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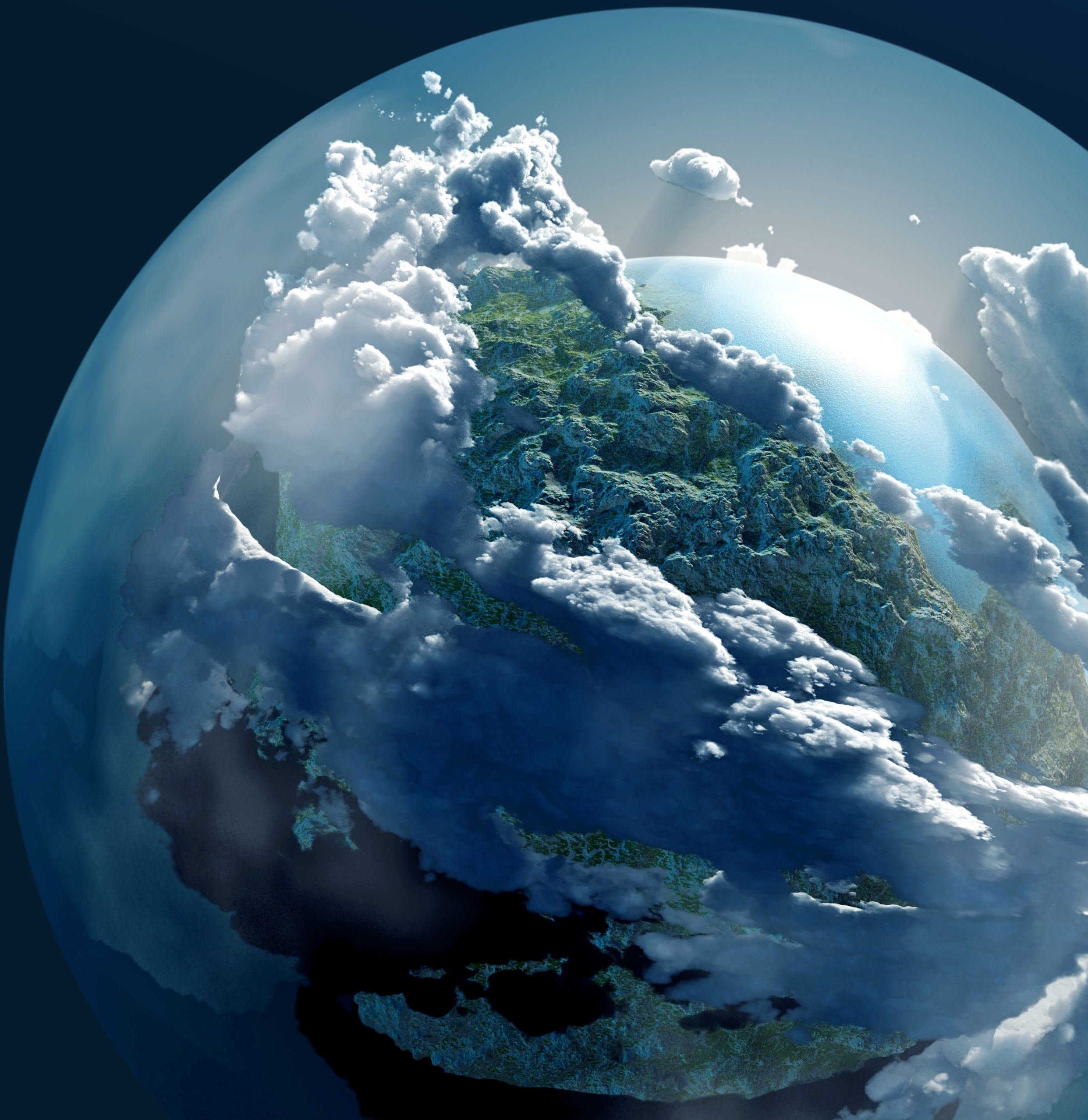
Nature in the balance: What companies can do to restore natural capital



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Preface

For much of human history, demands on natural capital were well within what the planet could provide. Now, however, population growth and increases in per-capita consumption are depleting the world's stock of natural capital more quickly than it is being replenished.

What can be done to bring human activity within safe boundaries at this juncture, recognizing that our understanding of these boundaries and our ability to extend them will naturally shift over time? What are the specific opportunities for companies to lead in this undertaking? And how can companies embark on the journey?

This report sets out to answer these questions by laying out our current best understanding of how demands on natural capital are affecting the planet and by identifying the actions that could help address those impacts. In doing so, it marks a first attempt to identify and size the actions corporations could take to catalyze action aimed at bringing demands on natural capital to within a safe operating space for humanity. The report joins a growing body of McKinsey research focused on the depletion of natural capital as well as the critical intersections between climate and nature. It builds on our previous work, dating back to 2007, to develop global greenhouse-gas (GHG) abatement cost curves, as well as on previous publications, including *Climate risk and response: Physical hazards and socioeconomic impacts* (January 2020), *The net-zero transition: What it would cost, what it could bring* (January 2022), *Why investing in nature is key to climate mitigation* (January 2021), *Valuing nature conservation* (September 2020), and "Where the world's largest companies stand on nature" (September 2022).[1]

The research was directed by McKinsey senior partners Daniel Aminetzah, Daniel Pacthod, and Hamid Samandari in New York; Kartik Jayaram in Nairobi; Tomas Nauclér in Stockholm; and Jonathan Woetzel in Shanghai. It was also directed by partners Julien Claes in Brussels, Duko Hopman in New Jersey, Joshua Katz in Stamford, and Dee Yang in New York.

The research team was led by Tucker Van Aken and Antoine Stevens and comprised James Allan, Gijs De Cort, Caroline De Vit, Arthur Depicker, Ivo Erben, Hanzel Gregorius, Jacob Harrison, Lyna Kim, Tim Lenters, Sébastien Marlier, and Jeroen Verhagen.

Many other colleagues within the firm provided valuable input and expertise: Deven Azevedo, Jordan Bar Am, Ryan Barrett, Tom Brennan, Shane Bryan, Adriano Canela, Celia Chaiban, Mark Conrad, Charlie Dixon, Spencer Dowling, Julia Engström, Per-Anders Enkvist, Karilyn Farmer, Nelson Ferreira, Patricia Fletcher, Anders Milde Gjendemsjø, Will Glazener, Dave Goddard, Ashley Gorst, Thomas Hundertmark, Martin Joerss, Sean Kane, Arjen Kersing, Mekala Krishnan, Floris Leijten, Megan Leitch, Oskar Lingqvist, Jukka Maksimainen, Diana Menzies, Hiren Mulchandani, Karl Murray, Jesse Noffsinger, Glen O'Kelly, Lesley Pandey, Dickon Pinner, Sergio Nistal Prieto, Giulia Reggiani, Sebastian Reiter, Justin Rosenthal, Olivia Sanchez Badini, Jimmy Sarakatsannis, Mohsen Shahi, Erik Sjödin, Robin Smale, Moa Strand, Rory Sullivan, Anders Suneson, Michael Taksyak, Bryan Vadheim, Gregory Vainberg, Alexander van de Voorde, Otto van der Ende, Jeremy Wallach, Joel Wållgren, Daan Walter, André Wise, Bart Woord, and Benedikt Zeumer.

[1] "Why investing in nature is key to climate mitigation," McKinsey, January 25, 2021; "Valuing nature conservation, McKinsey, September 22, 2020; "Where the world's largest companies stand on nature," McKinsey, September 13, 2022.

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In brief

Economic activity fundamentally depends on natural capital, the world's stock of natural assets. But today, natural capital is being rapidly depleted, with increasingly tangible consequences—from water shortages in California to a nitrogen crisis in the Netherlands. In this report, we examine the state of natural capital, the economic sectors depending on and affecting it, and the opportunities for companies to help reduce those demands. Our key findings include the following:

Human activity appears to be outside a 'safe operating space' on at least four of nine planetary boundaries identified by leading Earth system scientists. The four are biodiversity loss, chemical and plastic pollution, nutrient pollution, and greenhouse-gas (GHG) emissions. Two other boundaries—forest cover loss and freshwater consumption—appear to be in the "zone of uncertainty." The destabilization of any of these systems could result in irreversible and adverse environmental changes that would affect societies across the globe.

Agriculture is the largest contributor to the depletion of natural capital, followed by retail sales and services and the power sector. Crop agriculture accounts for 72 percent of freshwater consumption, 61 percent of nitrogen runoff pollution (a component of nutrient pollution), and 32 percent of terrestrial biodiversity loss, according to the midpoint of our estimates. Livestock agriculture is the largest contributor to biodiversity loss, at 53 percent, and to phosphorus pollution (another component of nutrient pollution), at 51 percent. It is also the second-largest contributor to nitrogen runoff and deposition. Agriculture's preponderant role stems from its direct land footprint and its position upstream of other sectors. Farmers are already profitably pursuing several on-farm opportunities to address these challenges, such as regenerative and precision agriculture.

Corporate action could play a key role in setting the globe on the path to recovery by 2050. Our estimate of 47 potential levers, each of which could be implemented today using existing commercial technologies, suggests that corporate action could fully return the world to within the planetary boundaries for freshwater consumption, nutrient pollution, and forest cover loss. Companies could also address almost half of the projected gap to the biodiversity loss boundary through 2050 and 60 percent of chemical and plastic pollution. Nature conservation, consumer dietary shifts, and other "whole of society" levers, while not sized, could also mitigate depletion of natural capital.

Corporate action on nature has meaningful overlap with climate action. Nine of the 47 levers identified have significant abatement potential for both carbon and other planetary boundaries. Together, these nine levers could provide 15 gigatons of CO_2-equivalent ($GtCO_2e$) abatement per year, or about 40 percent of annual emissions in 2020. They comprise eight agricultural levers, including regenerative and precision agriculture, and solar and wind power. Our estimates suggest these levers could address 64 percent of projected freshwater consumption, 44 percent of projected nutrient pollution, and 5 percent of projected biodiversity loss.

Twelve corporate actions with an estimated net-positive ROI of around $700 billion could potentially deliver about 45 percent of the abatement potential we identify. The 12 actions include regenerative-agriculture techniques, food waste reduction, and new delivery models that reduce plastic production (for instance, returnable and reusable container programs). Taken together—and if fully implemented—these 12 levers could achieve an annual benefit of around $700 billion, net of costs. Four other levers are low cost but have potentially high impact, delivering 8 percent of the identified mitigation potential at a net cost of around $15 billion per year, according to our estimates. These four are precision agriculture for cropland, regenerative agriculture in pastures, the recycling of construction plastic, and mechanical recycling. An additional 20 levers, representing 47 percent of the abatement potential, are ROI negative with today's technologies and no pricing of externalities or avoided risks. We estimate that these levers could be achieved at a net cost of up to $1.5 trillion per year. As markets and technologies mature, the ROI of those actions could increase.

The efforts that companies have made on climate action and the lessons they have learned could serve as a starting point for action on nature. As with climate, the first step is to measure and understand a company's current footprint, and the second is to identify actions each company can take, with an initial focus on those that have positive returns and are easier to implement. Many actions that benefit nature would simultaneously yield positive returns for companies.

Corporate action, while a crucial catalyst, will not be sufficient on its own. Public institutions, civil society, academia, and citizens at large all have a role to play, and government leadership needs to coordinate and encourage broad action. Critical enablers include setting clear standards and guardrails for corporate efforts; providing nature-related infrastructure, including data and skills; and creating new approaches to financing and financial accounting.

Executive summary

This report is part of a growing body of McKinsey research focusing on the depletion of natural capital and its potential consequences.[2] It marks a first attempt to identify and size the actions corporations could take to act as catalysts to return the planet to a "safe operating space for humanity."

The issue is a critical one: natural capital is in decline across multiple dimensions (Exhibit E1). By one estimate, current demands require resources at least 1.8 times greater than what the Earth appears to be able to sustain at this point.[3] Yet fatalism would be misplaced: one of our key findings is that while a range of economic sectors contribute to this depletion of natural capital, specific actions by companies using current technologies—and supported by broader enabling actions by the whole of society—could not only reverse the trend but also generate positive return on investment in a substantial number of cases.

The issues of climate and nature are closely intertwined. Addressing the natural-capital challenge is crucial to mitigating climate change, while addressing climate change could help avert or delay several emerging nature-related tipping points.[4] Nature itself provides proven technologies that are available now, cost little, and can remove carbon from the atmosphere and increase resilience to the effects of climate change.[5] Altogether, investing in opportunities to protect, manage, and restore nature—as well as enabling technologies and services such as measurement and verification—can address climate and be attractive today.

