demand.
- *Power-sector demand reduction.* Increasing German and French nuclear availability could offset 5 bcm of gas consumption. Meanwhile, further reducing power demand by 5 percent could reduce gas demand by an additional 14 bcm.
- *Sustained demand reduction in buildings and industry.* Assuming the behavioral change in building heating persists, Europe could continue to save approximately 19 bcm. Continued industrial shutdowns in 2023 could drive a further 20 bcm gas demand reduction.

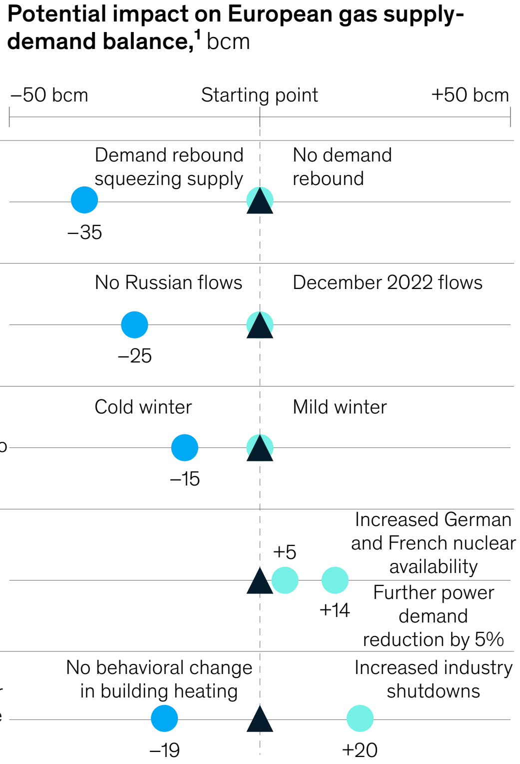
Beyond these signposts, an additional LNG regasification capacity of 70 bcm per annum is expected to come online over the next two years in Europe, which may further help Europe achieve

Exhibit 6

Five key drivers could impact the European supply-demand balance in 2023.

▲ 2022 level ● 2023 impact (decrease supply or increase demand) ● 2023 impact (increase supply or decrease demand)

		Key drivers	Baseline
Supply	1	Asian LNG demand development	2022 LNG import level maintained through 2023, assuming weaker Asian demand (less 35 bcm from 2021)
	2	Russian piped gas flows to Europe	Q4 2022 level of Russian piped flows continue throughout 2023
Demand	3	Winter weather	Mild winter in 2023 (similar to weather observed from October to December 2022)
	4	Power sector demand reduction	Projected gas demand in 2023 according to January 2023 assessment
	5	Sustained demand reduction in buildings and industry	15% industry shutdown (Q3–Q4 2022) and 20% gas reduction for heating due to behavioral change (September to October 2022) continues throughout 2023



[1] Europe includes the EU27, Norway, Switzerland, and the United Kingdom. Individual sensitivities and impact considered separately (not cumulatively). Based on publicly available data as of mid-January 2023 for volumes from January 1, 2023 to December 31, 2023.

Source: European natural gas demand tracker, Bruegel; Degree Days; Electricity Data Explorer, Ember; Day Ahead Prices, ENTSO-E; Supply, transformation, and consumption of gas monthly data, Eurostat; Global natural gas demand per sector, 2007-2025, IEA; Renewable Energy Statistics 2022, IRENA; McKinsey Energy Insights EU PipeFlow and LNGFlow models

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a supply-demand balance without price spikes.[19] At the same time, these signposts will likely affect Europe's ability to meet the gas storage target of 90 percent by November.[20] While we are coming out of winter with high levels of gas storage, there is still a significant gap to fill over the coming six months.[21]

Power-sector demand reduction could be a key driver of Europe's gas demand reduction in the near term, but the sector is also highly dependent on gas-fired power.[22] As gas power generation determines the marginal price on the power generation merit order curve, nearly tripling the gas price from €70 to €200 per megawatt-hour would likely only decrease gas demand from the European power sector by 8 percent but increase power prices by 70 percent (Exhibit 7).

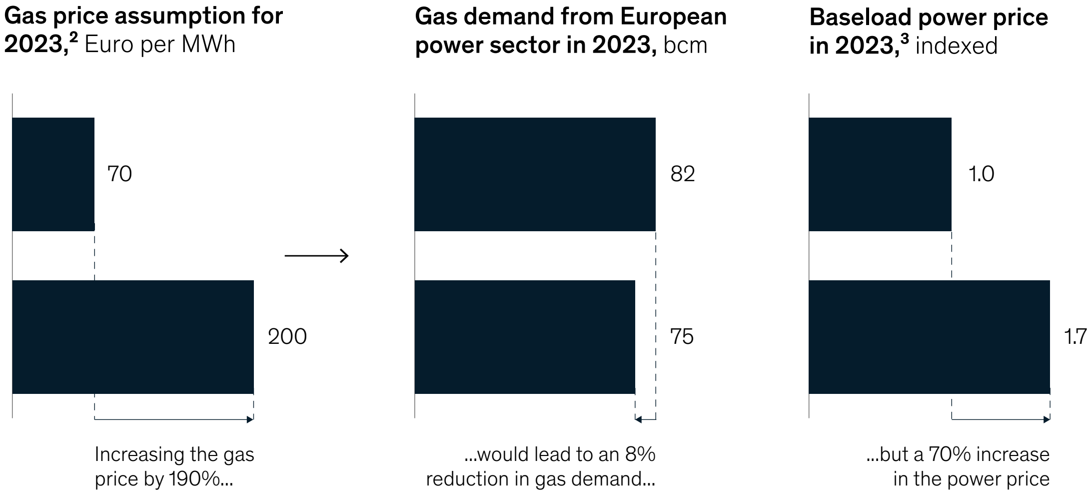
Consequently, any near-term contribution from the power sector to reduce gas demand would unlikely be driven by high gas prices and instead result from an overall reduction in power demand.[23]

In the future, Europe would likely need to continue to reduce its natural gas demand through specific drivers and policy initiatives to reduce energy dependence—including Fit for 55, RePowerEU, and

Exhibit 7

In 2023, even three-times higher gas prices of €200 per MWh would only reduce gas-fired generation by 8 percent.

Sensitivity of gas fired generation to gas prices in 2023[1]



[1] B2 macroeconomic scenario based on publicly available data as of mid-January 2023.
[2] €70 per MWh futures price for 2023 as of January 5, 2023. €200 per MWh comparable to futures prices for 2023 from September 2022.
[3] Load-weighted average across the EU19, Norway, Switzerland, and the United Kingdom, indexed to the base-case gas price of $70/MWh where the power model result is 1.0.
Source: McKinsey Power Solutions EU Power Model

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[19] McKinsey Energy Solutions Gas Intelligence Model.

[20] *Security of supply and affordable energy prices: Options for immediate measures and preparing for next winter*, European Commission, March 23, 2022.

[21] McKinsey EU PipeFlow model.

[22] Gas power plants are needed to fulfill demand as all other lower cost dispatchable capacity run at their highest available capacity. Some gas-fired combined heat and power needs to run at a minimum capacity to fulfill heat or steam demand to local district heating systems or nearby industry.

[23] McKinsey analysis based on quarterly power generation data; Electricity data explorer, Ember, January 15, 2023; Daily power statistics, ENTSO-E, January 23, 2023; Renewable Energy Statistics 2022, IRENA, January 15, 2023.

national policy initiatives—which could result in an accelerated energy transition.

Beyond the crisis: A further accelerated energy transition scenario?

Europe's current energy crisis may in fact accelerate the energy transition, as demand reductions may become increasingly necessary to balance energy markets. Higher energy prices projected over the next five to ten years may change the economics of the energy transition, creating momentum for businesses, governments, and consumers to accelerate the behavioral and infrastructural changes that will likely be key to meeting climate commitments.

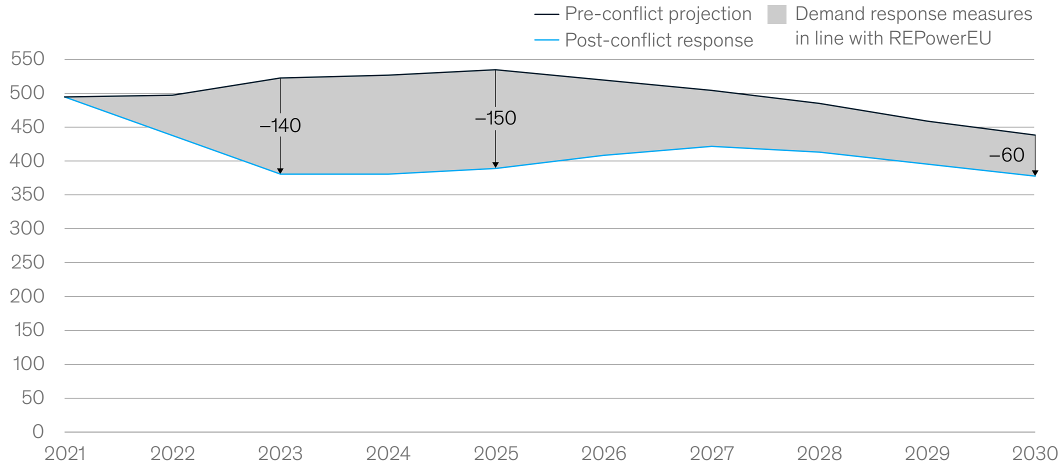
Specific action to reduce gas demand could accelerate Europe's energy transition. In buildings, heat-pump uptake in line with RePowerEU and reduced thermostat temperatures (assuming behavioral changes observed last quarter were to continue) could drive gas demand reduction. Industrial-electrification measures, like fuel switching, as well as energy-efficiency levers, could be applied across subsectors, while the accelerated build-out of RES, as well as longer lifetime extensions of nuclear and coal, could reduce gas demand.

In the longer term, the power sector will likely require levers to shift the supply stack away from a gas baseload. Balancing the transition away from gas may require delaying the phaseout of coal, extending the lifetime of nuclear plants, as well as accelerating the expansion of RES. The second half of 2022 saw an impressive acceleration in the build-out of RES and the momentum may need to continue (with a CAGR of 14 percent) to achieve the 2030 power supply mix needed to reduce European reliance on gas-fired power generation (Exhibit 8). The build-out of wind and solar plants could drive RES expansion, yet constraints such as sustained supply chain disruptions, slow permitting processes, and a lack of skilled workers for renewable installation could slow the pace of RES development in Europe.[24]

Exhibit 8

Significant near-term demand reduction could allow the market to balance, followed by a gradual stabilization from 2025.

Projected gas demand in Europe,[1] bcm



[1]Europe includes the EU27, Norway, Switzerland, and the United Kingdom. Based on publicly available data as of mid-January 2023.
Source: European natural gas demand tracker, Bruegel; Day Ahead Prices, ENTSO-E; Supply, transformation, and consumption of gas monthly data, Eurostat; McKinsey Energy Insights *Global Energy Perspective 2022*

McKinsey & Company

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[24] *Renewables 2022 analysis and forecast to 2027*, International Energy Agency, January 2023; McKinsey Power Model.

Assuming Europe can sustain and accelerate a few key gas-demand reduction measures, the market is likely to remain balanced without significant price spikes in the coming years. Early signs from 2022 suggest that Europe is on track to meet the European Commission's gas-savings measures, including a coordinated 15 percent voluntary gas demand reduction between August 1, 2022 and March 31, 2023, from the five-year average.[25]

Looking forward, if Europe meets RePowerEU targets and governments continue incentivizing energy efficiency in buildings and industry, gas demand could be reduced from the pre-war projection by 27 percent in the next year, and by 28 and 14 percent by 2025 and 2030, respectively (Exhibit 9). This would lead to a drop in European gas consumption from 495 bcm in 2021 to 378 bcm in 2030—a 24 percent reduction.

