



Infrastructure for a net-zero economy: Transformation ahead

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



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

An economy-wide transformation

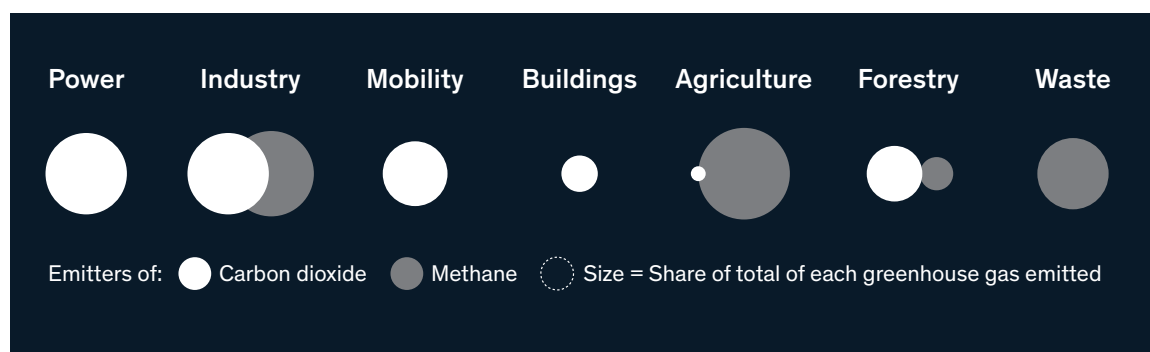
To stabilize the climate and limit rising physical risks from hazards such as extreme heat and more frequent storms, science tells us that it is necessary to stop increasing the concentration of greenhouse gases (GHGs) in the atmosphere—that is, to reduce net GHG emissions to zero. Since substantial GHG emissions now come from each of seven energy and land-use systems, every system would need to greatly reduce its emissions for this net-zero goal to be reached (Exhibit 1). Power and industry, two asset-heavy systems, together generate about 60 percent of global CO₂ emissions. Across all seven systems, the combustion of fossil fuels—coal, gas, and oil—accounts for more than 80 percent of CO₂ emissions, based on current accounting methodologies.

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

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

Exhibit 1

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



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

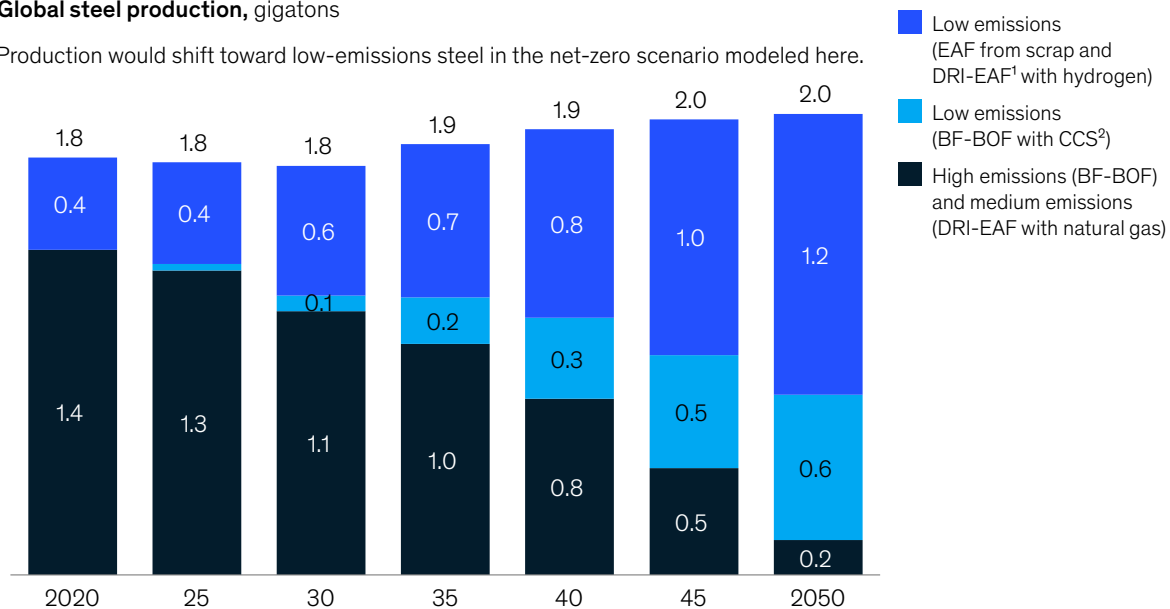
would be more than double what it is today as other sectors use more electricity and developing countries add generation capacity to meet their populations' energy needs (Exhibit 3). Other industries, such as those that manage carbon with carbon capture and storage (CCS) technologies, could also grow.