Time is not unlimited, however. The economic impacts of climate change and intensive natural-capital use are becoming clearer.[6] In California, water shortages threaten the Central Valley, which accounts for 25 percent of US food production.[7] In Europe, environmental damage stemming from nitrogen pollution has spurred governments to try to reduce the scale and intensity of agriculture.[8] In the Amazon, deforestation has reduced rainfall and is harming agricultural productivity.[9] Worldwide, less than 65 percent of fishery stocks are biologically sustainable, compared to 90 percent in 1974, and some fisheries have collapsed.[10] Should these trends continue, economic activity could be curtailed, in some cases quite severely, depending on the location and conditions. And this could in turn have broader implications, potentially including aggravated supply chain disruptions, population displacements, and conflicts. While business leaders face many immediate challenges, a failure to address

[2] McKinsey research on natural capital includes the reports *Valuing nature conservation* (September 2020), *Why investing in nature is key to climate mitigation* (January 2021), and *Blue carbon: The potential of coastal and oceanic climate action* (May 13, 2022). It also includes articles such as "Reduced dividends on natural capital?" (June 29, 2020) and "Where the world's largest companies stand on nature" (September 13, 2022), as well as targeted research on nature risk, fashion, fisheries, forestry, water, and more. McKinsey's research is supported by sustainability practitioners, Material Economics, McKinsey Nature Analytics, the McKinsey Global Institute, and Vivid Economics.
[3] As measured by biocapacity, or "the capacity of ecosystems to regenerate what people demand from [them]." See *How many Earths? How many countries?*, Earth Overshoot Day, accessed November 9, 2022.
[4] Timothy M. Lenton et al., "Climate tipping points — too risky to bet against," *Nature*, November 2019, Volume 575; Johan Rockström et al., "A safe operating space for humanity," *Nature*, September 2009, Volume 461; Will Steffen et al., "Planetary boundaries: guiding human development on a changing planet," *Science*, January 2015, Volume 347, Number 6223.
[5] "Why investing in nature is key to climate mitigation," McKinsey, January 2021.
[6] "Climate risk and response: Physical hazards and socioeconomic impacts," McKinsey Global Institute, January 16, 2020.
[7] Mu Xiao et al., "How much groundwater did California's Central Valley lose during the 2012–2016 drought?," *Geophysical Research Letters*, April 2017, Volume 44, Number 10; Alan M. Rhoades et al., "The changing character of the California Sierra Nevada as a natural reservoir," *Geophysical Research Letters*, November 2018, Volume 45, Number 23; *California's Central Valley*, United States Geological Survey, accessed November 9, 2022.
[8] See Box 3, "How the Netherlands is seeking to tackle its nitrogen crisis," in chapter 1.
[9] Deborah Lawrence and Karen Vandecar, "Effects of tropical deforestation on climate and agriculture," *Nature Climate Change,* January 2015, Volume 5, Number 174.
[10] *The state of world fisheries and aquaculture 2022: Towards blue transformation*, Food and Agriculture Organization, 2022; Malin L. Pinsky et al., "Unexpected patterns of fisheries collapse in the world's oceans," *Proceedings of the National Academy of Sciences*, May 2011, Volume 108, Number 20.

the challenge of natural capital could exacerbate macroeconomic instability, public-health crises, and geopolitical risk, among other considerations.

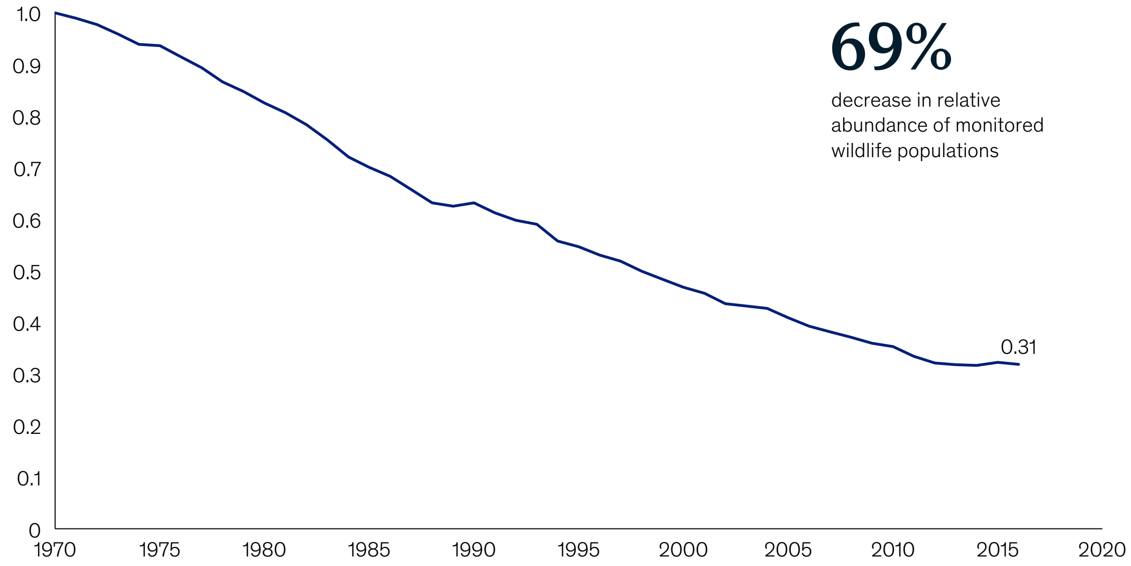
What could be done to move the economy back within what nature can afford? What are the specific opportunities for corporations to lead in this transition? And how could companies benefit? This report—using the best available current science—sets out to answer these questions. First, we lay out our current best understanding about how demands on natural capital are affecting the planet, and then we identify the actions that could help address those impacts (see Box E1, "Our approach and its limitations").

Companies have many compelling reasons beyond good stewardship of the planet in general to act now to replenish natural capital, as we outline in chapter 1. First, many of the potential actions we identify provide a positive ROI; altogether, our midpoint estimate is that there is an annual opportunity of about $700 billion for businesses to reduce operating costs while benefiting the natural environment. Second, transitioning to a nature-positive future can create new business opportunities because new technologies, services, and processes will be needed. Third, as nature degradation spurs stronger calls for action, investors and policy makers may push companies to act—for instance, through new investing criteria or regulations. Finally, failing to take meaningful action on nature could entail operational, transition, reputational, and market risks for companies.[11]

Exhibit E1

Nature is in rapid decline across dimensions.

Living Planet Index,[1] 1970–2018



Other indicators of nature's decline

20% decline in forested areas

33% of topsoil degraded

85% of wetlands lost

50% of coral reef system destroyed

[1]The Living Planet Index (LPI) "is a measure of the state of the world's biological diversity based on population trends of vertebrate species from terrestrial, freshwater, and marine habitats." Globally, monitored populations of birds, mammals, fish, reptiles, and amphibians have declined in abundance by 69 percent, on average, between 1970 and 2018. In other words, the average change in population size in the LPI is a decline of 69 percent. This does not mean that 69 percent of the species or populations are declining nor that 69 percent of populations or individual animals have been lost.
Source: See bibliography

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[11] Samantha McCraine et al., *The nature of risk: A framework for understanding nature-related risk to business*, World Wildlife Fund, 2019.

Box E1

Our approach and its limitations

In this report, we propose an analytical framework for private- and public-sector decision makers to evaluate the impact of human activity on nature and to take action to bring the economy's use of natural capital within a safe operating space for humanity. Our approach builds on decades of work by scientists, policy makers, and businesses, as well as by organizations such as the Stockholm Resilience Centre, Science Based Targets Network (SBTN), and the Taskforce on Nature-related Financial Disclosures (TNFD). We also build on our experience in helping companies address climate change, which intersects and has significant synergies with nature-related efforts.[1]

Through our analysis, we seek to accomplish the following:

— establish a holistic framework for thinking about natural capital, based on the notion of a "safe operating space for humanity," or planetary boundaries

— size sectoral contributions to the current and future state of natural capital across five planetary boundaries

— for five boundaries, identify a set of discrete levers that companies could implement, and estimate the associated costs and benefits

— define an approach for corporate actors to move forward on near-term, no-regret actions, and plan for additional future actions

— outline the additional actions that would be needed from international institutions, policy makers, and consumers in addition to corporate action

This analysis represents a partial view of what it will take for the economy to transition to a nature-positive footing; by "nature positive," we mean any activity or action that could contribute to reducing negative impacts or generate positive impacts on nature. The sized levers are globally relevant actions that nonfinancial corporate leaders can implement directly, using available technologies, without reducing overall output. For clarity, we report our estimates as global averages or midpoint values where we have estimated high and low values. We did not size actions that would have to be driven by policy actors (for example, subsidy reform), financial actors (for example, green financing), and consumers (for example, global demand reduction), although such actions can help support and enable corporate action. As such, this report focuses on how companies could lead the way and highlights how much additional action would be required from other stakeholders.

There is much this report does not cover. For instance, there are insufficient data for two of the nine planetary boundaries to allow meaningful analysis. Our analysis does not include systematic consideration of second-order effects, upstream and downstream relationships between sectors, or issues of social impact and environmental justice, though these are critical.[2] Nor do we consider impacts not captured in the metrics used in the planetary-boundaries framework, which focuses on global systems. Actions that have a meaningful local impact but generate limited contributions to planetary boundaries (for example, water pollution, chemical spills, nuclear waste, or sulfur emissions) would nonetheless be crucial.[3]

An important challenge is the current state of planetary science. While there is a broad scientific consensus about the existence of planetary boundaries and the momentum toward breaching them, scientists continue to debate which planetary systems are most critical and the exact thresholds beyond which the world would risk triggering potentially irreversible tipping points. This report relies on a range of assumptions to project where the planet could stand against the planetary boundaries in 2050, to attribute impacts to specific sectors, and to identify, size, and price actions that could bring us back within those boundaries.

More-refined analyses will doubtless be possible in the future as the underlying science advances, as better data are gathered, and as methodologies mature. But the humility that the current state of knowledge and analysis imposes should not obscure the urgency to initiate or accelerate efforts on the path to a nature-positive economy.

Full details of our methodology can be found in the relevant chapters and the technical appendix. For details on exhibit sources, see the bibliography.

[1] For more, see "Greenhouse gas abatement cost curves," McKinsey, accessed November 8, 2022.
[2] In general, this report excludes levers that have obvious negative second-order impacts or where there is a clear lack of scientific alignment (for example, clearing forest undergrowth to abate forest fires). Nevertheless, implementing any levers at a local or company level will require case-by-case analysis and engagement with local stakeholders to better understand local impacts.
[3] The planetary-boundaries framework highlights that both "top down" (global) and "bottom up" (local) impacts must be addressed to maintain a safe operating space for humanity. See Johan Rockström et al., "A safe operating space for humanity," *Nature*, September 2009, Volume 461.

Human activity seems to have pushed the planet outside a 'safe operating space for humanity' on four planetary boundaries

To frame our research, we use the latest scientific research on planetary boundaries. Introduced in 2009 and updated in 2015, these boundaries provide a framework for tracking the planet's ability to support human development. The framework defines a "safe operating space for humanity" with respect to the systems and processes that govern the stability of the Earth's atmosphere, oceans, and ecosystems.[12] While climate change and some of its cascading impacts are now more familiar, the planetary-boundaries framework outlines eight additional Earth systems that, if destabilized beyond a defined level, could trigger a tipping point and lead to irreversible environmental changes, according to what we know today.[13]

For this research, we focused on five of the seven planetary boundaries for which reliable data are available. We exclude ozone depletion, which is on a path to recovery thanks to the success of international efforts under the Montreal Protocols,[14] and conduct limited analysis on climate change, which has been covered extensively in other research.

Our findings highlight the current challenge: the impact of human activity is already extending beyond the safe space for at least four boundaries: biodiversity loss, chemical and plastic pollution, nutrient pollution, and greenhouse-gas emissions (Exhibit E2).[15] For the two other boundaries—forest cover loss[16] and freshwater consumption—the current impact of human activity is deemed to be in the "zone of uncertainty."[17]

Terrestrial biodiversity loss stands out, at an estimated 2.7 times beyond the planetary boundary as currently understood and 1.4 times beyond 1970 levels. This raises an alarm not only because of its direct impact on humanity but also because of the feedback loops between biodiversity and the other boundaries. For example, ecosystem degradation can alter precipitation patterns and river flow at subglobal scales and reduce ecosystem capacity for retaining nitrogen and phosphorus, thus increasing nutrient pollution.[18] Another standout is the chemical and plastic pollution boundary. We estimate that the world economy currently emits 2.6 times more plastic into water sources each year than in 2010—negatively affecting species, ecosystems, and food webs and reducing the ability of oceans to sequester carbon.[19]

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[12] Ibid.

[13] Nico Wunderling et al., "Interacting tipping elements increase risk of climate domino effects under global warming," *Earth System Dynamics*, June 2021, Volume 12.

[14] Kelsey Piper, "The shrinking ozone hole shows that the world can actually solve an environmental crisis," Vox, October 27, 2022.

[15] Outside of the "safe space" is defined as being outside of the identified "zone of uncertainty" (for biodiversity and climate change) or beyond the planetary boundary where there is no defined "zone of uncertainty." This report's use of control variables and planetary-boundary thresholds are explained in detail in Box 1 in chapter 2.

[16] This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch (GFW), which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary boundaries framework because plantation forests still enable land–climate interactions.

[17] The creators of the planetary boundaries include both a strict, inner threshold (the "boundary") informed by the precautionary principles and a looser, outer threshold, which corresponds to being outside the "zone of uncertainty." The risks are characterized as tipping points that could cause sudden, significant, and irreversible shifts in life-supporting Earth systems. Beyond the "boundary," risks of triggering a tipping point begin to increase, while beyond the "zone of uncertainty," those risks increase further.