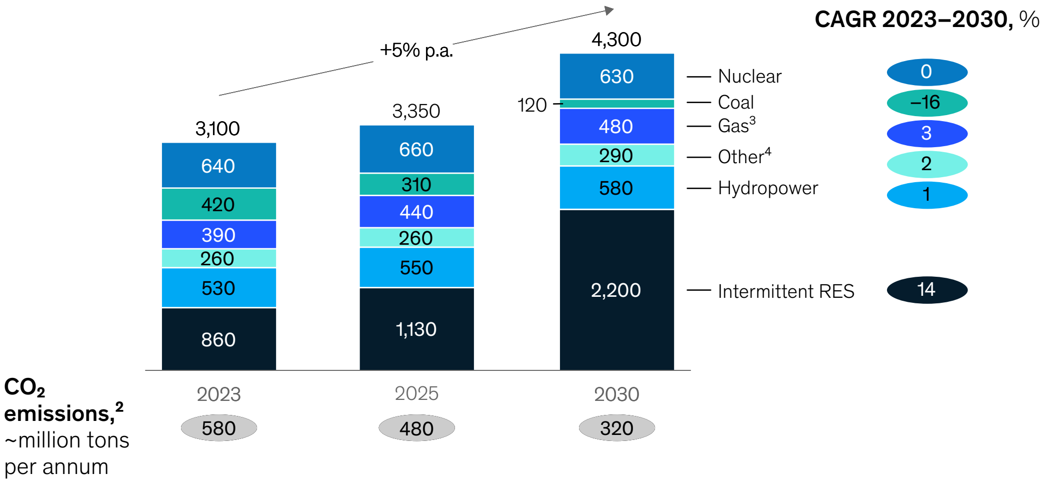
The global LNG market is expected to rebalance from 2026 onwards due to the ramp-up of new LNG projects (for instance, in Qatar and Canada). In the second half of this decade, European and Asian LNG prices will likely be determined by the full cycle cost of marginal LNG at around $9 to $10 per MMBtu.[26]

However, although energy markets are expected to balance if Europe can tick all the right boxes, the many variables at play produce uncertainty. Volatile prices and supply disruptions still pose a risk to many sectors of the economy, and European businesses may need to prepare to navigate these risks.

Exhibit 9

European power-generation outlook for 2023 to 2030 expects a strong growth in renewables, stabilization of gas-fired generation, and decline in coal-fired generation.

Projected power generation in Europe,[1] ~TWh



[1] B2 macroeconomic scenario based on publicly available data as of mid-January 2023. Europe includes the EU19, CH, NO, and the UK (Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom).
[2] CO_2 emissions are expected to be 13 percent lower than pre-conflict estimates in 2023 and remain below the pre-conflict outlook through 2030.
[3] Gas-fired generation recovers as gas price decreases, offsetting declining coal generation.
[4] Includes oil, geothermal, biomass, batteries, and other minor sources of electricity.
Source: McKinsey Power Solutions EU Power Model

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[25] *Gas Market Report*, *Q4–2022,* International Energy Agency, October 2022.
[26] McKinsey LNGFlow model; McKinsey analysis.

Three ways that businesses can navigate risk in the energy market

The war in Ukraine has shifted the geopolitical landscape and created a shock in the global energy market, which will likely shape the future of European industry for years to come. Three approaches can help businesses navigate volatility and disruption:

1. *Energy procurement and energy management.* Diversification of energy sourcing combined with demand-side management measures could allow businesses to stay competitive in an increasingly expensive energy market. As gas and power prices may remain volatile with price spikes, these levers may become ever more important to managing costs.

2. *Risk management and security of supply.* As there are still considerable price-volatility and supply risks, investment in natural gas substitutes, such as biomethane, or alternatively in storage, can hedge against potential energy supply chain disruptions. In a higher gas-price world, the business case for longer-term fuel switching or electrification measures that require significant capital expenditures may be even stronger.

3. *Signpost monitoring.* Active monitoring of key signposts in the energy market may allow businesses to plan and respond to changing supply and demand dynamics. Scenario planning may provide further flexibility to pivot between different levels of demand response.

European energy markets have experienced a seismic shift following the invasion of Ukraine that could lead to changes in the long-term supply and demand trajectory. To manage the supply shock in the near term and balance long-term European energy markets, Europe may need to further reduce its gas demand and accelerate its energy transition—while trying to navigate risks. The demand reductions undertaken so far have allowed the European energy markets to rebalance, but the additional demand reduction required to sustain this equilibrium in the near term may require difficult tradeoffs for the business community. Businesses may need to implement near-term measures now, but also start considering the longer-term measures that require upfront capital expenditures.

The following questions will remain relevant in the years to come: Will the shifts in global trade flows persist? Will the European LNG supply sit at the marginal end of the gas cost curve? Will Europe see substantive, sustained reductions in gas demand at the national, firm, and consumer levels? The answers will likely be crucial to Europe's energy future.

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The authors wish to thank Jacopo Degl'innocenti, Francisco Pais de Sousa, and Jan-Paul Wiringa for their contributions to this article.

Land: A crucial resource for the energy transition

To achieve its decarbonization targets, the European Union will need to expand renewable-energy capacity. Identifying and allocating sufficient land will be foundational to the effort.

This article is a collaborative effort by Stathia Bampinioti, Nadia Christakou, Bastian Paulitz, Lukas Pöhler, Antoine Stevens, Raffael Winter, and Ekaterina Zatsepina, representing views from McKinsey's Electric Power & Natural Gas Practice.

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As part of the European Green Deal, the European Union set a binding target of achieving climate neutrality by 2050.[1] More specifically, the Fit for 55 package sets an interim goal of reducing greenhouse-gas (GHG) emissions by at least 55 percent by 2030.[2] Furthermore, the European Commission announced its REPowerEU plan, which includes measures "to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition."[3]

Expanding capacity generated by renewable-energy sources (RES) is essential for the European Union to achieve its energy transition objectives. Although specific requirements vary by country, a rapid acceleration in the annual installation rate of new wind and solar photovoltaic (PV) assets is required. REPowerEU has set a target of 1,236 gigawatts (GW) of renewable capacity by 2030, requiring more than 700 GW of additional RES capacity to be added from 2023 to 2030, a threefold increase in annual installations compared with the RES capacity added from 2014 to 2022 (approximately 230 GW).[4] With REPowerEU targets of 600 GW of installed solar PV capacity and 500 GW of wind capacity by 2030, more than 90 percent of the targeted additional capacity will need to be supplied by wind and solar—both of which require large tracts of habitable land.

In a recent article, we explained how finding adequate land for RES projects is becoming increasingly challenging.[5] Beyond the technical suitability of the land, which is a hard limiting factor, a significant amount of land in Europe is unavailable for development because of strict regulations. And the land that remains available is often well suited for—and therefore must compete with—other societal or environmental objectives, such as agriculture and biodiversity conservation. The latter will likely become an increasingly significant limiting factor for land availability, considering the Kunming-Montreal Global Biodiversity Framework, which was adopted at COP15 in 2022.[6] One of the framework's goals is effective conservation and management of at least 30 percent of the world's land by 2030[7] (versus the current amounts of 8 and 17 percent of the world's protected marine and terrestrial areas, respectively[8]).

Using Germany (the largest economy in Europe) as a case study, we assessed the key trade-offs and major obstacles of land availability for RES development, particularly as it relates to protecting biodiversity and the need for other land allocations. Next, we applied geospatial analytics to identify cost-optimal land for RES projects. Finally, we determined actions that stakeholders in the public and private sectors can take to ensure that procuring land enables an orderly energy transition.

The challenges of identifying attractive locations for renewable energy

The amount of land required to meet the wind and solar PV capacity targets in Europe is significant. For instance, in France, Germany, and Italy, where roughly 50 percent of the EU RES installations are expected, meeting 2040 RES capacity targets would require an additional 23,000 to 35,000 square kilometers of land—an area equivalent to the size of Belgium.[9] Land will also need to serve as a source of biogenic CO_2 (easily replenished sources of carbon, such as wood and other biofuels) for bioenergy with carbon capture and storage and the production of e-fuels.

In addition, technical, regulatory, and environmental constraints often reduce the amount of land available for RES development. Technical limits

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[1] "European Green Deal: Fit for 55," European Council, March 29, 2023.
[2] Ibid.
[3] "REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition," European Commission, May 18, 2022.
[4] According to our analysis, more than 700 GW gross additions are required, including repowering older RES plants.
[5] "Renewable-energy development in a net-zero world: Land, permits, and grids," McKinsey, October 31, 2022.
[6] For more information, see *COP15: Final text of Kunming-Montreal Global Biodiversity Framework*, UN Convention on Biological Diversity, December 27, 2022.
[7] Ibid.
[8] ProtectedPlanet (website), accessed April 3, 2023.
[9] Assuming five to eight megawatts (MW) per square kilometer (km) for onshore wind and 43 to 60 MW per square km for solar PV.

include existing RES installations and areas with limited natural wind or sun intensity. And regulatory and environmental limitations, which acknowledge local communities’ concerns about land use, can reduce the land available for RES development. These limitations are valid and should be addressed when assessing trade-offs and obstacles as they relate to land availability. With these points in mind, our estimates show that about 9 percent of available land in Germany is suitable for wind and less than 1 percent of land in Italy is suitable without limitations for solar PV (Exhibit 1).

Limiting certain activities in protected areas[10] is key to promoting biodiversity.[11] Further, RES developers should take into account proximity to population settlements and other infrastructure, such as clinics, highways, and industrial areas, to avoid negative impacts on societal well-being. The overlap between such limiting factors can be thoroughly investigated to ensure that the energy transition’s targets are achieved through appropriate land use.

The biggest factor affecting land availability in Europe is regulations—specifically, rules that set a minimum distance between wind turbines and

Exhibit 1

Regulatory constraints limit the availability of land for onshore wind in Germany and for solar photovoltaics in Italy.

● Potentially suitable ● Build-out restricted due to Italian cropland regulation
● Excluded due to regulatory constraints ● Excluded due to technical constraints and unsuitable land cover

	Germany	Italy
Technology	Onshore wind	Ground-mounted solar photovoltaics (PV)
Land availability constraints based on total land mass, %	**104 GW** additional wind capacity required to meet 2040 renewable-energy-sources (RES) targets  **50–80%** of potentially suitable land near substations is needed for 2040 onshore wind targets while spatial planning, land-use designation in Germany, and ownership further limit the availability of land[1]	**63 GW** additional solar PV capacity (excluding rooftop solar PV) required to meet 2040 RES targets  **60–85%** of potentially suitable land near substations is needed for 2040 ground-mounted solar PV targets while spatial planning, ownership, and financial aspects further limit the availability of land[1]

Note: For separation of land area, technical constraints and unsuitable land cover are existing wind and solar PV, urban areas, forests, water, airports, low-wind-potential zones (for wind only), slope, and military zones. Regulatory constraints are distance regulations for onshore wind from settlements and on protected land. We separately show areas with regulatory constraints in Italy to develop utility-scale solar PV on cropland. General assumption for onshore wind is a density of 5–8 MW/km^2, not considering additional capacity needed if repowering is not possible in former areas, radars, military flight zones, and further country-specific detailed regulations. General assumption for solar PV is a density of 43–60 MW/km^2, excluding overlapping wind areas and rooftop solar PV (3:1 split between ground-mounted and rooftop solar PV for Italy). Germany has official 2040 RES targets; Italy only has official 2030 RES targets that were linearly extrapolated to 2040 for this analysis.

[1] Sites are restricted to a distance of less than 5 km to substations.

Source: McKinsey land use optimization model Space Fit based on Copernicus Global Land Service, ESA CCI Land Cover, Global Solar Atlas, Global Wind Atlas, MERIT DEM, Open Street Map, and Protected Area and Key Biodiversity Area data of 2020 downloaded from the Integrated Biodiversity Assessment Tool

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[10] Includes nature reserves, wilderness areas, national parks, natural monuments or features, and habitat or species management areas.

[11] For more information, see Key Biodiversity Areas (website), accessed April 3, 2023.

settlements. Such rules are frequently established at the regional level, which means regulatory-compliant land for RES development can vary widely even within countries. This can also create interregional tension. In Germany, for example, rules about distance from settlements and infrastructure for onshore wind vary from state to state, and approximately 60 percent of the country's suitable land is eliminated from consideration based on these rules. In Lower Saxony, the required minimum distance is double the total height of the turbine. By contrast, in Bavaria the distance to settlement is ten times the total height of the turbine,[12] limiting wind deployment to just 160 square kilometers. In Italy, land for solar PV is restricted because of regulatory limitations on the use of cropland, which accounts for roughly one-third of total land area and 80 percent of total available land after technical constraints. Cropland exclusion also poses a significant challenge, as it means that achieving 63 GW of additional solar PV capacity in Italy by 2040 requires up to 85 percent of available land.[13]

In addition to these constraints, using land for RES development can create competition with using land for food and biomass production, which is necessary for societal well-being. This is especially true for ground-mounted solar PV, for which virtually all suitable land can be used for other purposes. Although there are solutions that can help ameliorate the situation—for example, agrivoltaics could be a solution for using cropland for RES installations without significantly limiting food production—a lack of industry standards and regulatory incentives has hampered progress. Meanwhile, wind has only a small impact on crop yields, yet it can significantly affect biodiversity, particularly as it relates to habitat degradation or loss of birds and bats.