Exhibit 2

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

Global steel production, gigatons

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



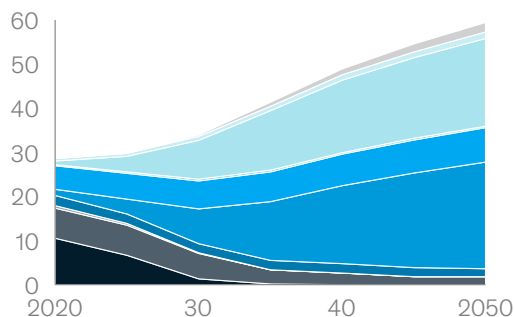
¹Direct-reduced iron, electric-arc furnace.

²BF-BOF = blast furnace, basic oxygen furnace, CCS = carbon capture and storage.

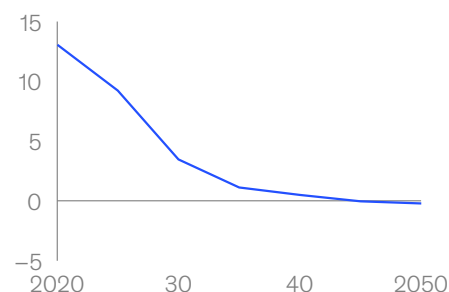
Exhibit 3

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

Electricity generation by source, peta-watt hours



CO2 emissions from electricity generation, billion metric tons

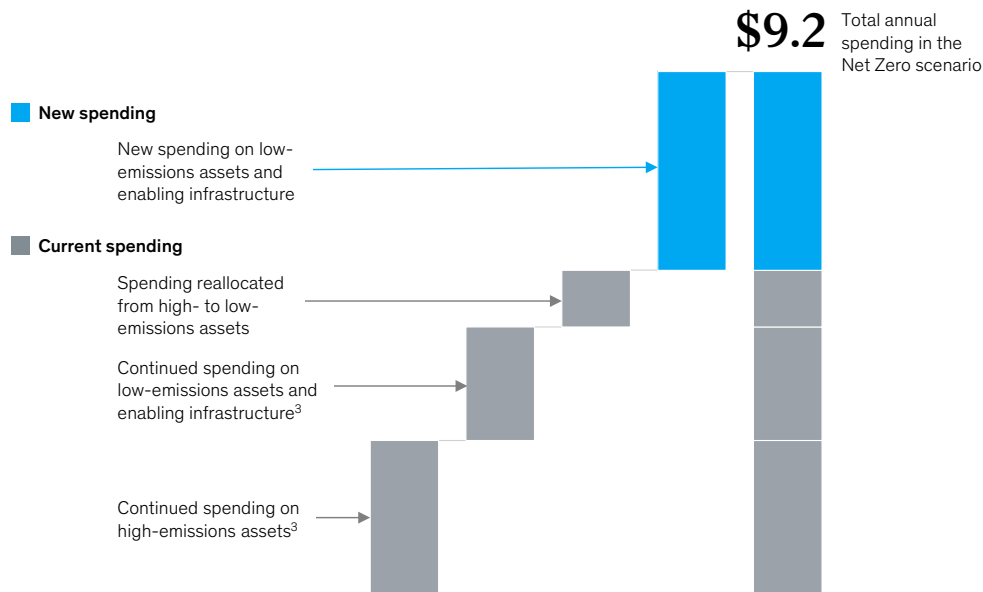


To achieve the production shifts envisioned under the NGFS Net Zero 2050 scenario, organizations would retire or transform some existing physical assets and acquire new ones. McKinsey analysis suggests that about \$275 trillion in cumulative spending on physical assets, or approximately \$9.2 trillion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