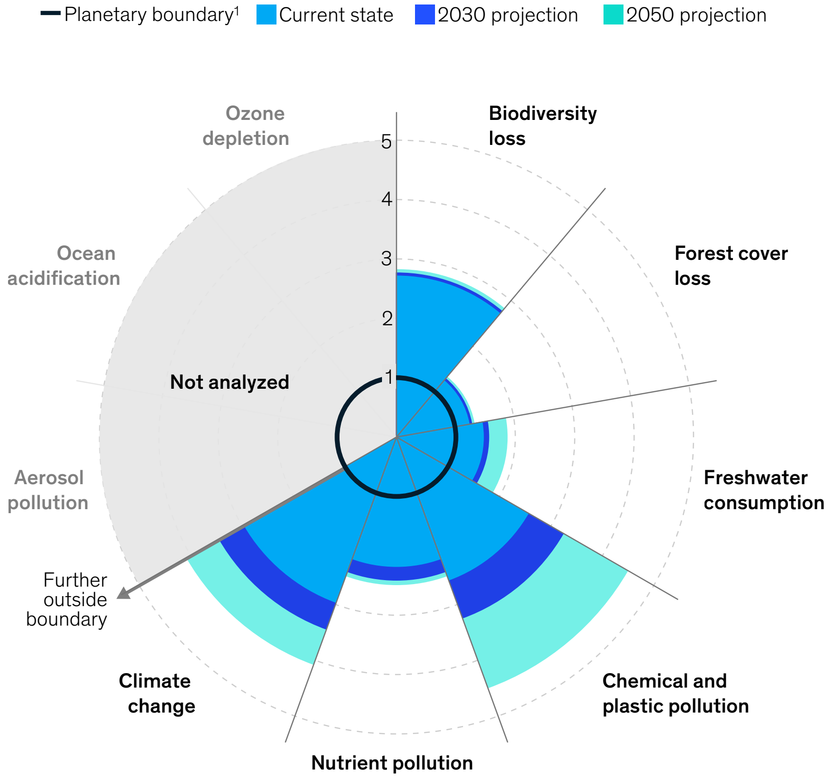
[18] Georgina M. Mace et al., "Approaches to defining a planetary boundary for biodiversity," *Global Environmental Change*, September 2014, Volume 28.

[19] This report follows recent scientific literature to focus on plastic-waste emissions to aquatic environments as the control variable of interest for "the introduction of novel entities" boundary, which this report refers to as "chemical and plastic pollution" or simply "plastic pollution." Although there is no "official" boundary for plastic-waste emissions to aquatic environments, following the suggestion of leading plastic-waste emissions scientists and research by the United Nations Environment Programme, this report uses 2010 plastic-waste emissions to aquatic environments as a reference boundary, which equates to eight metric megatons (Mt) per year. See Linn Persson et al., "Outside the safe operating space of the planetary boundary for novel entities," *Environmental Science & Technology*, January 2022, Volume 56, Number 3; Stephanie B. Borrelle et al., "Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution," *Science*, September 2020, Volume 369, Number 6510; Sarah E. Cornell, Joan Fabres, and Patricia Villarrubia-Gómez, "Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle," *Marine Policy*, October 2018, Volume 96; and United Nations Environmental Assembly, 2019.

Exhibit E2

Human activity seems to have pushed the planet two times beyond the 'safe operating space' on at least four boundaries.

Current and projected status against planetary boundaries, multiples beyond planetary boundary[1]



Boundary Control variable		
Biodiversity loss Biodiversity intactness index (BII)[2]	**Chemical and plastic pollution** Plastic-waste emissions to aquatic environments	Aerosol pollution Not analyzed—lack of reliable data
Forest cover loss[3] Forested land as a percent of potential forest cover	**Nutrient pollution[4]** Nitrogen runoff, nitrogen deposition, and phosphorous pollution	Ocean acidification Not analyzed—lack of reliable data
Freshwater consumption Blue-water consumption	**Climate change[5]** Contribution of GHG[6] emissions to warming	Ozone depletion Not analyzed—on path to recovery

Note: Refer to technical appendix section 2 for a detailed analytical approach for each boundary.
[1]This chart only reports the planetary boundary and does not include the looser, outer "zone of uncertainty." Beyond the strict boundary there is a nonzero risk of triggering a "tipping point" (systems collapse).
[2]BII is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.
[3]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions.
[4]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution. The exhibit shows the current state and projections for phosphorous pollution, which is the furthest beyond the boundary of the three.
[5]This report's analysis follows the planetary-boundaries literature to use "radiative forcing," which measures excess Earth system energy and, when positive, causes warming. Radiative forcing is driven in large part by GHG emissions.
[6]Greenhouse gas.
Source: See bibliography

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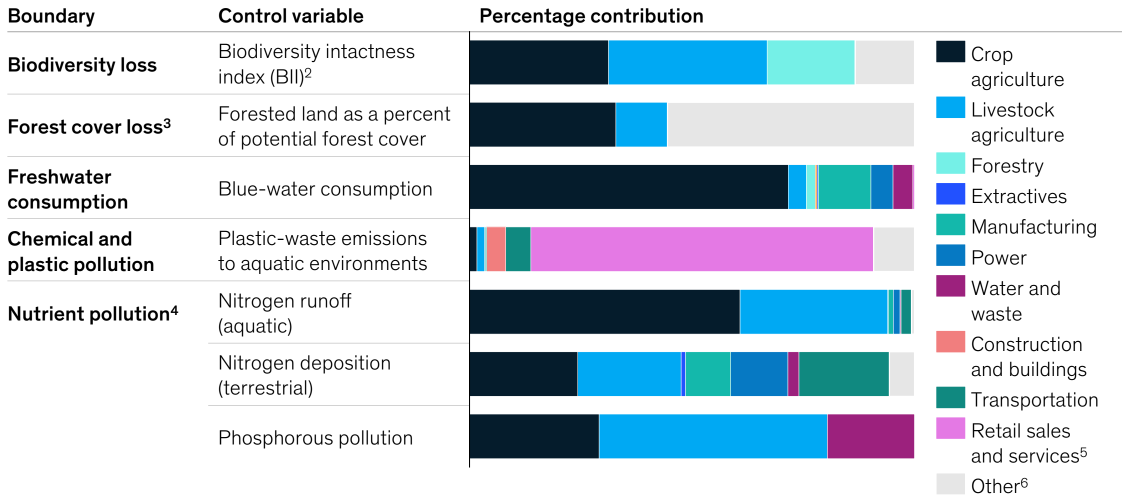
Agriculture is the largest contributor to exceeding planetary boundaries, as currently understood

As part of our analysis of planetary boundaries, we estimate the contributions of economic sectors to the current position against each boundary. This analysis only looked at direct impacts, rather than indirect ones manifesting themselves throughout an industry's entire value chain, even though those impacts are also critical. One sector in particular—agriculture—has the largest single direct impact, based on this analysis (Exhibit E3). The retail sales and services sector—which includes retail, accommodation and food services, IT, finance, insurance, professional and support services, education, health, and entertainment—is also a major contributor to some of the boundaries, according to this analysis, notably chemical and plastic pollution.

Exhibit E3

Agriculture is the largest contributor to exceeding planetary boundaries, as currently understood, followed by retail sales and services.

Sectoral contributions[1] toward each planetary boundary, % on relative scale



Note: Analysis focuses on five of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Greenhouse-gas emissions are excluded because they are well covered in other reports. Refer to technical appendix section 2 for a detailed analytical approach for each boundary.
[1]Sectoral contributions are calculated based on direct operations and do not account for upstream or downstream impacts (for example, construction contributes to biodiversity loss primarily through the purchase of materials, not directly).
[2]The biodiversity intactness index (BII) is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.
[3]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions. Report assumes no forestry-induced forest cover loss because that sector converts primary forest to secondary and plantation forest, which still conserves total forest cover.
[4]Nitrogen runoff: global nitrogen runoff contributing to surface water eutrophication risk; nitrogen deposition: global nitrogen deposition contributing to terrestrial ecosystem eutrophication and acidification risk; phosphorus pollution: global phosphorus pollution contributing to surface water eutrophication risk. This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.
[5]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
[6]This category includes biodiversity and forest loss attributed to grassland, peatland, bare land, and shrubland on primary forest which is not directly attributable to sectoral activities, as well as a very small contribution from urban land use.
Source: See bibliography

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Food systems have the most significant impact on the environment: they are the largest contributing sector in five of the nine planetary-boundary control variables we assessed. Our midpoint estimates suggest that crop agriculture accounts for 72 percent of freshwater consumption, 61 percent of nitrogen runoff pollution, and 32 percent of terrestrial biodiversity loss. We estimate that livestock agriculture is the largest contributor to biodiversity loss (53 percent) and phosphorus pollution (51 percent)[20] and is the second-largest contributor for nitrogen runoff and deposition.

The disproportionate estimated impact of agriculture stems from its direct land footprint (50 percent of total habitable land, far more than any other use[21]) and from the strong influence of downstream sectors such as the food-processing industry. Therefore, many actions that would address the impact of agriculture on natural capital would require sustained behavioral and operational changes from downstream actors. Examples include individual households (for instance, changes in diet and total fuel consumption) and buyers of agricultural products (for instance, reducing waste in food processing, groceries, and restaurants or purchasing sustainably cultivated fibers for textile manufacturing).[22]

Retail sales and services account for 77 percent of chemical and plastic pollution (as measured by plastic-waste emissions to aquatic environments), according to our midpoint estimates. Previous McKinsey research has identified the power sector and industry (including manufacturing and extractives) as the largest contributors to the GHG emissions that drive climate change.[23]

Corporate action could help set the planet on a path to recovery by 2050

Our research suggests that companies have the potential to shift the world's trajectory on natural capital and usher in a return to a safe operating space for humanity by 2050. It also suggests that they could do so through a set of targeted actions that use existing technologies and that in many cases could provide positive returns on investment.

Our research assesses the holistic effect of 47 potential corporate actions,[24] or levers (detailed below), across five planetary boundaries: biodiversity loss, forest cover loss, freshwater consumption, chemical and plastic pollution, and nutrient pollution.[25] Our analysis includes only levers that do not have a significant negative impact on other planetary boundaries. For example, a recent McKinsey report highlights that in many applications, plastics have a lower total GHG contribution than currently available alternatives and help reduce food waste from spoilage.[26] Because of these potential trade-offs, we largely exclude levers related to replacing plastics with alternative materials.

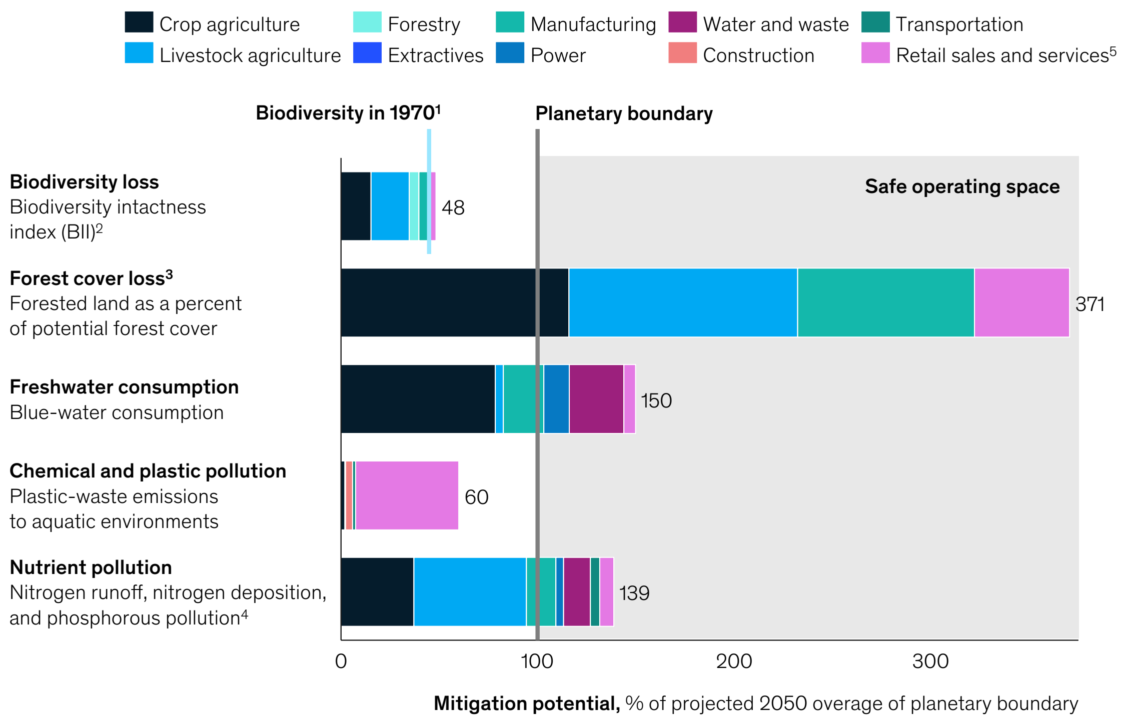
[20] This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste that is lost to the environment (that is, manure that is left over once manure has been processed or used for other agricultural applications). See Sanna Lötjönen, Markku Ollikainen, and Esa Temmes, "Dairy farm management when nutrient runoff and climate emissions count," *American Journal of Agriculture Economics*, May 2020, Volume 102, Number 3; and Fei Lun et al., "Global and regional phosphorus budgets in agricultural systems and their implications for phosphorus-use efficiency," *Earth System Science Data*, 2018, Volume 10.
[21] Hannah Ritchie and Max Roser, "Land use," Our World in Data, September 2019.
[22] *True cost of food: Measuring what matters to transform the U.S. food system*, Rockefeller Foundation, July 2021.
[23] "The net-zero transition: What it would cost, what it could bring," McKinsey, January 2022.
[24] This report used a bottom-up process to identify almost 900 lever ideas from various sources, including peer-reviewed articles, external industry experts, internal knowledge experts, and corporate and industry reports. We also drew on our experience serving a wide range of companies.
[25] See "Climate math: What a 1.5-degree pathway would take," *McKinsey Quarterly,* April 2020; "The net-zero transition," January 2022; and *Agriculture and climate change,* McKinsey, April 2020.
[26] "Climate impact of plastics," McKinsey, July 2022.

Overall, the midpoint results of our analysis suggest that corporate action could potentially return the world to safety in three of the planetary boundaries: forest cover loss, freshwater consumption, and nutrient pollution. The sized levers could also address 48 percent of the projected overage of the boundary for biodiversity (getting close to a pre-1970 level) and 60 percent of the identified boundary for chemical and plastic pollution. Exhibit E4 highlights the abatement potential identified across all boundaries examined.