Geospatial analytics can help optimize the potential of RES development

Geospatial analytics leverages geographic information from geolocated activities and remote sensing data such as satellites, combined with AI. This can help pinpoint optimal locations for RES projects while accounting for the needs of other land applications. Our analysis focuses on identifying suitable land and deploying spatial optimization for onshore wind projects in Germany.

Identifying suitable land areas for onshore wind development

The starting point for assessing land availability for wind projects is the total territory of a country. Areas are automatically considered off limits for onshore wind development if they are cities, closed forests or water bodies, military areas, or airports.[14] Technical constraints are overlaid on potentially available land; steep slopes areas with low technical capacity factors and other influence zones around existing installations are excluded. The resulting locations typically follow the topographic characteristics of a country. In Europe, mountainous regions such as the Alps and Pyrenees and regions with low potential for solar and wind account for the bulk of land excluded for technical reasons.

Next, prominent regulations for RES development are considered through settlement boundaries and environmental restrictions on strictly prohibited land types,[15] such as nature reserves, wilderness areas, national parks, and monuments. The restriction on settlement boundaries leads to the exclusion of land based on minimum distance to settlements for wind energy. Finally, environmental restrictions are also assessed, excluding loosely protected land and key biodiversity areas.

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[12] This refers to the so-called 10H rule. In November 2022, Bavaria passed a law that introduced some exceptions to the 10H rule, but the rule is still in place. Even with exceptions, the rule limits land availability for wind power build-out in Bavaria in the short and medium term. In the longer term (toward 2027), German national law obliges Bavaria to designate at least 1.1 percent of its land area for onshore wind.

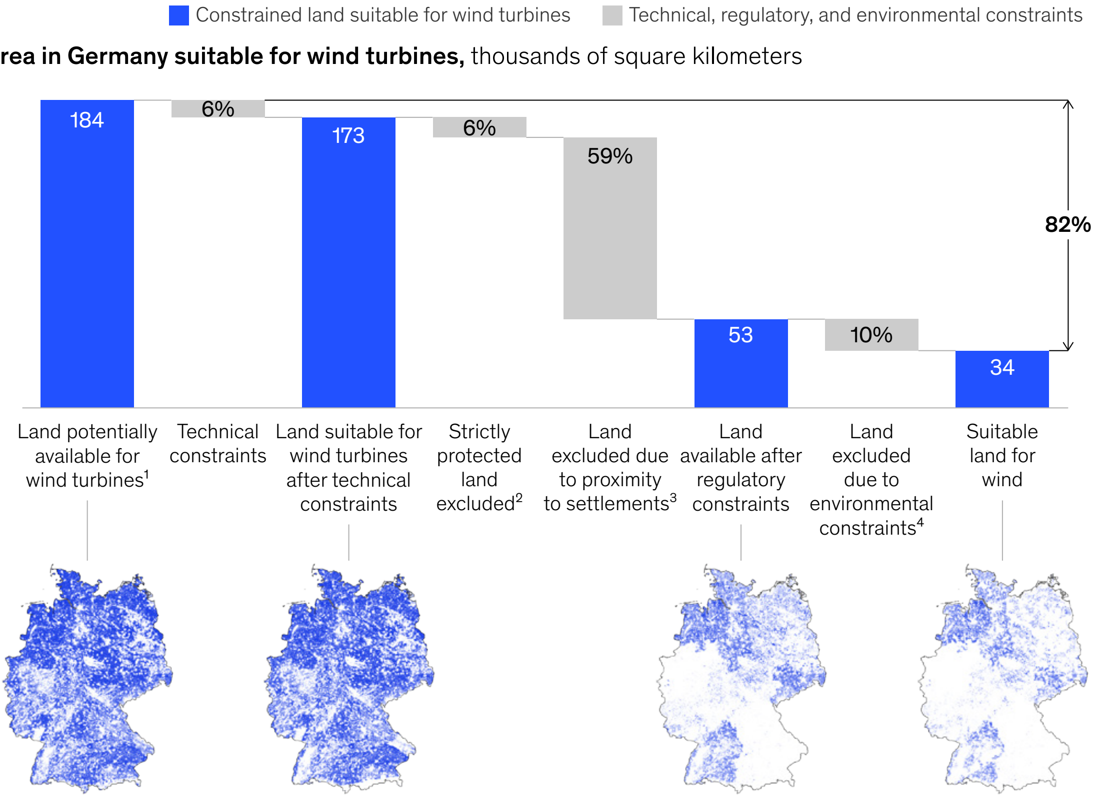
[13] Italy has no official 2040 RES target. For our analysis, we extrapolated official 2030 RES targets to 2040.

[14] Includes a buffer zone of three kilometers.

[15] *Guidelines for applying protected area management categories*, International Union for Conservation of Nature, Best Practice Protected Area Guidelines Series Number 21, 2013.

Exhibit 2

Technical, regulatory, and environmental constraints reduce available land for wind turbines by 82 percent.



[1] Potentially available land after removing cities, closed forests or water bodies, military areas, or airports.
[2] Includes a 200m buffer around protected land in protection categories I–IV (strict nature reserve, wilderness area, national park, natural monument or feature).
[3] Minimum proximity to settlements based on regulation at regional level.
[4] Includes protected land in categories V and VI (protected landscape/seascape, protected area with sustainable use of natural resources) or other.
Source: McKinsey land use optimization model Space Fit based on Copernicus Global Land Service, ESA CCI Land Cover, Global Solar Atlas, Global Wind Atlas, MERIT DEM, Open Street Map, and Protected Area and Key Biodiversity Area data of 2020 downloaded from the Integrated Biodiversity Assessment Tool (IBAT) and provided by BirdLife International

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According to the results of the analysis, technical, regulatory, and environmental constraints reduce available land for wind in Germany by 82 percent (Exhibit 2). The largest reduction (almost 60 percent[16]) is driven by regulatory rules about proximity to settlements, not environmental restrictions.

Deploying spatial optimization to identify locations for RES

Land that is potentially suitable for RES varies in both energy potential and cost to produce energy. Applying a spatial optimization model can determine systemwide locations for renewable development that reach the total energy-generation target while minimizing the average cost of energy.

Integer linear programming can help identify cost-optimal solutions for renewable deployment by showing an image of nonrestricted land areas overlaid with a grid. The optimization engine chooses a certain wind turbine technology or excludes it to form a spatial solution. With millions of potential area solutions possible within defined constraints, the optimization allows the integer

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[16] This number differs based on the order in which the filters are applied.

linear programming algorithm to select the best one to meet objectives such as the lowest total cost accounting for land, construction, grid connection, and maintenance. Additional constraints such as limiting the maximum installation density in a region to promote social acceptance and biodiversity[17] can also be considered.

In the case of Germany, not all suitable land is required to reach the 2040 RES target of 560 GW.[18] Our analysis shows that through a countrywide spatial optimization approach that selects the best wind locations and turbine technology mix, Germany could meet its wind targets by using 3 percent of the total land area, at an energy cost that could be more than 22 percent lower than that of a random selection of sites across suitable land.

However, this optimal scenario assumes a higher density of wind turbines than what has been achieved to date. Maximum installation density in Germany will need to increase by at least 20 percent over current values to meet the 2040 targets. And with limits on increased wind turbine density, the cost of energy would increase by approximately 16 percent compared with an optimal unconstrained scenario (Exhibit 3).

In the case of Germany, areas with high biodiversity and loosely protected land do not overlap significantly with favorable wind locations.[19] Protecting these areas therefore does not critically change the costs or the land requirements. In addition, regions with high wind capacity are less favorable for solar PV, meaning that competition

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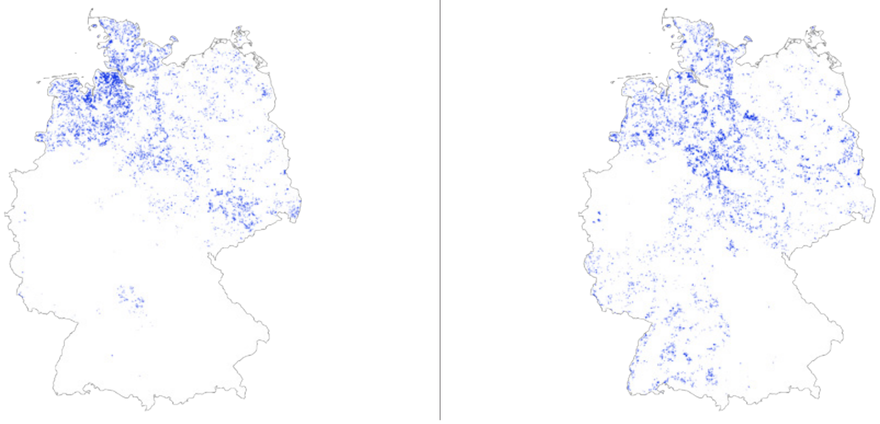
[17] A biodiversity intactness index can provide an estimated percentage of the preindustrial (before 1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area.
[18] Onshore wind and solar PV only.
[19] Our scenarios show that a significant amount of the suitable land for renewables overlaps with cropland with an inherently lower biodiversity intactness.

Exhibit 3

Scenarios illustrating different acceptable installation densities show variabilities in available land for onshore wind installations in Germany.

Scenario 1:
No constraints on installation density

Scenario 2:
Installation density limited to an increase of 20%



Source: McKinsey land use optimization model Space Fit based on Copernicus Global Land Service, ESA CCI Land Cover, Global Solar Atlas, Global Wind Atlas, MERIT DEM, Open Street Map, and Protected Area and Key Biodiversity Area data of 2020 downloaded from the Integrated Biodiversity Assessment Tool (IBAT) and provided by BirdLife International

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between types of renewable energy is not expected to escalate. However, favorable locations for wind energy in Germany show higher land opportunity costs from alternative land use and in general higher numbers of bird species, which further complicates securing the land (Exhibit 4).

Implications for stakeholders

Land-use stakeholders across the value chain can take the following actions to help mitigate the risk of bottlenecks when identifying and securing land for RES development:

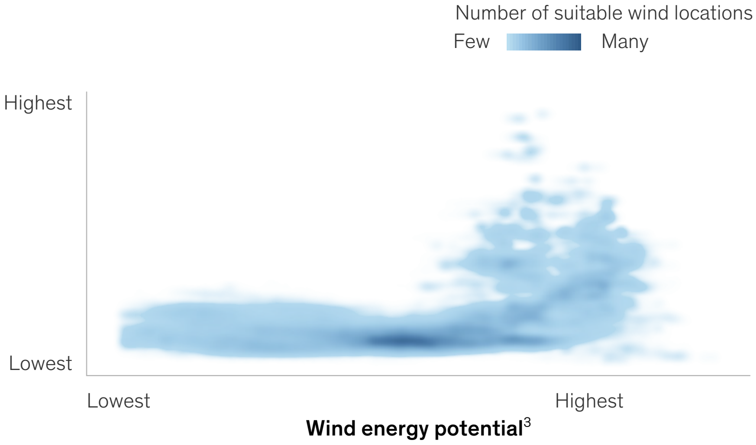
Updating spatial planning and land allocation. Assess the best sites for RES at the country level by considering parameters such as natural advantages (wind speeds and solar radiation, for example); competing land use (such as food production or biodiversity area); infrastructure proximity (such as road access to the sites); and availability (such as grid capacity) and regulations, including potential

Exhibit 4

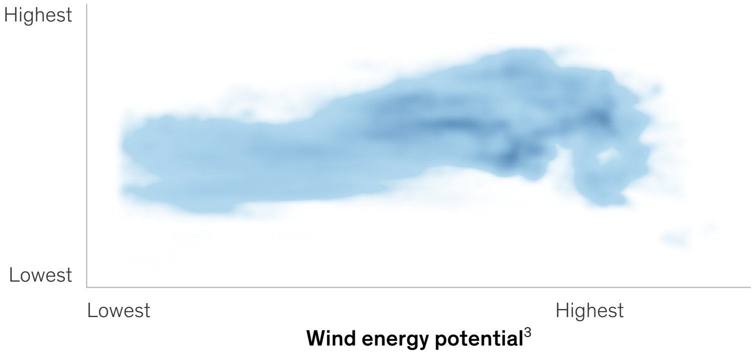
Favorable locations for wind energy in Germany show higher land opportunity cost and higher bird richness.