Exhibit 4

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

Annual spending on physical assets for energy and land and land-use systems¹ in the Net Zero 2050 scenario,² average 2021–50, \$ trillion¹



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

²Based on the NGFS Net Zero 2050 scenario using REMIND-MAGPIE (phase 2). Based on analysis of systems that account for ~85% of overall CO₂ emissions today. Spend estimates are higher than others in the literature because we have included spend on high-carbon technologies, agriculture, and other land use, and taken a more expansive view of the spending required in end-use sectors.

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

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

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

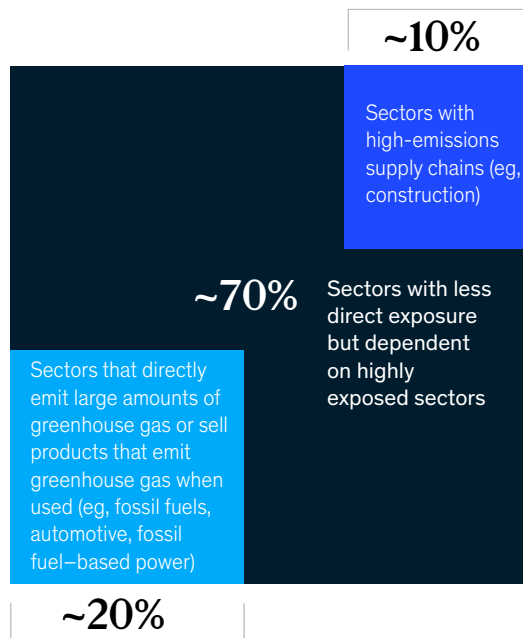
The outlook for sectors

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

Exhibit 5

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

Exposed sectors by share of global GDP created



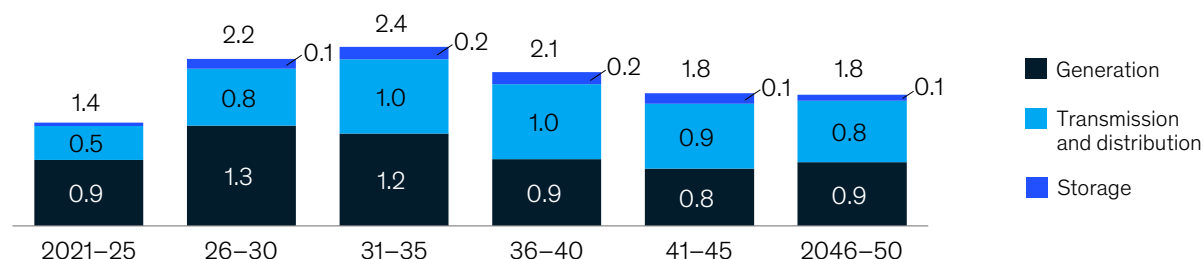
Power

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

Exhibit 6

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

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



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

Industry

Two heavy industrial sectors—steel and cement—together account for approximately 14 percent of global CO₂ emissions and 47 percent of the industry sector’s CO₂ emissions. While technologies are still emerging, steel and cement production can broadly be decarbonized in three ways: by installing CCS equipment at existing plants, by shifting to low-emissions fuel and other inputs, or by building new low-emissions production capacity. These approaches would require additional capital spending (Exhibit 7). This capital spending would, in turn, lift unit production costs, which will be a key challenge for steel and cement producers. By 2050, the average cost to produce a metric ton of steel would be 30 percent higher than it is today; for cement, the comparable increase would be 45 percent in the scenario modeled here.