Exhibit E4

Agriculture and retail sales and services seem to have the most abatement potential, though all sectors have a role to play.

All sectors, by sector



Note: Analysis focuses on five of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Greenhouse-gas emissions are covered in other reports and not recreated here. See "The net-zero transition: What it would cost, what it could bring," McKinsey, January 2022; "Climate math: What a 1.5-degree pathway would take," *McKinsey Quarterly,* April 2020; and *Agriculture and climate change,* McKinsey, April 2020. Refer to technical appendix section 3 for a detailed analytical approach for each boundary and sector.
[1]In the literature, the biodiversity intactness index (BII) zone of uncertainty ranges from 10 to 70 percent loss. However, this is subject to a great deal of debate and uncertainty, so the report uses the 1970-level of BII loss to contextualize a potential zone of uncertainty.
[2]BII is an estimated percentage of the preindustrial (pre-1750) number of species from remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.
[3]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions. Report assumes no forestry-induced forest cover loss because that sector converts primary forest to secondary and plantation forest, which still conserves total forest cover.
[4]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution, all weighted equally. This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.
[5]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
Source: See bibliography

McKinsey & Company

Our analysis demonstrates that corporate action, using technologies and approaches available today, could make a meaningful contribution to addressing the challenge of the planetary boundaries. But corporate action alone is not sufficient (Exhibit E4). “Whole of society” levers such as nature conservation could help close the remaining gaps, as could technologies not yet widely available and thus not included in our analysis, such as novel enzymes that can break down plastic and technologies to extend the shelf life of foods.

Of course, demonstrating a potential for abatement does not ensure its realization. Any given lever represents a fundamental change in the way companies operate—and, by extension, in the way people consume their products and services. The abatement potential we present assumes that each opportunity is pursued systematically and completely, where feasible, across the world; that there is collaboration and coordination between upstream and downstream partners (for instance, between farmers and the buyers of agricultural products); and that policy makers and other stakeholders create enabling conditions.

Almost half of the estimated abatement potential could provide a positive return on investment

Based on our midpoint estimates (and subject to the limitations outlined in Box E1, “Our approach and its limitations”), 12 levers would have a net-positive ROI in 2022 dollars. If fully implemented, these 12 levers could deliver around 45 percent of the total identified mitigation potential, amounting to an annual benefit of about $700 billion, net of costs.[27] These levers include switching to regenerative agriculture, reducing food waste, and implementing new delivery models (for instance, returnable and reusable container programs) to reduce plastic production and pollution.

Four levers—precision agriculture for cropland, regenerative agriculture in pastures, the recycling of construction plastic, and mechanical recycling—are defined as low cost.[28] Estimates suggest that together, they could deliver 8 percent of the identified mitigation potential at a net cost of around $15 billion per year.

Twenty levers[29] are estimated to be ROI negative in 2022 dollars. If fully implemented, they could deliver around 55 percent of the identified mitigation potential at an annual cost, net of savings, of about $1.5 trillion.[30]

Of these 20 levers, 13 are defined as moderate cost and could together deliver 32 percent of the identified mitigation potential at a net cost of around $1.1 trillion per year. These include agroforestry, biological pest control, drip irrigation, water-efficient manufacturing techniques, and biodegradable plastic for packaging.

[27] This report defines ROI in net terms for each lever, meaning that the reported figures include estimates of both costs and savings. Hence, ROI-positive levers are defined as levers where the estimated capital and operational savings exceed capital and operational costs on an annual basis. The net costs and savings are calculated in today’s dollars (2022) based on three components: (1) incremental capital expenditures required to implement the lever, calculated by dividing total incremental capital expenditure by the lifetime of the capital; (2) incremental operating expenditures required to implement the lever; and (3) incremental operating savings resulting from implementing the lever. We report midpoint estimates based on maximum feasible adoption of each lever.

[28] The cutoff between moderate and high cost is defined for each boundary. Biodiversity loss: $500 per hectare (ha), one-third the average agriculture operational cost in the United States; freshwater consumption: 90 cents per cubic meter, the average municipal price of water in the United States; chemical and plastic pollution: $22 per kilogram (kg) of plastic pollution, the average cost of plastic production that results in one kg of plastic pollution to aquatic environments; nutrient pollution: $1 per kg of nitrogen runoff, the average cost of nitrogen fertilizer production. The cutoff between low and moderate cost is defined as 10 percent of the medium to high cutoff.

[29] We exclude 11 other higher-cost levers in the topline ROI numbers, such as the use of nitrogen inhibitors in cropland and desalination, because these could provide mitigation above what is needed to address the freshwater and nutrient boundaries (and do not address other boundaries). They may have local applications.

[30] These figures represent a lower bound to the overall cost of bringing the world within planetary boundaries, given that the sized levers do not completely address biodiversity loss and plastic pollution. They also do not include the other, unsized boundaries.

The seven remaining levers of the 20 are defined as high cost and could together deliver 15 percent of the identified mitigation potential at a net cost of around $370 billion per year. These include the use of manure management, mine reclamation, and wastewater treatment.

These rough ROI estimates are bound to change over time. New technologies can reduce costs, and new policies and new investor expectations could encourage greater accounting of nature impacts. Conversely, costs may be higher, or returns lower, due to localized challenges in implementing levers or slow adoption. One limitation of our analysis is that the underlying models do not account for the cost of negative externalities or include an assessment of nature risk.[31] If included, such measures could make levers that are currently ROI negative more attractive.

Corporate action on nature would have meaningful overlap with climate action

Action to address loss of natural capital overlaps with decarbonization activities that companies are already contemplating or pursuing. The costs above exclude the total cost of action on climate, which is covered in more depth in other McKinsey research,[32] but there are synergies.

For our research, we include carbon abatement levers only if they provide abatement potential across noncarbon planetary boundaries—13 of 47 levers meet this criteria. Nine of the 13, including regenerative and precision agriculture, drip irrigation, and switching to solar and wind power generation, are included above and together could address 64 percent of the projected gap to the freshwater boundary, 44 percent of the gap for nutrient pollution, and 5 percent of the gap for biodiversity loss.[33] Estimates suggest these nine levers could also abate 15 $GtCO_2e$ of emissions per year, or about 40 percent of annual emissions in 2020.[34]

We exclude four of the 13 levers from top-line numbers because they are more expensive and exceed the requirements to address the five planetary boundaries analyzed. While we did not size CO_2 potential for the 34 other levers, many of them could also have a net climate benefit.

All sectors could meaningfully contribute to abating loss of natural capital

Of all sectors, agriculture seems to have the greatest opportunity to address projected overages or gaps in the biodiversity, freshwater, and nutrient planetary boundaries by 2050. Agriculture levers account for 72 percent of the total identified improvement in biodiversity loss, addressing 35 percent of the global overage in 2050, according to the midpoint estimate of our analysis. Agriculture could also bring the world entirely within the planetary boundary for forest cover loss, address 82 percent of the gap to the freshwater consumption boundary, and meet 94 percent of the gap for nutrient pollution in 2050.

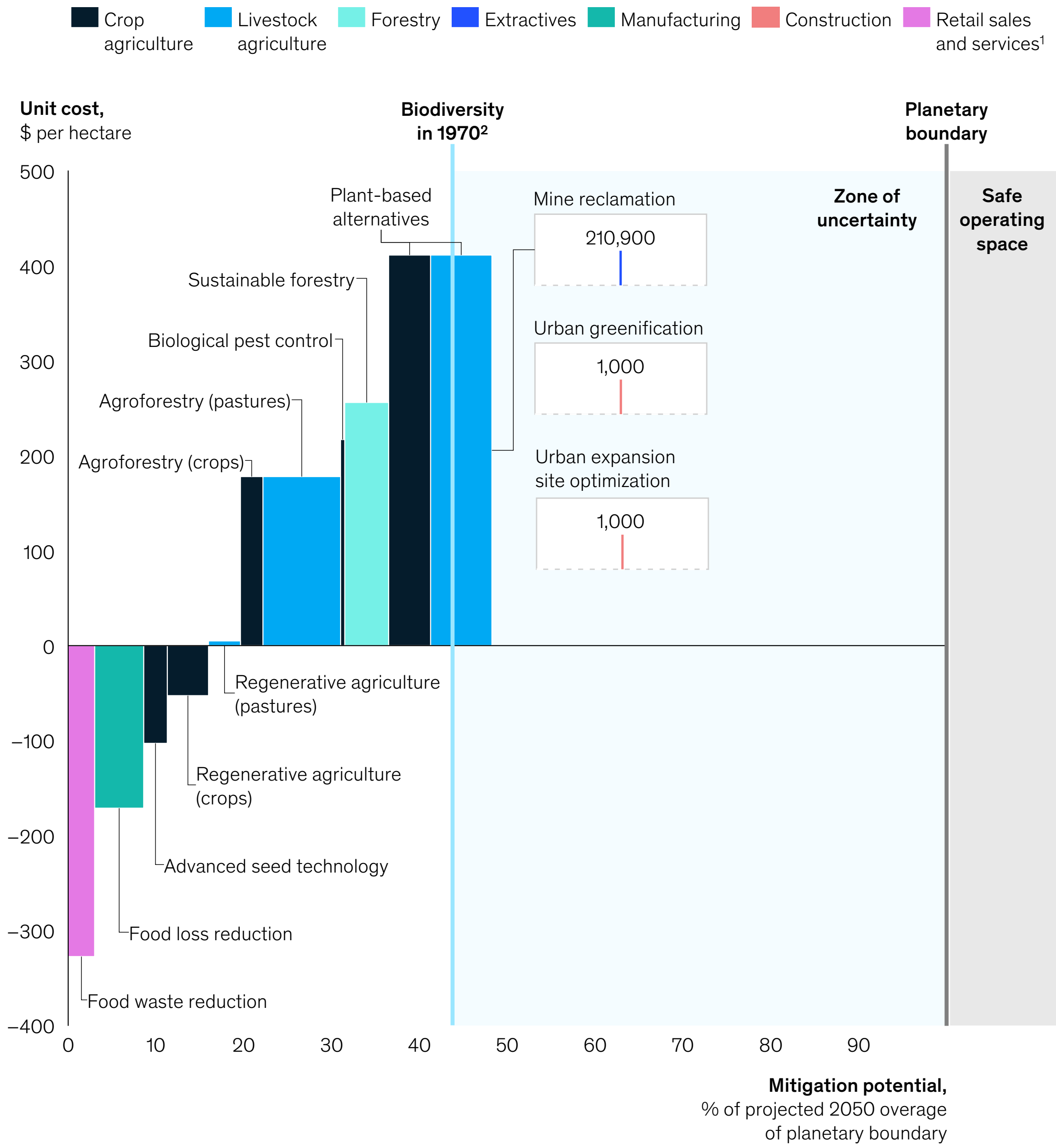
Exhibit E5 depicts the cost curve for biodiversity, highlighting the most cost-effective levers as understood today. The gap to the planetary boundary highlights the challenge of returning to the safe operating space for humanity by 2050.

[31] Financial markets typically do not value nature or externalities that negatively affect nature unless they are associated with a defined asset value or cash flow. Economic models also typically undervalue or fail to value nature due to several interconnected market failures: the benefits of natural capital are often public goods that are nonexcludable and non-rivalrous, the costs and benefits of nature are external to actors who conserve or destroy nature, and discount rates underestimate the value of long-term ecosystem stability compared with economic returns from short-term natural asset consumption. The immense complexity of interdependent and dynamic natural systems also poses a challenge. For a deeper discussion of these issues, see Andrew Deutz et al., *Financing Nature: Closing the global biodiversity financing gap*, Paulson Institute, Nature Conservancy, and Cornell Atkinson Center for Sustainability, 2020; Partha Dasgupta, *The economics of biodiversity: The Dasgupta review*, London: HM Treasury, February 2021.
[32] "The net-zero transition," January 2022; "Climate math," April 2020; *Agriculture and climate change,* April 2020.
[33] See *Agriculture and climate change,* April 2022 and "The net-zero transition," January 2022.
[34] 15 $GtCO_2e$ divided by 38 Gt emitted in 2020.

Exhibit E5

The biodiversity cost curve highlights the most cost-effective levers we identified and the challenge in closing the gap to the planetary boundary.

Corporate levers to mitigate biodiversity loss, volumes represent lever mitigation potential



Note: Refer to technical appendix section 3 for detailed analytical approach for each boundary and sector.
[1]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
[2]Biodiversity loss is calculated using the the biodiversity intactness index (BII), which is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments. In the literature, the BII zone of uncertainty ranges from 10 to 70 percent loss. However, this is subject to a great deal of debate and uncertainty, so the report uses the 1970-level of BII loss to contextualize a potential zone of uncertainty.
Source: See bibliography

McKinsey & Company

Midpoint estimates suggest that eight levers, if fully implemented, could have the largest effect in addressing the agriculture sector's impacts on nature. Four of these levers require collaboration across the supply chain, but the agricultural sector could implement four directly:

— **Regenerative agriculture**, which includes planting cover crops and using no-till farming, could address three out of five planetary boundaries by minimizing soil disturbance, limiting consumptive water losses, and enhancing habitats. At scale, it could mitigate 8 percent of the projected 2050 gap to the biodiversity boundary, 5 percent of the gap to the freshwater consumption boundary, and 16 percent of the gap to the nutrient pollution boundary. We estimate that regenerative agriculture, if fully implemented, could reduce farm operational and input costs and would therefore be ROI positive, potentially providing $65 billion in value annually.