Land competition analysis

Land opportunity cost[1] is high for land with high wind capacity



Bird richness[2] is high for regions with high wind capacity



[1] Agricultural rent based on economic return (crop yield and livestock) determined from Food and Agriculture Organization and MapSPAM data.
[2] Number of locally present bird species, based on species coverage in IUCN Red List from IBAT (2021).
[3] We use the capacity factor of a class 2 wind turbine from Global Wind Atlas as a measure for wind energy potential.

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assignment of renewable "go-to areas" with low environment conflict risk. These points can help safeguard sufficient land for RES development by allocating suitable areas for deployment based on up-to-date spatial plans. In addition, leveraging geospatial modeling can help increase the effectiveness of the development teams, allowing them to conduct targeted development activities, especially when the data sets are enriched by land ownership data, if available.

Revisiting regulatory rules. Review regulatory constraints that limit land allocation for RES development. For example, rules on RES development in proximity to settlements can be harmonized across different regions, promoting practices favorable for RES development when other alternatives are limited.

Maximizing repowering. Maximize potential development at existing installations by replacing older power stations with newer, energy-efficient ones. This can help increase overall installed capacity without requiring additional land.

Encouraging social acceptance. Consider financial incentives for local communities and landowners to facilitate land deployment for RES purposes. For example, structure and promote long-term land lease agreements, dedicate portions of the profits from electricity generation to citizens who live near wind parks, and work to prevent higher grid charges in RES-intensive areas so that local communities are not penalized for being friendly to RES.

Fostering hybrid land use. Develop mechanisms and relevant business models for land co-sharing while bringing together landowners, RES developers, utilities, and regulators. Large swaths of the land needed to achieve RES capacity targets can also be used concurrently for other purposes. For example, only about 2 to 3 percent of the official land area of a typical wind park cannot be used for other purposes.

Innovating to preserve biodiversity together with RES development. Investigate opportunities to promote and safeguard biodiversity during renewables development and operations in partnerships between environmental groups—such as nongovernmental organizations and governmental agencies—and developers. This could include safeguarded migration routes for animals or new biotopes.

Fostering solar PV deployment on sealed surfaces. Provide incentives for the maximum use of previously sealed surfaces for PV deployment, including those covered with concrete or stone for buildings, roads, parking lots, and other infrastructure. Doing so can help leave natural soil surfaces undisturbed, contributing not only to energy targets but also to food security targets.

Increasing the European Union's RES capacity at the rate needed to achieve its stated objectives will require substantial amounts of land throughout the region, which could be limited in some countries. Therefore, it is important for local communities, businesses, and regulators across Europe to act hand in hand and quickly to ensure that land for renewable-energy development does not become a bottleneck. At the same time, land-efficient and biodiversity-enhancing RES deployment strategies can help ensure sustainability and promote a comprehensive approach to renewable-energy-systems deployment.

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Renewable-energy development in a net-zero world: Disrupted supply chains

Global supply chains have been under enormous pressure from the COVID-19 pandemic and the Ukraine crisis. In the wind and solar sectors, these pressures are compounded by industry-specific challenges.

This article is a collaborative effort by Alberto Bettoli, Florian Heineke, Nadine Janecke, Thomas Nyheim, Andreas Schlosser, Sophia Spitzer, Christian Staudt, Raffael Winter, and Jakub Zivansky, representing views from McKinsey's Electric Power & Natural Gas Practice.

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As countries around the world work to meet aggressive decarbonization goals, energy from wind and solar sources are a beacon of hope. Carbon-free, inherently abundant, and increasingly affordable, these renewable sources remain a vital pathway to achieving global net-zero carbon emissions by 2050.

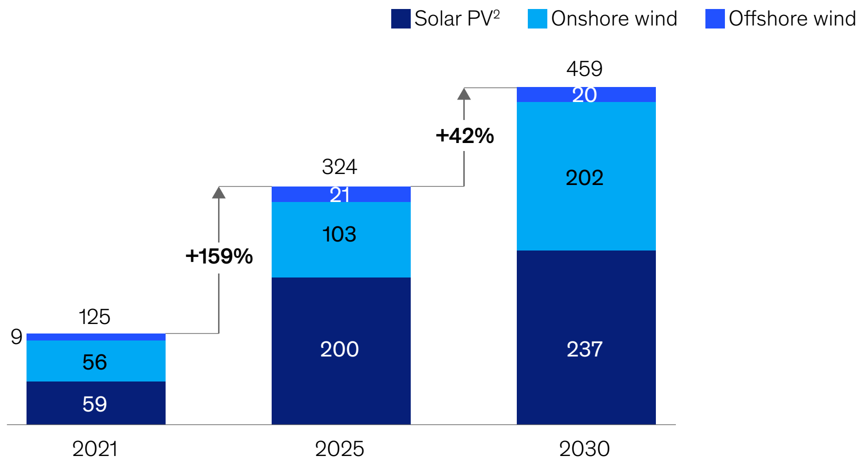
McKinsey estimates that between 2021 and 2030, planned global electricity generation from committed solar and on- and offshore wind projects (excluding China) will more than triple, from 125 gigawatts to 459 gigawatts (Exhibit 1).[1] This could further accelerate as countries seek to make renewables part of their strategy to address the current geopolitical energy crisis. The European Commission's recent REPowerEU proposal, for instance, seeks to boost the continent's share of electricity generation from renewables to 45 percent by 2030 (up from a target of 40 percent).[2] In the United States, the Inflation Reduction Act, which provides a comprehensive package of financial incentives for renewable-energy development, could also stimulate additional wind and solar capacity.[3]

Such rapid growth requires stable markets and resilient supply chains. In recent years, renewables markets have experienced high volatility because of fluctuations in the supply and prices of raw materials, as well as frequent changes in regulations (Exhibit 2). This lack of continuity has made long-term capacity planning and the practice of securing favorable prices for large quantities of raw materials very difficult.

Exhibit 1

Estimated annual final investment decisions for projects demonstrate dramatic activity in renewables markets globally.

Wind and solar capacity addition, by year of FID,[1] GW



Note: Figures may not sum, because of rounding.
[1]Final investment decision. Assuming construction times of 12 months for solar PV, 18 months for onshore wind, and 24 months for offshore wind. Share of utility-scale solar projects based on Wood Mackenzie data.
[2]Photovoltaics.
Source: McKinsey *Global Energy Perspective 2022* Achieved Commitments Scenario; Wood Mackenzie

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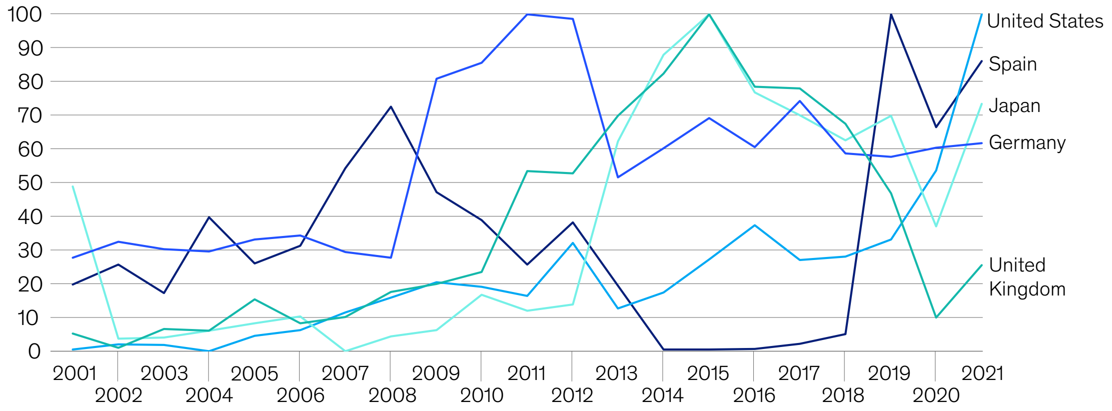
[1] *Global Energy Perspective 2022*, McKinsey, April 2022, Achieved Commitments scenario.
[2] For more information regarding REPowerEU, see "REPowerEU: Affordable, secure and sustainable energy for Europe," European Commission, accessed November 16, 2022.
[3] For detailed information about the Inflation Reduction Act, see "By the numbers: The Inflation Reduction Act," White House, August 15, 2022; "H.R.5376 - Inflation Reduction Act of 2022," US Congress, accessed November 16, 2022.

Exhibit 2

The markets for renewables are highly volatile.

Normalized annual net additions, 2001–21,[1] %



[1] Markets with annual capacity addition of >1 gigawatt or existing market presence.
Source: IRENA Statistics Time Series

McKinsey & Company

In Japan, for instance, the offshore wind market is currently on pause as the Japanese government revises its rules for auctions of offshore wind permits. Additionally, Danish wind turbine manufacturer Vestas canceled plans to build a turbine production facility in Nagasaki after it failed to receive orders from the winners of a previous offshore wind auction.[4]

Prices for the materials needed to create wind turbines and solar panels have also experienced significant volatility. The COVID-19 pandemic revealed the extent to which global supply chains are vulnerable to local and regional disturbances. Consider the supply of polysilicon, the starting material for wafers in solar cells. In China, which produces more than 79 percent of the world's supply (as of 2020), COVID-19 lockdowns, factory accidents, and floods have sharply reduced availability. Between 2020 and June 2022, the price of polysilicon rose by 350 percent.[5]

Cost inflation has also affected commodities needed for wind turbines. Due to the combination of rising global demand for wind energy and pandemic-related supply issues, the prices of steel, copper, and aluminum have experienced two- and threefold increases over the past few years. Earlier this year, disruptions due to the Ukraine crisis exacerbated the problem. Because price hedging in raw-materials purchasing is not a widespread practice, the wind industry has felt the squeeze. Turbines are 40–50 percent steel (used for towers, structure, and mechanical components), copper (generator winding and cables), and aluminum (nacelle). Leading turbine manufacturers and cable suppliers have tried to pass the increased costs of these materials on to their customers.[6] However, several have issued profitability warnings, in part because some of their long-term contracts with customers contain fixed prices that do not allow adjustments.

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[4] Craig Richard, "Vestas ices Japanese offshore wind turbine factory plan," *Windpower Monthly*, July 20, 2022; Andrew Lee, "Vestas shelves Japan offshore wind turbine factory plan over lack of orders," Recharge, July 20, 2022.

[5] Based on analysis using June 2022 PVInfoLink data.

[6] "Vestas warns Ukraine war adds to strain on wind industry, shares plummet," Reuters, May 2, 2022; Isla Binnie and Christoph Steitz, "Siemens Gamesa to fix onshore wind turbine unit in 2022," Reuters, September 27, 2022.

For a deep dive into supply chain resilience in the context of the European energy transition, we recommend "Building resilient supply chains for the European energy transition," McKinsey, October 17, 2022.

Renewables developers face three core supply chain challenges

In today's volatile conditions, renewables developers and OEMs will have to tackle several challenges in order to mitigate risk and build a more resilient supply chain.

Securing access to raw materials and rare earth metals at stable prices

The commodity squeeze challenging the wind and solar industries will only get tighter as demand increases from global decarbonization efforts. The rare earth metals neodymium and praseodymium, for example, are needed as high-power magnets in both wind turbine generators and electric vehicles. Yet McKinsey estimates that these materials will face a 50–60 percent shortage in 2030.[7] Recycling will play an increasingly important role but is expected to meet only 10 percent of total demand.

Green steel offers another example. Environmental, social, and governance (ESG) requirements are driving up wind and solar industries' interest in steel produced with minimal or zero CO_2. But ramping up production of steel with hydrogen instead of fossil fuels faces multiple hurdles. The construction of new large-scale facilities often involves lengthy efforts to obtain subsidies and to design and develop unique equipment. In parallel, steel producers have to install capital-intensive electrolyzers or secure hydrogen supply through (long-term) contracts. On top of that, significant infrastructure developments are required, such as the construction of a network of pipelines to transport large quantities of H_2.