Buildings

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

Exhibit 7

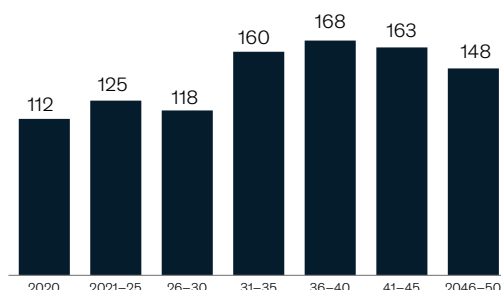
A net-zero transition in the steel and cement sectors could result in cost increases and require increased capital spending to decarbonize production.

Steel

Spending would be required in the net-zero 2050 scenario modeled here to build new low emissions production capacity (eg, hydrogen-based DRI-EAF¹) and install CCS.²

Annual capital expenditures, 2021–50³

Average over 5-year period, \$ billion

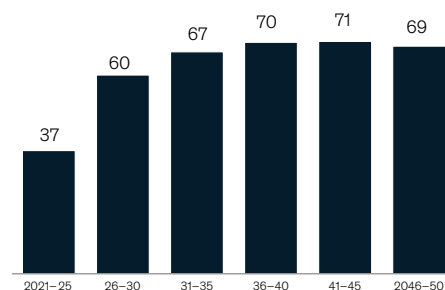


Cement

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

Annual capital expenditures, 2021–50³

Average over 5-year period, \$ billion



¹Direct-reduced iron, electric-arc furnace.

²Carbon capture and storage; Capital spending includes plant, equipment, and maintenance costs. Assumes global weighted average unit capex cost with weighting toward China, European Union, United Kingdom, United States, Mexico and Canada.

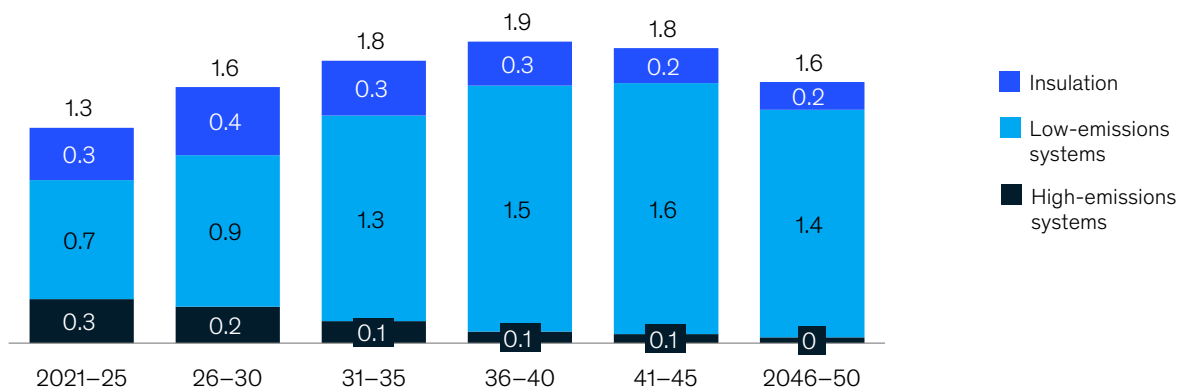
³Capital expenditures include the following components: plant, equipment and maintenance costs, CCS capex. CCS capital spending does not include CO₂ transportation, storage and usage. Capital spending associated with increased clinker substitution has not been sized.

Source: Mark Bolinger et al, "Queued up: Characteristics of power plants seeking transmission interconnection as of the end of 2020," Berkeley Lab, May 2021.

Exhibit 8

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

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



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

¹Includes spending in both the residential and commercial sectors.

Managing the transition

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

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

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

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