— **Agroforestry**, which includes planting trees in cropland and pastureland and implementing buffer strips of natural vegetation cover, is the largest lever for biodiversity, according to our estimates. Like regenerative agriculture, it could help improve the biodiversity potential of working lands. We assume that it would be implemented in a way that does not affect output (meaning that greater implementation is possible, although at a cost of lost productivity). Combined, agroforestry in cropland and pastureland could reduce 11 percent of the projected 2050 gap to the biodiversity boundary across cropland and pastureland for a cost of approximately $180 per hectare. We estimate that full mitigation would cost $300 billion globally each year.

— **Water-efficient agriculture techniques**, including alternate-furrow irrigation, optimized-drip irrigation, and water-efficient seeds, could reduce freshwater consumption to address 19 percent of the projected 2050 global overage. We estimate that water-efficient agriculture could provide $40 billion in net value globally each year from reduced water consumption when fully implemented.

— **Manure management techniques**, including anaerobic digesters on large farms and manure sequestration on smaller farms, could be a large part of the solution for nutrient pollution, potentially addressing 39 percent of the projected nitrogen surface runoff overage and 32 percent of the projected phosphorus pollution overage. Both techniques would involve increased costs, such as investing in necessary infrastructure and operational costs. We estimate the net annual global cost to be $45 billion.

Four additional levers could affect the agriculture baseline but would require close partnership between the agriculture sector and downstream sectors. Our estimates suggest that plant-based alternatives for meat and dairy; advanced seed technology, including genetically modified seeds; and reduction of food loss and food waste through supply optimization could help pull the economy back toward the boundaries.[35] The impact could play out in reducing the amount of land converted to agriculture or in enabling rewilding of current agriculture land. Taken together, these levers could address 23 percent of the gap to the biodiversity planetary boundary, 100 percent of the gap to the forest cover loss boundary, 45 percent of the gap for freshwater consumption, and 55 percent of the gap for nutrient pollution—while simultaneously generating net savings for companies. Advanced seed technology and food waste reduction would be ROI positive, with an estimated net annual savings opportunity of $320 billion. Corporate-driven adoption of plant-based alternatives (which would require pricing at a loss to achieve parity with animal-based products and to drive adoption) is currently estimated to be ROI negative and could cost $370 billion annually.[36]

[35] Moira Borens, Sebastian Gatzer, Clarisse Magnin, and Björn Timelin, "Reducing food loss: What grocery retailers and manufacturers can do," McKinsey, September 7, 2022.
[36] Wider adoption of plant-based alternatives would require broader policy incentives and is outside the scope of the corporate abatement potential identified.

Nonagricultural actors can also implement levers to address their direct footprints. The following four actions have significant potential for abatement:

— **Switching to solar and wind power** could reduce freshwater consumption by 12 percent of the gap to the planetary boundary and nutrient pollution by 4 percent. Our estimate suggests that implementing low-cost power generation switching could provide net value of $95 billion annually through lower operating costs.[37]

— **Addressing plastic waste**—by reducing the amount of plastic in packaging, implementing new delivery models (for instance, returnable and reusable container programs), expanding mechanical and chemical recycling of plastics, and using compostable bioplastics—could help the retail sales and services sector address 52 percent of the plastic pollution overage. Plastic reduction and alternative delivery models would be ROI positive, providing an estimated $35 billion annually in value by reducing the amount of plastic needed. The remaining levers are ROI negative, costing $40 billion annually from increased capital and operational costs. While the levers above could reduce plastic-waste emissions to aquatic environments in the long run, improved plastic-waste management will be critical in the short term because plastic production is expected to remain high.

— **Sustainable-forestry** measures—including variable thinning instead of clear-cutting, the creation of buffers, subsoiling, and multispecies forestry techniques—could help the forestry sector address 5 percent of the overage on biodiversity. These measures could result in an estimated net cost of $300 billion annually because of reduced profitability from variable thinning and buffers and the operational costs of implementing subsoiling.

— **Mine reclamation**, specifically in regions where it is not currently required, is unlikely to be able to address more than 0.1 percent of the projected 2050 overage of biodiversity loss. But it would be important at a local level and for other measures not quantified in this analysis, including water pollution, chemical pollution, and heavy-metal contamination, all of which have biodiversity impacts not captured in measures of mining's direct footprint.[38] Expanded mine reclamation efforts could cost up to $60 billion annually.

Four actions could guide corporate efforts on nature

There has been an increasing focus on how to define corporate road maps to climate action, but the playbook for corporate engagement on nature is still in early development. Some companies are starting to acknowledge dimensions of nature such as biodiversity loss, but very few have set quantified targets, and those commitments vary (Exhibit E6).[39]

Companies that have set targets include French beauty-care firm L'Oréal, which has developed more than 15 targets for 2030 for "managing water, respecting biodiversity, and preserving natural resources" based on the planetary boundaries framework,[40] and Ørsted, a Danish power company that has set targets for circular resource use and has committed to a net-positive impact on biodiversity for all of its projects starting in 2030.[41] In the United States, retailer Walmart has committed to protect, restore, or improve the management of

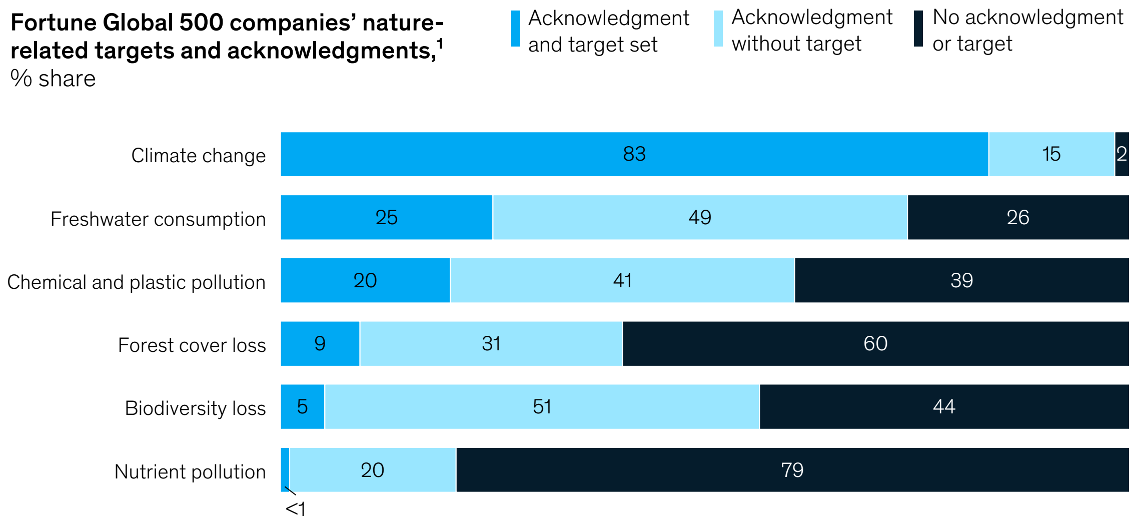
[37] Cost is based on estimates from McKinsey's Global Energy Perspective and was updated in May 2022. Estimates are forward looking, accounting for future returns over the lifetime and using future forecasts for electricity and gas prices. Actual returns may vary due to the complex and volatile global environment and local variation. Companies may experience higher prices today because of exceptionally high demand and elevated gas prices, among other factors.
[38] The direct land footprint of mining is relatively small on a planetary basis, although indirect impacts can be larger. The planetary boundaries framework may, therefore, underestimate the impact of mining. For instance, mining has been shown to increase deforestation up to 70 kilometers beyond mining lease boundaries, causing 12 times more deforestation than within the lease alone. See Laura J. Sonter, "Mining drives extensive deforestation in the Brazilian Amazon," *Nature Communications*, October 2017, Volume 8.
[39] "Where the world's largest companies stand on nature," McKinsey, September 13, 2022.
[40] *L'Oréal for the Future: Our sustainability commitments for 2030*, L'Oréal, June 2020.
[41] *Green energy for the planet and its people*, Ørsted, 2021.

at least 50 million acres of land and one million square miles of ocean by 2030, among other detailed and metrics-based nature goals.[42]

Exhibit E6

Corporate targets are common for climate change but far less common for other dimensions of nature.

Fortune Global 500 companies' nature-related targets and acknowledgments,[1]
% share



Note: Analysis focuses on six of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Figures may not sum to 100%, because of rounding.
[1]Includes 460 of the Fortune Global 500 companies. A target is defined as a company having set a quantified, time-bound, and outcome-oriented target across the entire organization. A commitment to spend a certain dollar amount without a target outcome or time period did not count as a target. An acknowledgment means that a company refers to that dimension of nature and either acknowledges its importance or reports ad hoc steps or initiatives it has taken to mitigate impacts, without specifying a concrete goal.
Source: See bibliography

McKinsey & Company

Given all the demands facing companies in a challenging macroeconomic environment, it can be hard to know where to start. Four steps could help companies find their way:

First, companies can assess their nature footprint—that is, the types, magnitude, and materiality of their impacts and dependencies on nature.[43] Before defining a nature strategy, companies would need transparency to ensure they can mitigate risks, address impacts on natural capital, and identify business opportunities. Companies can select metrics that broadly address impacts across their footprints from among numerous indicators already available.

Second, companies can identify which of their own activities have the potential to both reduce impacts on nature and improve company performance. For each potential company-specific lever, companies can determine the abatement potential, how long it would take to have impact, sources of financing, and possible returns, among other factors. The "mitigation hierarchy"—an international framework from the World Bank's International Finance

[42] *Sustainability*, Walmart, 2022.
[43] For a methodology that can help companies "identify which environmental issues to set targets on, for which parts of the business," see *Technical guidance for Step 1: Assess and Step 2: Prioritize*, Science Based Targets Network, September 2022.

Corporation—could provide guidance on the priority order of actions to take.[44] A range of ROI-positive activities could improve operational efficiency and reduce dependencies. Companies may choose to tackle these ROI-positive levers first but would likely want to keep sight of the abatement potential of each lever and what it would take to address the company's overall nature footprint.

Third, companies could set initial targets for nature and levels of commitment, define a set of actions, and integrate them into a broader portfolio of initiatives. Companies may look to organizations such as the Science Based Targets Network (SBTN) for guidance on how to set time-bound, science-based, and quantitative targets in line with the planetary boundaries.[45] Companies can also choose to make their nature commitments public, which provides an opportunity to build an identity around nature commitments. Nimbleness and flexibility are the name of the game, particularly in today's evolving environment, so company approaches may evolve over time.

Fourth, companies can closely monitor progress against their goals and may prepare to disclose that progress as it unfolds. Various organizations are working to develop standardized voluntary reporting metrics, and the Taskforce on Nature-related Financial Disclosures (TNFD) has developed detailed guidance across four pillars of disclosure: governance, strategy, risk management, and metrics and targets.[46] For companies that have made public commitments, disclosure is an opportunity to provide a progress update and help inspire broader action on nature.

These actions would all require an iterative test-learn-refine approach. As companies monitor progress and learn, they can refine their approach and test new levers. They can also integrate new technologies and the latest scientific thinking and respond to changes in market conditions, regulatory and consumer expectations, and more.

Corporate action on nature would need to be accompanied by enabling actions from other stakeholders

Companies can do much to support the return to a safe operating space for humanity, but they cannot do it on their own. Other stakeholders in both the public and social sectors would have a critical role to play in tackling issues including evolving regulatory and policy guidance, a lack of standardized metrics or definitions of nature, widely distributed and nonstandard nature-related data, a lack of funding and financial incentives, limited options for investing in nature's recovery, and a shortage of needed "green" skills. Three broad sets of enabling actions are required to overcome these and other barriers:

1. **Providing a framework for corporate nature efforts.** Standard nature reporting requirements would be needed to increase transparency, help companies identify which metrics are most critical, and make company disclosures consistent and comparable. Additionally, while companies could set ambitious targets on their own, governments can help encourage broader corporate action by setting clear guidance for nature actions and the outcomes to target.

[44] The mitigation hierarchy provides guidance on the priority order for companies to take in identifying and implementing actions to reduce their impact on nature. As outlined in the International Finance Corporation's Performance Standard 6, it includes, in order of priority, avoiding negative impacts, reducing negative impacts, restoring nature when negative impacts are unavoidable, and offsetting impact by restoring and protecting habitats that are off site from the project. Since nature is not perfectly fungible, many organizations exclude offsetting from the mitigation hierarchy. See *International Finance Corporation's guidance note 6: Biodiversity conservation and sustainable management of living natural resources*, IFC, January 1, 2012; Samuel Sinclair et al., *The conservation hierarchy underpinning the post-2020 biodiversity framework,* Convention on Biological Diversity, 2020.
[45] *Science-based targets for nature: Initial guidance for business,* Science Based Targets Network, September 2020.
[46] *The TNFD nature-related risk and opportunity management and disclosure framework,* Taskforce on Nature-related Financial Disclosures, June 2022.

2. **Developing and investing in the infrastructure—data, skills, and opportunities—that would help inform company actions.** Although data on nature are often publicly accessible, they are frequently spread across sources and can be difficult to aggregate and use. Improving data availability and supply chain traceability are key enabling measures, along with more training to develop a workforce with the broad set of "green skills" necessary to interpret and use nature-related data to inform decision making. Corporations would also need more options for investing in natural-capital preservation, which scientifically rigorous and well-regulated credit markets (including carbon credits, nature credits, and biodiversity credits) can help provide. While such infrastructure could be an opportunity for new businesses (such as data brokerages), the public and social sectors could play a key supporting role by helping aggregate open-source data, providing job training, and fostering credit initiatives.[47]

3. **Expanding financing and incentives.** Financing a nature-positive path would likely require more resources than today's approaches to nature finance can muster. Mitigating the impact of operations on nature could increase resilience and would provide a better long-term investment.[48] However, given that 55 percent of the identified abatement potential does not generate a near-term return on investment under current assumptions, new financing, incentives, and ways of thinking would be needed to address the funding gap. For example, governments could consider reassessing subsidies or use internal accounting to price nature externalities and guide decision making.[49] Financial stakeholders could also implement policies and create new financial products that would help direct funding flows toward nature-oriented outcomes.[50]

In the current economic environment, companies face a multitude of challenges, including talent retention, macroeconomic pressures, geopolitical instability, and supply chain problems. But taking action on nature would not add to existing burdens. It could bring tangible benefits for both natural capital and company revenue. Companies could start the journey by understanding their footprint and implementing ROI-positive actions that address both climate and nature capital. Over time, companies could adopt increasingly ambitious targets for nature and start to build new businesses around the technologies and approaches that can help return the economy to a safe operating space for humanity.