Scaling manufacturing capacity to meet regional demand

The growing demand for renewables has been pushing up factory utilization rates in the industry. Unless additional capacity is added, this can make supply chains more vulnerable to unplanned events. The COVID-19 lockdowns, factory accidents, and floods that affected polysilicon manufacturing, for instance, have helped increase capacity utilization rates to 100–110 percent since 2020, causing shortages and price hikes.[8] Across renewables supply chains, extensive investments are needed to grow capacities in line with demand and avoid large-scale imbalances between supply and demand.

In addition, the dominance of one region and the relatively small number of suppliers weaken the resilience of renewables supply chains. In the case of polysilicon, 79 percent of global capacity is located in China, and half of that is concentrated in the province of Xinjiang, making wind and solar players across the globe especially vulnerable to disruptions in this area. Additionally, the top ten

Renewables developers and OEMs will have to tackle several challenges in order to mitigate risk and build a more resilient supply chain.

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[7] Ibid.

[8] McKinsey analysis based on PV InfoLink and IHS data.

suppliers of polysilicon, only three of which are outside China, have a total capacity of more than 90 percent of global capacity (Exhibit 3). The fact that many of these suppliers have announced capacity expansions in recent years will likely only boost their share of the market.

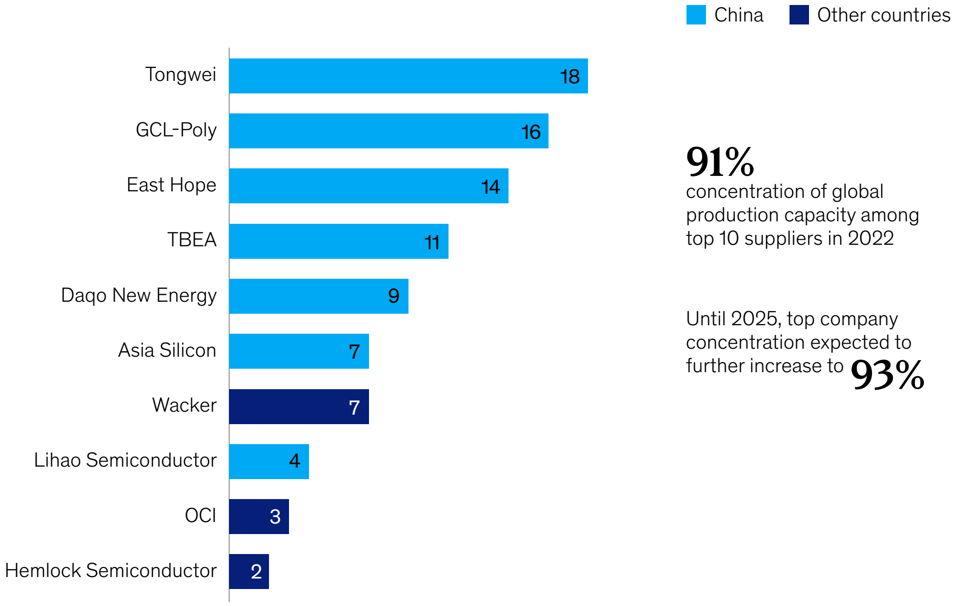
Building up logistics and installation capacities
The installation of new wind and solar capacity is going to require a lot of talent and a lot of machinery. Yet developers often face a shortage of both. Over the past two years in the United States, for example, qualified engineering, procurement, and construction (EPC) capacity for large-scale, one-gigawatt-plus solar plants has faced a gap of about one to two gigawatts per year.[9] Unable to hire enough talent, EPC contractors have been bidding selectively on fewer projects, which has eroded competition and increased prices for developers. Instead of the usual six to eight bids for projects, many developers are receiving one at a higher price. EPC contractors have grown their margins, while solar developers have had theirs squeezed.

Another area of limited capacity is the vessels used to install offshore wind turbines. Although the wind turbines for large offshore projects have gotten bigger, a limited number of vessels have been upgraded for the task of transporting and installing them. In 2020, the Global Wind Energy Council

Exhibit 3

Seven out of the top ten polysilicon suppliers are based in China, and they collectively hold nearly 80 percent of polysilicon capacity.

Share of capacity of top 10 suppliers, 2022, %



91%
concentration of global production capacity among top 10 suppliers in 2022

Until 2025, top company concentration expected to further increase to 93%

Source: McKinsey analysis based on PV InfoLink (Q1 2022 data)

McKinsey & Company

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[9] McKinsey analysis.

identified a total of only nine large-scale (more than ten megawatts) turbine vessels.[10] The companies in a position to add this urgently needed capacity are limited to a small circle of established players. Only three companies plan to own more than three heavy lift and jack-up installation vessels.[11]

Considering that the construction of one vessel takes several years, and vessel capacity will likely need to double to build twice as many offshore wind projects in 2025, this poses a real threat to the 20 offshore wind farms, representing a capacity of 42 gigawatts, that have already passed the final investment decision stage.[12]

How to make sourcing a strategic priority

In order to build resilient supply chains and thus achieve ambitious expansion targets, sourcing needs to become a strategic priority. While there are a wide range of approaches and solutions, we see three key success areas.

Getting creative with vertical integration

Long-term partnerships, targeted acquisitions, and shareholder agreements can be critical levers for securing raw materials and decreasing the price volatility of key components. The electric-vehicle-battery industry offers a potential road map. Tesla forged a parts-purchasing agreement with the Chinese neodymium magnets manufacturer JL MAG in 2020 and struck a long-term agreement to buy nickel from the Brazilian mining company Vale SA earlier this year. The company has also announced deals with mining companies in China and the Democratic Republic of the Congo for cobalt and lithium. These arrangements promise to give Tesla a steady supply of some of the highest-demand raw materials needed for electric vehicles. At the *Financial Times'* 2022 Future of the Car conference, CEO Elon Musk summarized the strategy: “It’s not that we wish to buy mining companies, but if that’s the only way to accelerate the transition, then we will do that.”[13]

In the renewables sector, Ørsted, the multinational Danish power company and the world’s largest developer of offshore wind, has pioneered a similar approach. In a strategic partnership with German steel producer Salzgitter AG, announced in early 2022, Ørsted will supply the hydrogen and zero-carbon electricity (from wind) that Salzgitter needs to produce green steel, which Ørsted will then purchase for its wind turbines. In addition, scrap from decommissioned Ørsted wind turbines will cycle back to Salzgitter’s steel production process. This arrangement not only reduces resource consumption and promotes circular-economy principles but also reduces the need for green-steel production capacity, thus helping to ease pressure on the supply chain.[14]

Partnering with suppliers to boost manufacturing capacity

Given the vulnerability of global supply chains, renewables developers may benefit from partnering with their suppliers to build additional manufacturing capacity. This could include the insourcing of critical components, the expansion of manufacturing facilities, or the creation of new facilities.

In many countries, governments are eager to help in this effort and have created policies and incentives that seek to promote clean-energy manufacturing within their borders. For example, in 2022, Italian utility Enel pursued both these options in an effort to support the growth of the national renewable-energy supply chain in Italy. The company announced a 15-fold increase in its production of bifacial photovoltaic modules at its factory in Sicily, from 200 megawatts per year to three gigawatts per year by 2024.[15] In addition, Enel entered into a strategic partnership in 2022 with engineering firm Comal to build a factory for the production of solar trackers, which direct solar panels toward the sun. This facility will support up to one gigawatt per year of photovoltaic-energy production with all-Italian tracking systems.[16] Similarly, in the United States,

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[10] “GWEC Market Intelligence releases global offshore wind turbine installation vessel database,” Global Wind Energy Council, September 30, 2020.

[11] Global Offshore Wind Farm Database, 4C Offshore, accessed August 15, 2022.

[12] *Global Energy Perspective 2022*, McKinsey, April 2022.

[13] Sheila Dang, “Elon Musk says Tesla open to buying a mining company,” Reuters, May 10, 2022.

[14] “Heading for a circular economy—Salzgitter AG and Ørsted launch strategic partnership,” Ørsted, January 25, 2022.

[15] “Enel Green Power signs grant agreement with the EU for solar panel gigafactory in Italy,” Enel, April 1, 2022.

[16] “Enel and Comal: A solar tracker factory at the Montalto di Castro power plant,” Enel, February 17, 2022.

> Long-term partnerships, targeted acquisitions, and shareholder agreements can be critical levers for securing raw materials and decreasing the price volatility of key components.

the Inflation Reduction Act seeks to support the growth of a national renewable-energy supply chain. It allocates an estimated $30 billion in production tax credits to accelerate US manufacturing of solar panels, wind turbines, batteries, and critical-minerals processing.[17]

Making risk management a common practice

Tools such as price hedging and long-term agreements that secure the cost of raw materials such as steel can significantly mitigate the effects of sharp price increases. The fact that wind and solar suppliers were caught off guard by the recent increases indicates that risk management capabilities are not sufficiently developed among renewable-energy OEMs. Developers should work with their suppliers to jointly invest in upskilling employees in risk identification and price hedging for raw-material purchases. This will be particularly important when suppliers are committing to long-term offtake agreements. Risks and appropriate countermeasures will need to be integrated into the design of these partnerships.

For developers, early and proactive risk identification should become an important part of the evaluation and management of suppliers, with consideration given to future capacity constraints, price volatility, and access to raw materials and rare earths even before a supplier is awarded with a contract. In particular, access to rare earths could be established as a bidding criterion. Among OEMs, initiatives to secure access to raw materials are a point of differentiation rather than an industry-wide standard.

While many industries are struggling with supply chain issues, those with a forecast of rapidly increasing demand face particular challenges. Early development of creative strategic measures is critical. With a focus on vertical integration, strategic diversification, and proactive risk management, renewables developers can prepare for the challenges ahead.

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[17] “Summary of the energy security and climate change investments in the Inflation Reduction Act of 2022,” Senate Democrats, accessed November 16, 2022.

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Powering up new leadership for a changing energy environment

Realizing it can no longer be ‘business as usual,’ industry chiefs need to transform themselves and their organizations to succeed.

by Anton Derkach, Ignacio Fantaguzzi, Neil Pearse, and Micah Smith

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Technological, economic, regulatory, and geopolitical forces are driving a rapid evolution of the global energy landscape. Although opinions vary on the pace and extent of the resulting transitions, attempts to balance energy security, affordability, and long-term decarbonization ambitions are contributing to unprecedented uncertainty about the global energy future.

While transformation of the global energy mix is not new, the current transition is larger in scale and more complex than previous ones due to the multitude and sometimes divergent drivers of the transition. As one industry CEO summed it up: “The energy industry has basically been static for a long time, although we did not know it was static. We’ve now moved from a largely internal, incremental agenda, to a whole set of existential risks and opportunities in front of us.”

On one hand, the increasing urgency around climate change and reducing greenhouse-gas emissions is driving the transition to cleaner energy sources.[1] Many countries and corporations have committed to achieving net-zero emissions within the next few decades. Early movers—industry incumbents and pure-play, clean-energy players—are leading the paradigm shift, disrupting traditional business models, and making permanent structural changes to these industries.

On the other hand, the rebound in energy demand after the first wave of the COVID-19 pandemic, coupled with supply-side constraints over the past year, have revealed the magnitude of the challenge in achieving climate-change ambitions. Global energy demand and supply-side variability are expected to increase over the next decade. Until alternative energy sources are universally efficient, scalable, and affordable, traditional energy sources and related infrastructure will continue to play an essential role.

These considerations introduce a high degree of uncertainty about the path ahead, including how energy supply and demand, competitive and geopolitical dynamics, and societal implications will evolve. One thing is clear, however: the search for sustainable, reliable, and affordable energy will be at the core of global aspirations.

Five ways leaders can transform to succeed in this shifting landscape

These unprecedented and evolving challenges need to be tackled by all leaders of companies in the energy sector, from pure-play, new-energy startups to more traditional oil and gas companies balancing old and new business models, risk profiles, and cultures.

Many of the elements of what it takes to succeed in the evolving energy environment will likely differ from those experienced in the past. Fresh demands may be placed on leaders, and a fundamentally new approach to leadership will likely be required for incumbents and startups. This is irrespective of the business strategy adopted—which may range from a full pivot to clean energy, to a combination play, to an ongoing focus on a core hydrocarbon business but with the introduction of emissions abatement. Overall, we see companies—and leaders—needing to operate with substantially greater speed and entrepreneurialism, and this is especially applicable in the new energy sector. They may need to develop and practice fresh ways of collaborating, both within their organizations and in the emerging energy ecosystems. A major challenge is attracting and retaining talent in an environment where traditional energy companies are under intense negative public pressures.

We interviewed 15 C-suite executives across organizations in the energy sector to gain their perspectives on the critical leadership capabilities required to succeed in this new energy era.[2] The interviews were complemented by a global survey of more than 140 senior industry leaders. The survey asked leaders to identify and rate the importance of different leadership capabilities against the backdrop of the current macro environment, and to offer their perception on how leaders in their organizations are currently performing across these capabilities. Finally, we layered in data from our

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[1] *Global Energy Perspective 2022*, McKinsey, April 26, 2022.
[2] McKinsey Global Survey of Senior Industry Leaders.

extensive body of leadership research and decades of experience helping organizations with their leadership transformations.

Based on our experience and research, we defined five key roles that leaders typically perform, from setting focus and direction to showing up as a leader, and identified two broad categories of leadership qualities and mindsets, which we have called “traditional” and “emerging” (Exhibit 1).

The survey results illustrate a high level of agreement from respondents on the importance of emerging leadership qualities and mindsets to succeed in the new energy environment, while reiterating the ongoing relevance of traditional qualities (Exhibit 2). We observed a larger gap between desired and current levels of competency for emerging leadership qualities and mindsets. This is unsurprising, as successful leaders and executives have practiced and honed the traditional qualities for many years.

A closer look at the data suggests that some traditional leadership qualities are more important than others. For example, being an effective executive delivering financial returns for shareholders continues to be a prerequisite, and detailed planning and working toward defined delivery is still important.

In terms of emerging qualities, numerous respondents highlighted the importance of meeting stakeholder expectations, with growing pressure on energy firms beyond creating value for their shareholders. Furthermore, there is clear recognition of the need for new leadership approaches to operate through shorter decision cycles and with greater experimentation, and to take advantage of market fluctuations and emerging and uncertain new-energy opportunities.

Shifting one’s mindset and embracing emerging leadership qualities can be a challenge for senior leaders who have relied on traditional tool kits. However, there is also a great opportunity here. During our research, many sector leaders expressed excitement about building and leading new kinds of organizations, and designing them

Exhibit 1

Traditional and emerging leadership capabilities can be applied across five key roles.

	Traditional	**Emerging**
Setting focus and direction	Executive: Ensure profits are predictably delivered to shareholders, through stable performance and effective risk management	Visionary: Engage people with a compelling purpose to deliver impact and value to customers and all other stakeholders
Designing how value is created	Planner: Focus on beating known competitors to capture increased share of existing value	Architect: Focus on working with customers and broader stakeholders to generate new value through reimagining and disrupting industry norms
Organizing how people work together	Director: Develop defined organizational structures with clear roles, responsibilities, and authorities	Catalyst: Develop empowered teams and cross-unit networks, encouraging transparency, collaboration, and inclusiveness across the organization and externally
Getting work done	Controller: Operate through detailed analysis, planning, and control to deliver outcomes and minimize variances	Coach: Operate through short cycles of rapid decisions, experimentation, and learning to respond to new challenges and uncover new opportunities
Showing up as a leader	Expectation-setter: Lead with focus on setting clear professional expectations for subordinates and managing for defined delivery	Authentic leader: Lead with authenticity and openness, encouraging personal well-being, creativity, and autonomy

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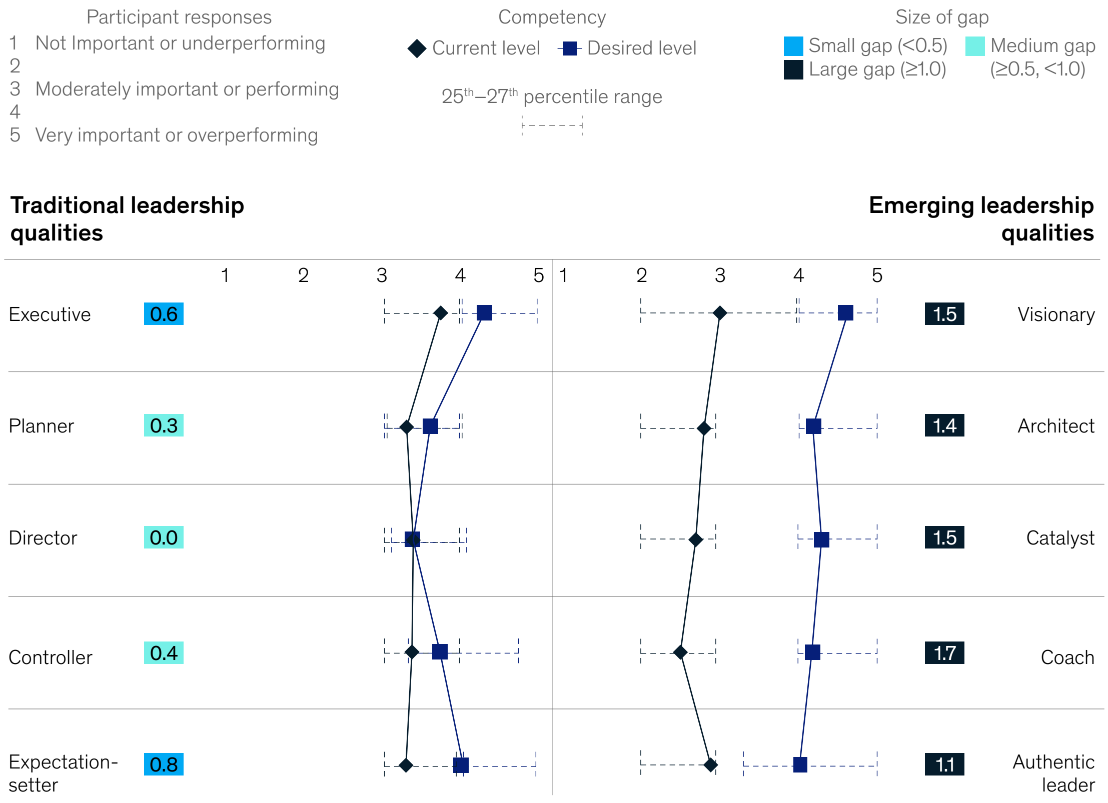
Exhibit 2

There is an increased gap between the desired and current levels of competency for emerging qualities and mindsets.



Source: Global survey of senior industry leaders; n=140.

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to succeed today and in the future. There was also much enthusiasm about the prospect of exhibiting greater purpose, promoting employee empowerment, facilitating collaboration inside and outside their organizations, and operating with higher levels of agility and entrepreneurialism.

What does this leadership transformation require? We see it as including five key unlocks, involving mindset and behavioral shifts (Exhibit 3).

1. Setting focus and direction: Beyond profit to impact

The purpose of any organization is to create value for its stakeholders. In today's open environment, where people have more information and options than before, leaders are well-placed to deeply understand how their organizations will add unique value to customers, colleagues, investors, partners, and other key stakeholders. While generating financial returns for shareholders remains critical, the purpose of an organization now extends to the role it plays in benefiting society.

The energy sector is becoming keenly aware of this need to widen the scope of value-add. The CEO of a downstream company emphasized what this means for leadership: "In the past, the oil and gas industry has been made up of engineers and accountants. In today's world, we need to include communicators in our leadership to help us find an emotional attachment to what we do. Their involvement will help demonstrate how using practical solutions to do things more sustainably can be exciting and

Exhibit 3

The leadership transformation requires five key unlocks.

		Traditional leadership	Emerging leadership	
1. Setting focus and direction	Executive	Profit	Impact	Visionary
2. Designing how value is created	Planner	Competition	Co-creation	Architect
3. Organizing how people work	Director	Command	Collaboration	Catalyst
4. Getting work done	Controller	Control	Evolution	Coach
5. Showing up as a leader	Expectation-setter	Professional	Human	Authentic leader

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inspiring." The CEO of a European private energy company echoed this sentiment, saying: "There is a huge opportunity ahead to have unbelievable impact. It's the kind of opportunity that only arises once in a generation. We can change our country, we can change our region, we can contribute to global change. Realizing this opportunity will be monumental, and stepping away is unthinkable. This is what is inspiring us now."

Top-performing organizations know that purpose is both a differentiating factor and a must-have. A strongly held sense of corporate purpose is a company's unique affirmation of its identity and embodies what the organization stands for, from a historical, emotional, social, and practical point of view. Future-ready companies recognize that purpose helps attract and retain talent and ensures these individuals thrive. Investors understand why this is valuable, and factor purpose into their decision-making.

Crafting a compelling, purposeful narrative is particularly important for companies navigating the energy transition. Leaders may look to build new, lower-carbon businesses while generating most of the cash flow and profits from the traditional core. A balance may then need to be struck between the past and the future in a way that is coherent and inspiring for employees in all parts of the business. On maintaining this balance, one executive reflected: "We originally got this wrong and over-indexed on the newer businesses when describing our purpose. This led to many in the traditional heart of our company questioning their role and even reconsidering their future with us. We quickly had to rebalance and find a more sophisticated narrative: celebrating our role in supplying secure and reliable energy to the world, while leading the charge to make sure this was ever cleaner through decarbonization and building new-energy businesses."

Nonetheless, few companies harness purpose fully. In a McKinsey survey of employees at US companies, 82 percent said organizational purpose is important, but only half that number said their purpose drives impact. Leaders may wish to spend time thinking about, articulating, and championing their company's purpose as it relates to the real impact of day-to-day business practices. One CEO put it this way: "We need to transform and unite our leadership.

Leadership transformation will help us position our company and its culture to meet the new challenges. A united leadership is important to give our people and stakeholders a consistent message about the kind of place we want our company to be." This emphasizes the importance of an inspiring company identity beyond the attachment to functions and business units.

2. Redesigning value creation: Beyond rivalry to camaraderie

Leaders seeking to succeed in the new energy environment may look at moving beyond a win/lose, "fixed mindset" approach, where the dominant focus is on protecting market share and beating competitors in existing businesses. Instead, they could make greater strides by adopting a win/win, "growth mindset" approach, by shifting focus to new value opportunities—working with suppliers, customers, and other stakeholders to introduce new technologies and solutions that will lead to new products, services, and businesses—and creating major new markets that do not exist today.

Such a shift in focus may require changes to capital allocation, operations, and performance management. Moreover, some changes may be contingent on actions by other entities. For example, mass uptake of electric vehicles depends on utilities expanding grid capacity to support charging networks. Companies may find they need to partner with other organizations to meet common needs, such as the necessity for industrial-scale networks in hydrogen production and distribution. Leaders may have to engage and work with a wide range of external partners and stakeholders to enhance and evolve the ecosystem within which the organization operates, exploring and generating mutually beneficial opportunities. They could benefit from developing connected thinking: joining traditionally separate sectors; fostering new links between companies, organizations, and citizens; and taking calculated risks.[3]

An executive in an energy service company emphasized the profound challenges they face, and the need for new and often uncomfortable thinking and action: "We are moving away from stable businesses that we are familiar with to ones we don't understand. This is uncomfortable. In ten years, we will look back and say we did not take enough risks." Another executive said: "We instinctively play defense instead of offense, because we believe we have so much to lose. I don't have a fear of losing, but I do have a fear of not showing up for the game. We need to take more swings, which will then help us get more hits."

While leaders may be required to take risks and try new approaches, they are well-placed to do this while being conscious of the resources used and with capital discipline. In most organizations, the "old" is subsidizing the "new", which needs to be managed. One CEO from our research stressed the challenges of managing this duality: "Both the old and the new need to be included in the energy transition. There is nothing sustainable about not making money." He also said he needs to be increasingly clinical about "stopping some projects that don't work" to create space for those that show more potential.

Further, there is the need for new forms of ownership and governance. In this context, one CEO commented: "It is very easy to lose investors if you say, 'Don't worry, we will lose money on this for the next ten years.' But to succeed now, you need to find the oxygen and the space to develop the new and the uncertain."

3. Organizing how people work: Beyond command to collaboration

To survive and thrive, energy organizations and their leaders are well-placed to engage with their teams in ways that make them feel connected. Social capital—the presence of networks, relationships, shared norms, and trust among individuals, teams, and business leaders—is increasingly the glue that holds organizations together.[4] When teams feel connected, they tend to get more work done and do it faster. When colleagues trust their managers and one another, they are more engaged, more willing to go beyond minimum work requirements, and more likely to stick around.