Building a nature-positive economy is not the responsibility of corporate actors alone. It will require multiple actors to invest in science to better understand the problem and its potential solutions, collaborate to define standards and the right level of ambition as knowledge accumulates, and overcome a range of technical and financial barriers. It will be a journey—but it will lead to a destination of much greater prosperity and an economy operating within safe limits.

[47] *The future of nature and business,* World Economic Forum, 2020.
[48] "Does ESG really matter?," *McKinsey Quarterly,* August 10, 2022.
[49] Jessica Fan, Werner Rehm, and Giulia Siccardo, "The state of internal carbon pricing," McKinsey, February 10, 2021.
[50] "Does ESG really matter?," August 10, 2022.

The issues of climate and nature are closely intertwined. Addressing the natural-capital challenge is crucial to mitigating climate change, while addressing climate change could help avert or delay several emerging nature-related tipping points.

1 The business case for a nature-positive path

The nature crisis is generating growing attention from central banks, the financial sector,[51] and prominent global organizations such as the World Economic Forum, the Paulson Institute, the World Bank, Business for Nature, and the World Business Council for Sustainable Development.[52] This attention is spurring an increasing number of businesses to make pledges related to biodiversity or becoming “nature positive” (see Box 1, “What we mean by ‘nature positive’”).[53] Meanwhile, the Taskforce on Nature-related Financial Disclosures (TNFD) is establishing a framework for how businesses report and act on nature-related risks and opportunities, while the Science Based Targets Network (SBTN) is developing methods to help companies set science-based targets for nature.[54]

Such calls and actions amount to a recognition that the impact of economic activity on natural capital—an “externality,” in economic terms—has reached such a level that it can no longer be ignored. A failure to take meaningful action on nature could potentially have operational, transition, reputational, and market risks for companies.[55] Localized depletion of natural capital may already be a threat to corporations’ business models and supply chains.[56]

Companies could act now to seize the business opportunities and minimize risks created by the depletion of natural capital. First, many of the levers or corporate actions we have identified are ROI positive, according to our estimates. These include crop fertilizer reduction, water system leak management, food waste reduction, and alternative delivery models for packaging, among many others. As outlined in chapter 3, we estimate that, on average, nature-positive action could also benefit companies, providing a combined value opportunity of nearly $700 billion annually through reduced operating costs. Second, transitioning to a nature-positive future could create new business opportunities because new technologies, services, and processes will be needed. Third, as nature degradation spurs stronger calls for action, investors and policy makers may push companies to act—for instance, through new investing criteria or regulations. Acting now could better position companies to benefit from these changes.

[51] “Nature positive” language was included during the most recent G-7 and G-20 meetings, at COP26, and by the Network for Greening the Financial System (NGFS) representing 114 central banks and financial supervisors.
[52] *The global risks report 2022, 17th edition*, World Economic Forum, 2022; see also *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, IPBES, 2019. Andrew Deutz et al., *Financing nature: Closing the global biodiversity financing gap*, Paulson Institute, Nature Conservancy, and Cornell Atkinson Center for Sustainability, 2020; *The economic case for nature: A global Earth-economy model to assess development policy pathways*, World Bank, 2021. As of November 2022, more than 1,100 companies have signed on to Business for Nature’s “Nature is everyone’s business” call to action. See *Business for Nature’s call to action*, Business for Nature, accessed November 11, 2022.
[53] “Where the world’s largest companies stand on nature,” McKinsey, September 13, 2022.
[54] “Nature risk is the next challenge that demands a global solution,” McKinsey, May 20, 2022; “For sustainable business, ‘planetary boundaries’ define the new rules,” Global Commons Alliance, November 18, 2020.
[55] Samantha McCraine et al., *The nature of risk: A framework for understanding nature-related risk to business*, World Wildlife Fund, 2019.
[56] For example, CDP reports that suppliers expect $1.26 trillion in revenue losses in the next five years due to climate change, deforestation, and water insecurity. *Transparency to transformation: A chain reaction (global supply chain report 2020),* CDP, February 2021. See also “Risk, resilience, and rebalancing in global value chains,” McKinsey Global Institute, August 6, 2020.

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Box 1

What we mean by 'nature positive'

The term "nature positive" has become increasingly prevalent in the business and political communities,[1] reflecting a broad desire on the part of leaders to address the nature crisis and capture their intent in a simple phrase.[2] There is no consensus on what nature positive means for businesses.[3] By one definition, nature positive is "a high-level goal and concept describing a future state of nature (e.g., biodiversity, ecosystem services and natural capital) which is greater than the current state,"[4] reflecting an intent to align stakeholders around a goal of generating "net gains in nature" by 2030.[5] Absent specific and standardized metrics, it will be difficult to measure whether a business aligns with this definition.[6]

In this report, we use the term "nature positive" to mean any activity or action that could reduce negative impacts or generate positive impacts on nature. However, the pursuit of one or even many such activities does not necessarily qualify a company as nature positive. Similar to the approach of the Taskforce on Nature-related Financial Disclosures' beta framework, this report does not attempt to define "nature positive" at the company level. Instead, it looks to the many organizations working to define the term to inform its findings, including the Global Biodiversity Framework of the Convention on Biological Diversity (CBD).[7]

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[1] "Where the world's largest companies stand on nature," McKinsey, September 13, 2022; "Nature risk is the next challenge that demands a global solution," McKinsey, May 20, 2022.
[2] Sophus O.S.E. zu Ermgassen et al., "Are corporate biodiversity commitments consistent with delivering 'nature-positive' outcomes? A review of 'nature-positive' definitions, company progress and challenges," *SocArXiv*, July 2022.
[3] EJ Milner-Gulland, "Don't dilute the term Nature Positive," *Nature Ecology & Evolution*, 2022; Martine Maron et al, "Setting robust biodiversity goals," *Conservation Letters*, May 2021.
[4] *Glossary of Key Terms*, Taskforce on Nature-related Financial Disclosures; *Develop and implement a transformational and effective post-2020 global biodiversity framework*, International Union for Conservation of Nature, 2020; *"Nature-positive" — an opportunity to get it right*, Science Based Targets Network, July 11, 2021; FAQs, Get Nature Positive, accessed November 11, 2022.
[5] Harvey Locke et al., *A nature-positive world: The global goal for nature*, 2021.
[6] Oliver Balch, Michael Ofosuhene-Wise, and Eva Zabey, *How business and finance can contribute to a nature positive future now*, Business for Nature, October 2022.
[7] *The TNFD nature-related risk and opportunity management and disclosure framework*, June 2022.

New businesses and technologies are needed to drive the transition to a nature-positive future

While the transition to a nature-positive global economy would entail significant cost—as well as structural changes in everything from how we produce and consume goods to where we live—it could also generate opportunities for new growth, products, and services for the companies that choose to act with the appropriate mix of foresight and strategic nimbleness.

First is the opportunity to provide the solutions underpinning the corporate actions, or levers, identified in chapter 3. For instance, sustainable agricultural equipment, part of the agricultural decarbonization lever, could present a market opportunity of up to $50 billion by 2030.[57] As another example, the market for alternative protein could reach well over $100 billion by 2030 and many multiples of that by 2050.[58]

Second, companies can capitalize on the opportunity to improve the technologies identified in these same levers. For instance, while plant-based proteins are already included in the cost curves, further or faster advances in animal meat replacements could create cost savings and scale for lab-grown protein and fats, as well as alternative protein fermentation, alternative animal feed using single-cell protein production from manure, insect-based feed, and fish-meal alternatives.[59] As another example, chemical conversion to reduce plastic waste currently has a high cost to implement, partly because of the extremely high temperatures required. However, research has identified new catalysts that could speed the conversion and decrease the temperature required, which could reduce the cost.[60]

Third, companies can provide the new technologies needed to address the depletion of natural capital. The levers discussed in this report are based on technologies that are commercialized (or nearly commercialized) today and therefore do not address the full set of technologies that could be available during the next decades. Research attention and early-stage funding have already identified many of these opportunities, and others could emerge in coming years and decades. Several emerging technologies show promise, including the following:

1. **Forestry and agroforestry.** A large range of relevant technologies could help bring down the cost of growing, planting, and monitoring the health of trees.[61] These range from advanced planting using drones to remote sensing and machine-learning technologies used for monitoring forest health.[62] Tree genetics and climate smart forestry practices could help increase carbon uptake of forests.[63] These technologies could reduce costs, create alternative revenue streams (for example, through carbon sequestration), and further address biodiversity loss.

2. **Food waste technologies.** Reducing food waste could release the pressure on land use and help nonagricultural companies reduce their upstream impacts. These include shelf-life extension (for example, biodegradable films and hydrogels) and sensors and

[57] McKinsey analysis.
[58] Vivid Economics Alternative Proteins Model, November 2022.
[59] Tomas Laboutka, "Make room for alternative proteins: What it takes to build a new sector," McKinsey, March 25, 2022; Hermione Dace and Karen Hooper, *The protein problem: How scaling alternative proteins can help people and planet*, Tony Blair Institute for Global Change, November 17, 2021; Simon Creasey, "The fermentation flurry in plant-based food," *Just Food Magazine*, February 2021; Sirada Patthawaro and Chewapat Saejung, "Production of single cell protein from manure as animal feed by using photosynthetic bacteria," *Microbiology Open*, December 2019, Volume 8; Kristin Elliott, "Alternative aquaculture feeds," *Aquasend*, June 5, 2019.
[60] Chuhua Jia, "Converting plastic waste into fuel," *Harvard Science in the News*, June 30, 2021.
[61] Dan Guida, "How automation is transforming greenhouses and nurseries," NIP Group, March 31, 2020.
[62] "Touch the sky to plant trees – yes, there are companies using drones to plant trees," *Change Started*, July 25, 2020; Narayan Kayet, "Forest health monitoring using hyperspectral remote sensing techniques," *Spatial Modeling in Forest Resources Management*, October 9, 2020.
[63] Yumin Tao et al., "Enhanced photosynthetic efficiency for increased carbon assimilation and woody biomass production in hybrid poplar INRA 717-1B4," *BioRxiv*, March 9, 2022.

monitors in the supply chain.[64] The global market for smart packaging, including foods, pharmaceuticals, and other products, could reach $26.7 billion by 2024.[65]

3. **Plastic waste.** Novel enzymes could reduce plastic pollution by degrading plastics in a matter of days.[66] While this would not address the more pressing collection problem, it has the potential to help address the quantity in landfills. Beyond traditional mechanical recycling, chemical recycling technology including chemolysis, hygrothermal recycling, and gasification could provide new opportunities for plastic reuse.[67]

Finally, there is an opportunity to help provide the cross-cutting enabling technologies and services that would be needed to support corporate action. For example, supply chain transparency is critical for companies to measure and monitor their footprint. The World Economic Forum estimates that there is a $515 billion opportunity in transitioning to more transparent supply chains, with opportunities ranging from QR codes and IoT-sensor devices to blockchain applications.[68] New reporting requirements could also create market opportunities for tracking and tracing technologies and monitoring services. As an indication of the size of the nature reporting opportunity, the carbon footprint management market could reach a value of more than $18 billion by 2031.[69]

Early action is an opportunity to get ahead of stakeholder action and regulatory change

As the effects of nature's degradation become increasingly visible, investors, consumers, and policy makers may push companies to address their impacts on nature. Action now would help companies get ahead of such changes and build an identity around nature-positive actions.