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[3] Roland Theuws, "Energy transition: Strategies and insights from the C-suite," Amrop, 2018.

[4] Taylor Lauricella, John Parsons, Bill Schaninger, and Brooke Weddle, "Network effects: How to rebuild social capital and improve corporate performance," McKinsey, August 2, 2022.

Social capital matters to an organization's performance. By leaving frontline employees on the sidelines, companies miss out on critical information that could bring key strategic insights. An executive at a private oil and gas company noted how they are attempting to tap into their employee base: "Disruptive trends may start at the margins of an organization, where frontline employees operate. These employees' perspectives and ideas often do not get clearly communicated to leadership, making it easy to brush them off, thinking they are not important."

Leaders could engage and unleash the full potential of everyone in the organization by empowering people in small units (cross-network teams) instead of managing individuals through the narrow lens of rigid job descriptions. Small units might then be focused on a clear and distinct value-contribution mission, giving them the autonomy, access to information, guidance, training, and multidisciplinary capabilities they need to operate with high levels of entrepreneurship to successfully deliver on their goals. One oil and gas executive described this evolved leadership as "turning the whole pyramid leadership structure on its head. The people doing the work are key, and everyone else supports them. Servant leadership, role-modeling, and listening to the people who understand how the work gets done are all part of this new approach."

Leading this empowered network requires high-performing leaders who offer effective and efficient leadership, beyond the management of internal politics inherent in a hierarchy of individual managers and traditional governance groups. It requires fundamental shifts in the mission, culture, and operating models of every leader and leadership team in the network.

This new leadership style is often challenging. One head of production at an international energy company said: "My biggest change was giving up control and delegating. It wasn't easy, but that's exactly the change that was needed. Instead of asking teams for updates and reports, leaders now focus on giving context, setting the mission, and defining the purpose and intent. Leaders ask, 'How can I help?' when engaging with teams, and focus on tackling problems. Teams are empowered to figure out how to deliver the mission within the boundaries defined by standard processes."

To amplify and realize the full potential of everyone in the system, leaders could foster peer-to-peer transparency, relationships, and workflow across the various "small units." This can be done by removing roadblocks that prevent empowered teams from bringing ideas to reality, fostering connections across the organization, helping people to connect what they're working on with the organization's vision and aspiration, and encouraging an inclusive and welcoming environment where people bring their authentic selves to the office and pursue the full range of their aspirations.

4. Getting the work done: Beyond control to evolution

Energy companies operate in a highly dynamic, unknown, and volatile environment, where major "black swan" opportunities and challenges are emerging with increasing frequency. As energy markets and related policies find a new equilibrium, organizations must keep an eye on the horizon to plan robustly for the uncertain future, while maintaining business continuity on their core value proposition.

Hence, in addition to the primary disciplined focus on executing today and co-creating tomorrow, leaders could build effective "first responder" capabilities to tackle major discontinuities within any business cycle. One senior executive in a traditional oil and gas company put it this way: "The old style was slow and steady decision-making. But when you decided, you carried through with it. This doesn't work in the energy transition. Instead of slow and flawless execution of large, incremental decisions, we need to rapidly learn and evolve."

Successful leaders have traditionally managed their organizations through planning and control based on extensive analysis, while seeking to minimize disruptions. Today, leaders could learn to become comfortable with operating in shorter, rapid cycles. This requires increased focus on quick, low-risk decisions and experiments, learning from those that fail, and scaling those that succeed. Leaders could begin and end each rapid cycle with a retrospective to review progress, deepen learning, and plan for the next cycle. Each cycle could focus on a set of short-term outcomes, accomplished via prioritized deliverables and initiatives that reflect available short-term capacity and appropriately manage risk. Outcomes, deliverables, activities, and resources may be reprioritized during each cycle to reflect rapidly changing realities.

What this means for leadership in the new energy world is captured by the director of strategy at an offshore driller, who said: “In an industry where it is becoming increasingly challenging to raise capital, a sharp external focus and agile thinking can create opportunities.” The CEO of a traditional oil and gas service company summed up what many executives said: “We need to become entrepreneurial and non-bureaucratic. Being slow and considered may be important in large, traditional engineering projects, but this approach doesn’t work in the new energy space. Right now, we love to control and work in silos. This must change.”

The CEO of an integrated energy company emphasized the importance of empowering those who work in their organizations: “I want to see us acting more quickly, allowing employees to take decisions at the lowest level possible. We need to empower them to identify and make decisions without having to consult their bosses. It’s OK for us to make mistakes if we take accountability, fix them, and learn. It would be much worse if we didn’t make mistakes, which would tell me that we are not taking risks and are playing too safe.” Many of the leaders we interviewed emphasized the need to take risks to succeed in the emerging energy era.

For organizations to continually evolve in this emergent way, leaders may need to overcome status-quo bias—to imagine a world or a market that is very different from what it is today. Recognizing the inherent challenges in such a transformation, a leader in a major energy company said: “In fairness, it is difficult as a leader to take your attention and resources from a business area that is already highly profitable, to focus on an extremely uncertain one.” Leaders in the energy sector may increasingly need to balance their attention between current activities and future opportunities.

5. Showing up as a leader: Beyond professional to human

Navigating this uncertainty is an immense challenge that will require best-in-class talent to solve complex problems. As traditional business models are disrupted, organizations in the energy industry will need to ensure they retain their core experienced workforce while attracting diversified talent in line with new business needs. The competition for talent is intense and potential employees are looking for more than financial compensation. Creating an attractive destination for top talent means fostering an inclusive employee experience. This influences whether employees remain and thrive, which in turn drives the company’s financial sustainability.

Leaders across all levels have a critical role to play in creating an environment where employees can bring their full authentic selves to work and feel empowered to pursue a sustainable work/life balance. For this to happen, leaders themselves need to show up with greater wholeness and authenticity. One industry executive connected this with the impact of the pandemic: “In COVID-19, leaders had to become more authentic—we all went through the same war together. This is an asset now in terms of the leadership we need.”

One way this leadership manifests itself is in relation to the demand by today’s employees for more flexibility and autonomy.[5] Leaders can facilitate this by allowing employees a degree of autonomy—empowering them to do their best work where they feel deeply motivated and energized. Another executive in the energy business effectively captures this role for leadership using a metaphor: “Think of it as driving on a highway. You can set some limits, like the road barriers on left and right. But once you set some boundaries, you must let others drive. You cannot take everyone on the back of a lorry that you are driving.” An executive in another global company reinforces this point: “Traditionally, there has been

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[5] Dane Fetterer and Holger Reisinger, “Forget flexibility. Your employees want autonomy,” *Harvard Business Review*, October 29, 2021.

a lot of focus on presence in the office but, since COVID-19, employees demand flexibility. Many senior leaders find it hard to make this adjustment, and this could lead to high performers leaving the company."

Conclusion

These five mindset and behavioral shifts could contribute to a unique and more powerful kind of leadership. When leaders identify and build the culture they want the organization to embody, they can create a virtuous cycle, attracting the right talent that will thrive, unlock their value agenda, and turbocharge their performance.

However, the road to transformation is full of bumps and bends. Such shifts often require changing current systems and ways of operating, which will inevitably create some organizational resistance. Leaders may need to brace themselves for complexity and chaos, while demonstrating deep self-awareness, as they address their own embedded biases and overhaul their own mindsets for the new environment.

The transformation can also require organizations to commit to leadership development and a holistic cultural transformation—broad ideals and small incremental changes may no longer be sufficient. Emerging behaviors and mindsets cannot exist as mere slogans on a wall or in catchy email signatures. They require embodiment on a day-to-day basis, being continuously role-modeled by senior executives; integration into core business activities and specific actions; and demonstration in the moments that matter.

These are exciting times for the energy sector, given its placement at the center of the critical challenges facing our world. Meeting these challenges requires the development of the extended characteristics of leadership we have highlighted here. The good news is that industry leaders are aware of the challenges and are consciously starting to address the demands of new leadership. This not only requires new talent from places outside the traditional energy sector, but also active transformation of existing leadership.

One sector CEO summed up the challenges: "Where do we get the entrepreneurs we need now to lead in the next phase of the energy industry? You need some new leaders from outside the industry, in balance with those from the existing business. You need the new-energy zealots to provide inspiration, but you also need leaders to demonstrate that real practical progress is being made on the ground. We are finding that there are many 'entrepreneurs in residence'—leaders who are more incremental but who just need permission to be entrepreneurs. We need to activate them!"

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Net zero: Next moves for CEOs

How leaders can invest in a sustainable future *and* navigate near-term energy pressures successfully.

by Anna Moore and Humayun Tai

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Net zero doesn't have to mean zero sum. In this episode of *The McKinsey Podcast*, McKinsey partner Anna Moore and senior partner Humayun Tai talk to global editorial director Lucia Rahilly about the "devilish duality" leaders have faced since the outbreak of the war in Ukraine—and about how to follow through on longer-term decarbonization commitments while managing short-term energy disruptions successfully.[1]

After, hear how investors can use their capital and influence to help reverse the impact of climate change, from Columbia professor Bruce Usher. He spoke with us about his book, *Investing in the Era of Climate Change* (Columbia University Press, October 2022), as part of our *Author Talks* series.[2]

The McKinsey Podcast is cohosted by Roberta Fusaro and Lucia Rahilly.

This transcript has been edited for clarity and length.

The serpentine path to net zero

Lucia Rahilly: A little more than a year ago, leaders around the globe gathered at COP26 and made clear commitments to reach net-zero emissions goals. How disruptive do you expect the war in Ukraine to be, in terms of those commitments and, by extension, our collective progress toward net zero?

Humayun Tai: The long-term direction doesn't change: the commitment is to net zero.

The Ukraine crisis does bring into question this "duality" we talk about: on the one hand, we're pushing toward net zero; on the other, we ask how the system can function in terms of affordability, energy security and supply, and system resiliency, when fully pushed into renewables and other kinds of alternative energy.

Another issue would be around the macro shocks—inflation, short-term supply chain constraints—that many companies and governments are experiencing. We're being asked, "Can you actually still progress on net zero while trying to address those issues?"

There's definitely a disruption right now. We knew this path moving to net zero would never be linear, that we would have setbacks and step forwards—technology, innovation, regulation, and the like.

Anna Moore: We have to ask ourselves, can we continue to allocate capital in a way that still makes that long-term trajectory Humayun was describing a reality? We need to be sure we're continuing to allocate capital toward decarbonization investments. The economics of green-hydrogen projects have come forward as a result of comparative investments and conventional fuels looking more expensive now. That doesn't mean that you necessarily have capital inflows shifting. These are long-term projects, so we need to be sure that we're actually allocating capital accordingly.

This also highlights a broader point around trade-offs along the path to net zero. We have trade-offs between different sustainability goals—for instance, decarbonization versus water consumption. We have trade-offs, of course, with respect to job creation and job preservation. We have this near-term trade-off in the context of the Ukraine crisis. But I think it highlights a broader set of trade-offs and decisions we need to make at the company and society level about, "What does 'good' look like?"

Humayun Tai: The 2020s is a critical decade. Because those investments, to Anna's point, are going to last a long time; the outcome will lead to decarbonization over the next 20 to 30 years. The longer these investments get delayed—and we do see live investments getting delayed—the harder it will be to hit the 2050 net-zero number. So when we think about long term versus short term, this is quite material. What happens now is not just about the short run; it sets the path to a long-term target for 2050.

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[1] Bob Sternfels, Anna Moore, Daniel Pacthod, and Humayun Tai, "A devilish duality: How CEOs can square resilience with net-zero promises," McKinsey, November 1, 2022.

[2] "Author Talks: An investor's guide to the net-zero transition," McKinsey, November 23, 2022.

Balancing change with practicalities

Lucia Rahilly: Let's take up this issue of short- versus long-term trade-offs. As you said, we've talked about affordability as an example of the tension between short-term shocks and longer-term imperatives, when gas prices spiked as an effect of the war. How do you view the economic calculus for leaders? Does net zero really have to be "zero sum"?

Anna Moore: In the long term, of course not. We've published research about the $9 trillion to $12 trillion a year we believe will be created by the 2030s in new green value pools.[3] That covers everything from carbon management to sustainable materials to new energy and new-energy infrastructure, et cetera. We believe that for companies, the window of opportunity on many of these areas is time bound.

I'll take sustainable materials as one example: we see a 50 percent to 60 percent supply–demand gap for low-carbon steel by 2025. That gap will close to about 35 percent by the 2030s and, by the end of the 2030s, close entirely because we'll have more capacity online. So steel producers who want to scoop up that additional margin and capture that green value pool will be those who bring investments online now.

We would say, as we advise clients typically, to invest during a downturn. That's particularly acute right now, especially because so many investments are being delayed. That doesn't mean that you don't also need to keep the lights on in the core business while we go through this transition. We explore in our article what this means, practically, for CEOs. I would highlight, recognizing that there's not going to be one successful technology pathway, for instance, that we will need to invest in maintaining and preserving the core business while also investing in the new. The article puts particular emphasis on the CEO's role in balancing those investments.

Lucia Rahilly: The transition to net zero, as you're saying, requires massive up-front investment in a variety of areas. Where can CEOs look to find that capital?

Anna Moore: Part of this is investors changing their investment criteria and capital allocations toward more sustainable technologies. The most famous example, of course, is Mark Carney and GFANZ [Glasgow Financial Alliance for Net Zero], and the $130 trillion of assets under management that are committed to a net-zero pathway: fantastic. And in the first half of 2022, we saw $120 billion in net new money going to sustainable funds.

So we indeed have capital that's flowing toward the green transition, as well as to new green investments. In the spirit of introducing and acknowledging some of the nuance, we also continue to have capital flows toward conventional technologies and energies.

So where is the capital coming from to fuel the transition? It's coming from investors focusing more on sustainability and shifting their asset allocation.

> 'So where is the capital coming from to fuel the transition? It's coming from investors focusing more on sustainability and shifting their asset allocation.'
>
> – Anna Moore

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[3] "Playing offense to create value in the net-zero transition," *McKinsey Quarterly*, April 13, 2022.

But we will continue to have capital flows toward conventional technologies as well, and it becomes a question of how we manage that balance over time.

Lucia Rahilly: Anna, can you share a client example of a green transition?

Anna Moore: I work with a client in cement and building materials. Cement is a notoriously high emitter of global greenhouse-gas emissions.

In the cement world, there's a real trade-off between new materials, alternatives to cement, versus decarbonizing existing production. And so, as a management team, this client has needed to think through, one, "What does this mean for our M&A strategy?" And two, "What does it mean for the scale of decarbonization investments that we make in our existing facilities? If it costs us hundreds of millions for every asset to decarbonize, how do we do that? Over what phasing?"

And three, "How do we think about cannibalizing ourselves or not? If there are real alternatives and substitute materials, do we do that to ourselves now? Do we wait for others to bring this to the market?" And, "Do we grow some of that internally through our own R&D? Or do we buy in or partner with existing, exciting start-ups that are coming from the wider ecosystem? That also means a shift in how we think about our workforce and in the types of skills and partnerships that we need."

This is an illustration of how one business is thinking about this, but it also gives you a sense of the range of areas where these kinds of trade-offs show up in the decisions the management team needs to make.

Humayun Tai: The step-up on both the public and private side will be important. There's a whole public-sector theme here as well, particularly when we talk about Global North and Global South. From a Global South perspective, policy and governments are stepping in to really push decarbonization investments, as well as, of course, the conventional investments that are needed. On the private side, there are certainly dedicated funds toward decarbonization that are increasing. There has been a lot of debate and controversy recently around ESG [environmental, social, and governance] funds, and this is quite different regionally. When you talk about North America, the nuance is different than when you talk about Europe or Japan, for example.

Another source is private-sector funds. That incumbent source of capital, using those balance sheets, is going to be another large piece of the capital infusion that's going to come into new-growth businesses or decarbonization businesses. So this is traditional businesses reinvesting in new businesses.

And, of course, there's the VC [venture capital] private equity infrastructure of fund financing and sovereign-wealth capital that is really now focused on green investing, decarbonization investment—that's another slug of capital that will come in. So at the end of the day, there will be blends of public–private funding—again, very nuanced by region.

How to play offense

Lucia Rahilly: What does what we're calling "playing offense" look like in this context?

Anna Moore: One signifier is making long-term investments while preserving the short term. Another is capturing a green premium and being laser focused on where there truly is market share gain, or green premium to be had, from new, sustainable value pools.

We see a premium for steel. We don't see such a premium, for instance, for green copper, simply because the existing market is already quite tight. Companies need to be quite granular in assessing, "Where do I truly have premium or market share gain as a consequence?" And then steer their strategy around that.

I would call out, for instance, carbon management as a fundamentally new sector in the economy that we estimate will be $100 billion to $200 billion a year. You also see tooling and machinery

> **‘From a Global South perspective, policy and governments are stepping in to really push decarbonization investments, as well as, of course, the conventional investments that are needed.’**
>
> – Humayun Tai

companies shifting from serving oil and gas to serving renewables. It’s tweaking the existing asset base to match where the direction of travel is around sustainability.

The final marker of playing offense successfully is building the partnership muscle. There’s so much uncertainty that the best way to manage it is to share it with your supply chain partners. Take automotive OEMs. They’ve been increasingly working with steel producers, aluminum producers, and plastics manufacturers to design decarbonized cars and share a little of the risk: signing long-term supply agreements, redesigning together what they want the automobile to look like, what it’s going to be made out of, how they’re going to price it, what they think consumer willingness to pay looks like, and how they share that value across their value chain. So it’s about getting quite specific with your supply chain partners to share the risk and the benefit.

Humayun Tai: Think about some of the traditional oil and gas companies seeing long-term decline in the need for oil in various forms. They are now turning to a real balance sheet commitment to a clean-fuels build-out and assessing different businesses in the clean-fuels broader spectrum. We see utilities that have now committed completely to going from building fossil to renewables. And in many cases, it’s a bit of a blend, particularly in regard to the Global South. Other examples are technology companies on the chip side and advanced-electronics companies committing more capital and resources to building out services and technologies for energy transition. Smart investors are building that before the full demand gets there, taking that kind of risk and going on the offense.

Risk versus reward

Lucia Rahilly: Humayun, how should CEOs think about risk and reward when they’re allocating investments to this green transition?

Humayun Tai: There are a couple of different elements to consider. The first is purely financial: “If I decarbonize and shut down my coal power plant, and now I’m building a renewables power plant, what’s the economics of that, given the marginal cost?” So that’s clear.

Second, what are the policies that then shape stranded-asset risk? In many different jurisdictions, there are subsidies or funds—for example, government funding that companies can access to ameliorate the challenge of the stranded asset. In many cases that ecosystem pushes policy to at least negotiate what that stranded-cost transition is.

Third is when you lean forward and say, “It may not make financial sense right now in the short run. But when we do our calculations, and we look at the uptick in the market demand for green steel, for example—customers willing to pay a premium in ten to 15 years—it actually makes sense."

That's not a cost-of-capital issue, necessarily; that's a revenue line issue is the way I would think about modeling the cash flows of that investment. That then requires foresight, intuition, and some risk taking to say, "How will markets shape up, how will customer demand shape up, how will policy shape up to actually create that level of offtake, to create the policy conditions in which we or others that rely on our products will have to build muscle and understanding to actually buy a zero-carbon, or close-to-zero-carbon, product?"

Anna Moore: As companies think through risk–reward trade-offs, there's clearly a question around timing, scale, and return on green investments, but also questions around, more fundamentally, "How does the business model need to shift?" And "How do my skills to support that need to adjust?" And "Where could I have stranded-sustainable-asset risk in addition to carbon-asset risk?"

Let's take an example from telecoms: previously, many cell phone manufacturers effectively built their business around replacing your phone every year or two. If you think forward to 2050, where we're consuming fundamentally less, that business model needs to change. "How I get value" needs to fundamentally shift.

If you consider the built environment, of course we need to decarbonize cement and concrete, and we also need to despecify buildings. That also means getting engineers and regulators to be comfortable with using less cement and concrete. And that means changing professional liability, it means reskilling.

The second area of uncertainty is around competition between different decarbonization investments or pathways. Humayun mentioned the stranded-asset risk for many existing carbon assets. I think we're also going to have stranded-sustainable-asset risk. You can think through areas where there's competition between different decarbonization pathways: for example, cross-laminated timber versus green cement and concrete. We will presumably have a mixture of both, but to what extent? You're going to have competition between those different materials and potentially stranded-asset risk.

In Europe there's a huge debate around using biomass, and surely, at least in the near to medium term, we're going to use biomass as an energy source. But ultimately, we will evolve beyond that, and so you also end up with stranded-transitional-technology risk.

The stakes of stagnancy

Lucia Rahilly: When you're talking to CEOs, does the notion of declining consumption and declining demand resonate? How do CEOs respond to that potentiality?

Humayun Tai: There's no longer any doubt that fossil-based energy will decline. That is now table stakes conversation. The question is when. Is this a 30-year transition? Is it a 50-year transition? We're back to timing.

Anna Moore: Those who don't grapple with the way we need to reduce consumption risk are finding that they haven't made the progress they need to. We're starting to see more acute changes in the climate and in the livability of our world. Such changes will lead to much sharper and more challenging policy shifts. Then they will end up with a disorderly transition.

Companies can get ahead of that by thinking through, "What does a sustainable 2050 business model look like, and what would it look like in order to fundamentally reimagine my business?"

Humayun Tai: We know the Global South is going to bear more of the cost of this transition. So adaptation is important, and it becomes an opportunity in some ways.

The other thing is biodiversity—water and some of the nature-based capital aspects. How do we get ready for impacts on biodiversity and water? What opportunities are there for companies to play an increasingly important role there, as the carbon budget may fall short?

Lucia Rahilly: Great discussion. Anna and Humayun, thank you so much for joining us today.

Humayun Tai: Thank you, this was fun.

Anna Moore: It was a pleasure.

Roberta Fusaro: Now, let's hear from Columbia professor Bruce Usher, author of the book *Investing in the Era of Climate Change*, about how investors should leverage their capital and influence to reverse the impact of climate change.

Bruce Usher: The most valuable companies globally are tech companies. Now let's forward 30 years, because that's what matters to investors. What will impact business and investors more than anything in the next three decades? My answer is climate change.

We've got three decades to completely rebuild this entire global economy that we just spent the last 300 years creating. That's going to require extraordinary amounts of investment capital. Estimates are $100 trillion to $150 trillion dollars. Investing that capital is going to create, for investors, new risks and new opportunities.

The actions that investors take over the next few decades are going to change the planet. They're going to remake that global economy and reduce emissions to meet those science-based targets. How they go about doing that, how quickly that capital is invested and how effectively it's invested is going to make all the difference in terms of allowing us to avoid catastrophic climate change. The reality is that the capital exists, but mobilizing and investing that capital is a pretty significant challenge. In the context of many of the other great challenges that society faces, we actually have at hand the ability to solve this one.

In the past with electric vehicles, there was nothing we could put on the highway, so golf carts were about as far as you could go. Today that situation has completely changed. We have technologies and business models that already exist to reduce more than half of global emissions, and those products are commercial, and they are scalable today.

We also already have technologies to reduce the other half of the emissions we need to get down to zero. Those technologies exist, but they didn't a couple decades ago. They're not yet commercial, but they're under development and many of them are already being financed by venture capitalists and other early-station investors.

So, for investors, understanding how different sectors of the economy are going to change, and which companies are going to be successful as those changes manifest themselves, is challenging. I would recommend that investors follow five different tactics.

The first recommendation: take the long view. Bill Gates famously said a number of years ago, we tend to overestimate the changes that are going to occur in the next two years, and we underestimate the changes that are going to occur in the next ten.

The second recommendation I have is, beware of greenwashing. A lot of companies are making promises that they cannot meet or do not intend to meet. The third recommendation is a phrase I learned years ago when I worked as a trader in finance: "The trend is your friend."

The fourth recommendation is to avoid businesses that anticipate a change in human behavior. Human behavior is very set in its ways. Beyond Meat does not try to say to people, you shouldn't eat meat. It's saying, we've got a product for you that tastes an awful lot like meat. And the last piece of advice, which is similar to the first one, is that it's better to act early than late.

What I found in researching for the book was that the connections between these sectors are really important. Renewable energy, electric vehicles, energy storage, green hydrogen, and carbon removal: these are very separate industries. But, in fact, they're very closely connected. And more important, as we see growth in one sector, it has serious ramifications for these other sectors. In fact, they turbocharge growth in the other sectors for both technology reasons and having to do with capital and how these sectors work together.

And that's really important because, ultimately, we have to move all of this in the same direction.

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