Investor action

The risk of negative repercussions for a failure to act on nature is growing. For instance, 111 financial institutions managing more than €16.3 trillion in assets have committed to set targets on their impacts on nature, which will influence the projects they choose to finance.[70] In February 2022, BlackRock said it "may withhold support for management proposals" if it is "concerned that natural capital-related risks and opportunities are not being effectively managed, overseen, or disclosed."[71] And Norway's sovereign wealth fund sold its stake in more than 60 companies due to deforestation concerns.[72] As McKinsey research on ESG has highlighted, companies that do not address such concerns may not endure in the long run.[73]

To the extent that investor expectations grow in this arena, new opportunities could also begin to emerge. Financial institutions increasingly offer preferential access to capital for

[64] Grant Gerke, "Rethinking barrier films, food waste and the circular economy," *Flexible Packaging*, October 12, 2021; Emma Shipman et al., "Can gene editing reduce postharvest waste and loss of fruit, vegetables, and ornamentals?," *Horticulture Research*, January 1, 2021, Volume 8.
[65] Wai Cheung and Dirk Schaefer, "Smart packaging: Opportunities and challenges," *Procedia CIRP*, June 27, 2018, Volume 72.
[66] Hongyuan Lu et al., "Machine learning-aided engineering of hydrolases for PET depolymerization," *Nature*, April 27, 2022, Volume 604.
[67] Chemolysis is the use of water or a chemical agent such as methanol or glycol to break down plastic material into monomers. Hydrothermal recycling uses water at an elevated pressure and temperature to cut long-chain hydrocarbon bonds into plastics to produce oils and chemicals. Gasification is a high-temperature, high-pressure environment where oxygen or steam is in contact with the feed material to produce synthesis gas that can be converted into monomers. See "Rethinking plastics in a circular economy," Economist Impact, 2021.
[68] *The future of nature and business*, World Economic Forum, 2020.
[69] *Carbon footprint management market by component (solution and services), by deployment mode (on premise, cloud), by industry vertical (energy and utilities, manufacturing, residential and commercial buildings, and transportation and logistics, IT and telecom): Global opportunity analysis and industry forecast, 2021-2031,* Allied Market Research, May 2022.
[70] Finance for Biodiversity Pledge website, accessed October 30, 2022.
[71] *Our approach to engagement on natural capital*, BlackRock, February 2022.
[72] Michael Taylor, "Norway's wealth fund ditches 33 palm oil firms over deforestation," Reuters, February 28, 2019.
[73] "Does ESG really matter?," August 10, 2022.

green actors, reducing the overall cost of capital.[74] For example, Louis Dreyfus Company B.V. renewed its $750 million revolving credit facility to include a sustainability-linked interest rate measured against environmental outcomes.[75]

Consumer demand

Businesses that adopt and maintain nature-conscious practices, especially first movers that act with conviction, could accrue a green premium—or "greenium"—for their offerings. Surveys show that 67 percent of global consumers say that environmental health and the impact of their choices on the planet are important to them.[76] Between 12 and 25 percent of customers say they would be willing to pay more for certain sustainability labels, such as "all natural," "eco-friendly," or "sustainably produced," although those claims must be backed up by real action.[77] Other indicators suggest that nature action will be increasingly important. For example, generational shifts in attitude may also make corporate environmental claims more important over time.[78] There are also indications that nature-conscious companies perform better on employee retention.[79]

Policy change

Multiple nature-related policies are coming online and could influence business operations and profitability. Companies that can get ahead of new regulations and policies may have the opportunity to build a durable competitive advantage, as has happened with previous environmental regulations.[80] The longer companies wait, the more difficult and costly it would be to make the transition and the more likely that new regulation may be abruptly imposed.

At a global level, governments aim to agree to a new set of goals for nature at the 2022 UN Biodiversity Conference. Among the targets to be outlined, Target 15 is most relevant to businesses and—in the current draft—includes the expectation that businesses would assess and report on their dependencies and impacts on biodiversity, measurably reduce negative impacts by 2030, and increase positive impacts.[81]

It will most likely take some time for agreements made at the biodiversity conference to translate to national and regional policies and regulations for corporations, and a number of governments may choose not to enact them, particularly given current macroeconomic conditions. Nevertheless, national and jurisdictional-level policies are already in place or in preparation:

— In France, article 29 of a 2019 energy-climate law requires that companies disclose biodiversity risks and adverse impacts, as well as their strategy for reducing biodiversity risks.[82] The United Kingdom's new policy paper, "Greening finance: A roadmap to sustainable investing," requires disclosure of both climate risk and other environmental impacts.[83]

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[74] Research by ING has found that issuers of green bonds save, on average, between one and ten basis points, while research by the Climate Bonds Initiative has found green bonds are typically oversubscribed compared with their vanilla counterparts. See Padhraic Garvey and Benjamin Schroeder, "The corporate premium in green finance," ING, June 9, 2021; Caroline Harrison, *Green bond pricing in the primary market H1 2021,* Climate Bonds Initiative, September 2021.
[75] The key metrics were CO_2 remissions, electricity consumption, water usage, and solid waste sent to landfills. See "Louis Dreyfus Company announces its first sustainability-linked revolving credit facility," Louis Dreyfus Company, May 28, 2019.
[76] "How health-conscious consumers want to live in a healthy world," NielsenIQ, October 2021.
[77] Jurgita Biceika and Maria Coronado Robles, "Sustainable food: Will consumers pay a premium?," Euromonitor International, April 21, 2022.
[78] "Meet Generation Z: Shaping the future of shopping," *McKinsey Podcast*, August 4, 2020.
[79] Oliver Balch, Michael Ofosuhene-Wise, and Eva Zabey, *How business and finance can contribute to a nature positive future now*, Business for Nature, October 2022.
[80] Stefan Ambec et al., "The Porter Hypothesis at 20," *Resources for the Future, 2011*; Pierre Mohnen and George van Leeuwen, "Revisiting the Porter hypothesis: an empirical analysis of Green innovation for the Netherlands," *Economics of Innovation and New Technology*, 2017, Volume 26.
[81] *First draft of the post-2020 global biodiversity framework*, United Nations Environment Programme, July 5, 2021.
[82] "France's law on energy and climate adds coverage of biodiversity, ecosystems, and renewable energy to investors' non-financial reporting," Green Finance Platform, 2021.
[83] *Greening finance: A roadmap to sustainable investing*, HM Treasury, October 2021.

— In the United States, a new rule proposed by the SEC would require companies to increase their reporting on climate risk, while in the European Union, the Corporate Sustainability Reporting Directive (CSRD) is already in effect.[84] While disclosure itself may impose some costs on companies, the real impact could happen if standard disclosures lead to a valuation differential for lower performers, as has been seen for companies with exposure to climate risk.[85]

— In the European Union, the European Commission introduced a draft Nature Restoration Law in June 2022. If it becomes law, it will require EU member states to revitalize forests, wetlands, and other landscapes harmed by human activity.[86] The European Union may also require all future bilateral trade agreements to be biodiversity positive.[87] Both actions may require companies to adjust their spatial footprints.

— Beyond Europe, Costa Rica has been particularly successful in embedding biodiversity considerations in a wide range of policies.[88]

These regulations may inspire action in other countries, paving the way for more specific and stringent nature-related policies and regulations around the world. Still, many developing countries may need additional incentives, including additional financing and support, before committing to increase their commitments on nature.[89]

[84] Laura Corb, Kimberly Henderson, Tim Koller, and Shally Venugopal, "Understanding the SEC's proposed climate risk disclosure rule," *Inside the Strategy Room*, McKinsey, June 3, 2022; *Corporate sustainability reporting,* European Commission, 2022.
[85] "Understanding the SEC's proposed climate risk disclosure rule," June 3, 2022.
[86] *Nature restoration law*, European Commission, June 22, 2022.
[87] *Methodology for assessing the impacts of trade agreements on biodiversity and ecosystems*, European Commission, March 2021.
[88] Brian J. Huntley, "Good news from the South: Biodiversity mainstreaming – a paradigm shift in conservation?," *South African Journal of Science*, September 2014, Volume 110, Number 9/10.
[89] This divide can be seen in policy and behavior. For instance, Brazil, Indonesia, and South Africa, all of which are rich in biodiversity, are not members of the High Ambition Coalition for Nature and People, which includes more than 100 countries that support the goal of protecting 30 percent of land and ocean by 2030. They have also not signed the Leaders' Pledge for Nature, which includes 93 countries and is committed to reversing biodiversity loss by 2030. The African Union and other developing countries are also calling on developed countries to commit at least $100 billion annually initially, rising to $700 billion annually by 2030. See Mike Shanahan, "Explainer: COP15, the biggest biodiversity conference in a decade," *China Dialogue*, August 11, 2022; Nkechi Isaac, "African Union seeks billions in funding to conserve biodiversity," Alliance for Science, April 6, 2022.

A failure to take meaningful action on nature could potentially have operational, transition, reputational, and market risks for companies.

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2 A future within the planet's boundaries

Modern civilization evolved under a stable set of conditions beginning about 12,000 years ago. During this period, known as the Holocene, consistent temperatures, rainfall, and nutrient flows allowed settled agricultural societies to emerge and develop into our advanced modern-day economies.[90] This period continues today. But continued depletion of natural capital could trigger extreme changes to the planet, undermining the conditions on which society and the economy have come to rely.[91] For instance, if rainfall patterns and temperatures change so much that existing agricultural lands become unproductive or cities lose access to water, scientific research suggests that the result could be mass migration and humanitarian disaster.

Several frameworks seek to measure human impact on the environment. For this research, we focus on planetary boundaries (see Box 2, "How we use the planetary boundaries"). These boundaries provide a framework for tracking the status of natural capital and its ability to support human development. They also define a "safe operating space for humanity" with respect to the Earth's systems and processes that govern the stability of the atmosphere, oceans, and land-based ecosystems.[92]

Although there is continued debate, scientists have broadly aligned around nine planetary boundaries and estimated safe limits for each (Exhibit 1). There are additional boundaries, but scientists believe these nine pose the greatest risks to society if their function is compromised, and there is greater consensus on what to measure.[93] For this research, we look in detail at five of these boundaries—biodiversity loss, forest cover loss, freshwater consumption, chemical and plastic pollution, and nutrient pollution—and examine greenhouse-gas (GHG) emissions.[94] We find that four of these six boundaries appear to be outside the safe operating space for humanity, and all are projected to get worse by 2050.

Using the planetary boundaries as our framework, we estimate each sector's contribution to five boundaries, excluding GHG emissions, which have been covered in other reports.[95] Based on what we know today, one sector in particular—agriculture—appears to have the largest single direct impact. A detailed technical appendix outlines how we approached the calculations for each stage of the analysis, which required a unique approach for each planetary boundary.

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[90] John Gowdy, "Our hunter-gatherer future: Climate change, agriculture and uncivilization," *Futures*, January 2020, Volume 115.
[91] Will Steffen et al., "The trajectory of the Anthropocene: The Great Acceleration," *Anthropocene Review*, January 2015, Volume 2, Number 1.
[92] Johan Rockström et al., "A safe operating space for humanity," *Nature*, September 2009, Volume 461.
[93] For more details on the planetary boundaries, see technical appendix. There is an ongoing debate around whether these nine are sufficient. For instance, there have been proposals to include other planetary boundaries such as soil degradation, which is essential to supporting life but being rapidly damaged by human activities. However, there is not yet a scientific consensus on whether to include soil or on appropriate variables to measure soil health. See Clarisse T. Kraamwinkel et al., "Planetary limits to soil degradation," *Communications Earth & Environment*, December 2021, Volume 2, Number 249.
[94] This report does not assess other originally defined, or recently proposed, planetary boundaries (stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, marine habitat change, green-water use; see end of next section for more details), although these boundaries are also important.
[95] This report uses ten economic sectors based on the International Standard Industrial Classification of All Economic Activities. The sectors include agriculture (both crops and livestock), forestry, fisheries, extractives (oil and gas and mining), manufacturing, power, water and waste, construction, transportation, and other services. See *International Standard Industrial Classification of All Economic Activities*, United Nations, 2008.

Exhibit 1

The report analyzes nine control variables across six planetary boundaries.

Planetary boundary	Shorthand	Control variable	Description and importance
Change in biosphere integrity	**Biodiversity loss**	Biodiversity intactness index (BII)[1]	The genetic and functional diversity of life that allows the biosphere to persist; biodiversity loss can undermine ecosystem functioning and resilience
Land-system change	**Forest cover loss**	Forested land as a percent of potential forest cover	The land and sea interaction with the atmosphere (eg, via energy or water transfer that impacts water flows, chemical cycling, and other systems)
Climate change	**Climate change**	Radiative forcing caused by GHG emissions[2]	Changes in atmospheric composition that affect the climate (eg, GHG concentrations that drive climate change)
Freshwater use	**Freshwater consumption**	Blue-water consumption	Extraction of water from rivers and lakes and the water in the soil available to plants
Introduction of novel entities	**Chemical and plastic pollution**	Plastic-waste emissions to aquatic environments	New substances with the potential to affect the entire Earth system (eg, plastics, which can affect species, ecosystems, and oceanic carbon cycling)
Biochemical flows	**Nutrient pollution**	Nitrogen runoff, nitrogen deposition, and phosphorous pollution	Biogeochemical flows (eg, nitrogen and phosphorus, which, in excess, can affect plant growth on land or cause eutrophication and algal blooms in water)
Atmospheric aerosol loading	**Aerosol pollution**	Not analyzed—lack of reliable data	Particle matter in the atmosphere with the potential to affect climate function
Ocean acidification	**Ocean acidification**	Not analyzed—lack of reliable data	pH levels that influence carbonate chemistry in surface ocean waters
Stratospheric ozone depletion	**Ozone depletion**	Not analyzed—on path to recovery	Stratospheric ozone levels that absorb radiation from the sun

[1]BII is not available for the marine realm.
[2]Greenhouse-gas emissions. This report's analysis follows the planetary boundaries literature to use "radiative forcing," which measures excess Earth system energy and, when positive, causes warming. Radiative forcing is driven, in large part, by GHG emissions.
Source: See bibliography

McKinsey & Company

Understanding planetary boundaries

The planetary-boundaries concept was first introduced in 2009 by an international team of 28 environmental and Earth system scientists led by Johan Rockström from the Stockholm Resilience Centre and Will Steffen from the Australian National University.[96] The framework quickly gained prominence, prompting debate in scientific circles,[97] helping lay the foundation for what became the Sustainable Development Goals,[98] and influencing the thinking of leading businesses.[99] Members of the original team published a major update to the framework in 2015,[100] and further updates are expected.

For each system, the scientific community has identified "control variables" to track and has estimated a safe threshold to stay below in order to ensure the stability of Earth's natural systems and a safe operating space for humanity. Beyond these thresholds, irreversible environmental changes could be triggered (see Box 3, "Tipping points"). Reflecting the uncertainty inherent in defining planetary boundaries, the creators identify a conservative, inner "boundary" and a looser, outer "zone of uncertainty."[101] Thresholds for the zone of uncertainty are not established for all planetary boundaries. Criticism of the boundary framework includes the unknowability of precise thresholds, unclear interactions between and among boundaries, and a global focus when many nature impacts are fundamentally local.[102]

It is also important to note that planetary boundaries are not mutually exclusive; indeed, there are complex feedback loops between them. For example, changes in climate can drive biodiversity loss, and vice versa.[103] In addition, ecosystem degradation can alter precipitation patterns and river flow at subglobal scales and reduce ecosystem capacity for retaining nitrogen and phosphorus, increasing nutrient pollution.[104] These complex interactions apply to all boundaries.

An important challenge is the current state of planetary science. While there is a broad scientific consensus about the existence of planetary boundaries and the momentum toward breaching them, scientists continue to debate which planetary systems are the most critical and the exact thresholds beyond which the world would risk triggering irreversible tipping points. Better analyses will doubtless be possible in the future as the underlying science advances, as better data are gathered, and as methodologies mature. But the humility that the current state of knowledge and analysis imposes should not obscure the urgency of initiating or accelerating efforts on the path of a nature-positive economy.

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[96] "A safe operating space for humanity," September 2009.

[97] Although citations may be an imperfect metric for impact, the original article has been cited more than 7,000 times in academic literature, while the 2015 follow-up has been cited nearly 4,000 times. The 2015 update drew on "over 60 scientific articles that have been published specifically scrutinizing different aspects of the Planetary Boundaries framework." See *Dot Earth*, "Can humanity's 'Great Acceleration' be managed and, if so, how?," blog entry by Andrew C. Revkin, *New York Times*, January 15, 2015.

[98] *Resilient people, resilient planet: A future worth choosing*, United Nations Secretary-General's High-level Panel on Global Sustainability, 2012.

[99] The World Business Council for Sustainable Development (WBCSD) has adopted the framework to guide its 2050 vision, and companies such as H&M, IKEA, and L'Oréal have used the boundaries to guide their nature-related efforts. See *Vision 2050: Time to transform*, World Business Council for Sustainable Development, March 25, 2021; "Ten years of nine planetary boundaries," Stockholm Resilience Centre, November 1, 2019.

[100] The updated report reevaluated where the planet stood against the boundaries, renamed and updated the definitions of boundaries, and responded to criticisms of the original publication, especially by better emphasizing the uncertainly inherent in setting thresholds. Will Steffen et al., "Planetary boundaries: Guiding human development on a changing planet," *Science*, January 2015, Volume 347, Number 6223.

[101] The choice of control variables and thresholds has generated considerable debate, as not all thresholds are equally well understood by science. The authors themselves characterize the proposed boundaries as "rough, first estimates." Johan Rockström et al., "Planetary boundaries: Exploring the safe operating space for humanity," *Ecology and Society*, 2009, Volume 14, Number 2.

[102] Linus Blomqvist, Ted Nordhaus, and Michael Shellenberger, *Planetary boundaries: A review of the evidence,* Breakthrough Institute, June 2012; Helen Fisher, "Are planetary boundaries a great truth?," Context Group Ltd, July 28, 2020; "Can humanity's 'Great Acceleration' be managed," January 15, 2015.

[103] Pamela McElwee, "Climate change and biodiversity Loss: Two sides of the same coin," *Current History*, 2021, Volume 120, Number 829.

[104] Georgina M. Mace et al., "Approaches to defining a planetary boundary for biodiversity," *Global Environmental Change,* September 2014, Volume 28.

We have three reasons for using this framework to understand human impact on natural capital and the potential of corporate action to help assuage this impact. First, the planetary boundaries help frame the complex issue of how to tackle nature-related crises in line with the familiar logic of climate change—namely, that there seem to be limits beyond which life on Earth will change. Second, it appears to be the best available holistic framework for defining how much pressure on the environment could be too much on a global scale and for informing science-based targets for preserving natural capital.[105] And third, by defining the problem, even imperfectly, the planetary boundaries allow us to begin to apply economic thinking to determine the set of actions that could provide a global solution.

[105] The Science Based Targets Network (SBTN) is using the planetary boundaries to inform the setting of science-based targets for nature, although setting such targets using the boundaries is a difficult exercise due to different geographic scales of impact and implications around allocating impacts across value chains. See "For sustainable business, 'planetary boundaries' define the new rules," Global Commons Alliance, November 18, 2020; Roland Clift et al., "The challenges of applying planetary boundaries as a basis for strategic decision-making in companies with global supply chains," *Sustainability*, 2017, Volume 9, Number 279.

Box 2

How we use the planetary boundaries

This report uses the boundaries as the foundation for our analysis in three respects: (1) to identify the control variables to measure and thresholds to define where human activity has "crossed" a boundary; (2) to model the planet's current state and sectoral contributions; and (3) to project the boundaries forward to 2030 and 2050 to define the amount of abatement needed to return to a safe operating space for humanity.

The science behind planetary boundaries remains a work in progress, however. As such, the results of our analysis should be understood as a directional first attempt.

Choice of control variables and thresholds

In general, we adhere to the control variables and thresholds proposed by the creators of the planetary boundaries and in subsequent studies, including both the strict, inner threshold (the "boundary") and a looser, outer threshold, which corresponds to being outside the "zone of uncertainty." Where multiple control variables exist, we select the one with the most conservative safe threshold. Where control variables and thresholds have not yet been established but for which there are reasonable proxies, we use those. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevents analysis. We exclude ozone depletion because it is on a path to recovery.[1] We also examine greenhouse-gas (GHG) emissions, although we do not construct a cost curve for them in chapter 3 or provide a sectoral breakdown because we have addressed this topic extensively in other McKinsey research.[2]

Biodiversity loss

Global control variable: The planetary boundaries framework uses two control variables to measure "biosphere integrity," which we refer to as biodiversity loss. Extinction rate is used to measure genetic diversity, and the biodiversity intactness index (BII) is used to measure functional diversity. The extinction rate has exceeded its planetary boundary but is difficult to attribute directly to economic activity, so we focus on BII. The authors of the planetary boundaries

[1] Kelsey Piper, "The shrinking ozone hole shows that the world can actually solve an environmental crisis," Vox, October 27, 2022.
[2] "The net-zero transition: What it would cost, what it could bring," McKinsey, January 2022.

framework characterize BII as an "interim control variable," because interactions between BII and Earth system responses are still a nascent science and because BII is a relatively coarse measure of functional biodiversity.[3] A limitation of BII is that it is not available for the marine realm.[4] We explored overexploitation of current fish stocks as a proxy for marine biodiversity loss but do not systematically report our findings.[5]

Thresholds: A BII of 1.0 corresponds to species "abundances across all functional groups at preindustrial levels," with "preindustrial" corresponding to 1750.[6]

— Boundary: The current boundary is set at a conservative 0.9 for the planet, corresponding to a 10 percent loss in biodiversity.

— Zone of uncertainty: The actual tolerable loss of biodiversity could be much greater,[7] so we do not establish a threshold for BII's zone of uncertainty. Instead, we report the level of biodiversity loss in 1970 (just over 20 percent) to contextualize where we stand today,[8] resulting in an effective zone of uncertainty of 0.9 to 0.8.

Forest cover loss

Global control variable: The control variable for "land systems change" is the current area of forested land as a percent of potential forest cover,[9] which is why this report refers to the boundary as "forest cover loss." What constitutes a forest is highly debated, with more than 800 different definitions in use.[10] For this report's analysis, we use a data set from the Food and Agriculture Organization (FAO) of the United Nations, focusing on deforestation since 2000, and define deforestation as a persistent conversion of forest to any other land use. This differs from other major databases, such as Global Forest Watch (GFW), which classifies any sort of forest degradation as deforestation.[11] Moreover, natural forest conversion to plantation forests is not considered forest cover loss in the planetary boundaries framework because plantation forests still enable equilibrium land–climate interactions. Forest conversion to plantation forests still has a negative impact on the biodiversity loss planetary boundary. Thus, our estimate of forest cover loss is lower than what might be seen in analyses based on the GFW's database. Since BII is also calculated using change in land use, BII decreases and forest cover loss often overlap, although the systems have different impacts on the planet.

Thresholds: The current boundary is 75 percent cover relative to potential forest cover, while the zone of uncertainty is 75 to 54 percent cover relative to potential forest cover. These thresholds are the weighted average of three individual biome boundaries (tropical, temperate, and boreal forests), each of which has a unique threshold.[12]

[3] A common critique of the biodiversity planetary boundary is that there is not a clearly understood potential for a tipping point. However, this criticism was anticipated and addressed by the first paper that proposed the biodiversity planetary boundary, as a known tipping point is not necessary in order for the boundary to be a valid precautionary threshold. See Will Steffen et al., "Planetary boundaries: Guiding human development on a changing planet," *Science,* January 2015, Volume 347, Number 6223 and Georgina M. Mace et al, "Approaches to defining a planetary boundary for biodiversity," *Global Environmental Change*, September 2014, Volume 28; for criticism, see Ian Donohue, José M. Montoya, and Stuart L. Pimm, "Planetary boundaries for biodiversity: Implausible science, pernicious policies," *Trends in Ecology & Evolution*, February 2018, Volume 33, Number 2.
[4] Kirsty L. Nash et al., "Planetary boundaries for a blue planet," *Nature Ecology & Evolution*, October 2017, Volume 1, Number 11.
[5] This approach only provides a view on target species and does not account for bycatch impacts on nontarget species, nor does it account for ecosystem and habitat impacts from bottom trawling, exploitation from mining, pollutants, or other pressures; "Planetary boundaries for a blue planet," October 2017.
[6] See "Planetary boundaries," January 2015.
[7] Ibid.
[8] The first year for which there is a global BII estimate is 1970; the midpoint estimate is 0.8 (corresponding to a 20 percent loss in biodiversity), while the upper and lower uncertainty bounds are 0.86 and 0.77, respectively; Helen Phillips et al., "The biodiversity intactness index - country, region, and global-level summaries for the year 1970 to 2050 under various scenarios," Natural History Museum, October 27, 2021.
[9] "Planetary boundaries," January 2015.
[10] Joseph Sexton et al., "Conservation policy and the measurement of forests," *Nature Climate Change*, October 2015, Volume 6.
[11] Florence Pendrill et al., "Disentangling the numbers behind agriculture-driven tropical deforestation," *Science*, September 2022, Volume 377, Number 6611.
[12] Potential forest cover is a modeled number and does not refer to a specific period in history: "The area of forested land that is maintained on the ice-free land surface, expressed as a percentage of the potential area of forested land in the Holocene (that is, the area of forest assuming no human land-cover change)." See Will Steffen et al., "Supplementary materials for planetary boundaries," January 2015; C. Delire, J. A. Foley, and P. K. Snyder, "Evaluating the influence of different vegetation biomes on the global climate," *Climate Dynamics*, July 2004, Volume 23.

Climate change

Global control variable: The 2015 update to the planetary boundaries proposes a dual boundary for climate change with parameters for both atmospheric CO_2 concentration and increases in radiative forcing. Although most discourse around climate focuses on drivers of climate change (emissions) or the outcome (temperature), the planetary boundaries focus on the current state of the climate system, which is best measured in radiative forcing because this measure is more inclusive of the multiple drivers of climate change. Positive radiative forcing means Earth receives more incoming energy than it radiates to space, which will cause warming and is exacerbated by GHG emissions. It is possible to translate between radiative forcing and CO_2-equivalent (CO_2e) emissions using an established empirical relationship between the two.[13]

Thresholds: Our analysis follows the planetary boundaries literature to use radiative forcing, which is generally more stringent than CO_2 concentration, to underpin our analysis. The boundary is set at 1.0 watts per square meter (w/m^2), while the zone of uncertainty is between 1.0 and 1.5 w/m^2. The authors use 1.0 w/m^2 because it is "likely" consistent with 1.0 to 1.7 degrees of warming.[14] (The equivalent for atmospheric CO_2 concentration is 350 to 450 parts per million.)

An alternative way of thinking about the climate change boundary could be to align our thinking with the 1.5-degree pathway established by Intergovernmental Panel on Climate Change (IPCC).[15] In this case, we could think about a CO_2e emissions budget that could keep the planet on track for 1.5°C of warming through 2050. One could consider alternative, potential boundaries that look like the following:

— Boundary: According to 2022 estimates from the IPCC, there is a 50 percent chance of limiting global warming to 1.5°C if the emitted carbon dioxide starting from 2020 is limited to 500 metric gigatons (Gt) through 2050.

— Zone of uncertainty: Similarly, there is a 67 percent chance of limiting global warming to 2°C if emitted CO_2 starting from 2020 is limited to 1150 Gt.[16]

Freshwater consumption

Global control variable: The planetary boundaries framework uses blue-water use to measure freshwater use, although an additional planetary-boundary approach for green water was recently proposed.[17] Following the established method, we only measure blue-water consumption in our analysis. The boundaries also consider a global perspective and requirements for aggregated catchment-specific environmental water flow.[18] We incorporate the uncertainty range resulting from these different approaches to arrive at a unified threshold.

Thresholds: The current boundary is 1,100 cubic kilometers (km^3) of consumptive blue-water use per year, while the zone of uncertainty is 1,100 to 4,500 km^3 of consumptive blue-water use per year.[19]

[13] M. Etminan et al., "Radiative forcing of carbon dioxide, methane, and nitrous oxide: A significant revision of the methane radiative forcing," *Geophysical Research Letters*, December 2016, Volume 43, Number 24.
[14] Piers Forster et al., "The Earth's energy budget, climate feedbacks, and climate sensitivity," in *Climate change 2021: The physical science basis. Contribution of working group I to the sixth assessment report of the Intergovernmental Panel on Climate Change*, Intergovernmental Panel on Climate Change (IPCC), August 2021.
[15] "The 1.5-degree challenge," McKinsey, accessed November 14, 2022.
[16] Jim Skea et al., *Climate change 2022: Mitigation of climate change*, IPCC, 2022.
[17] Lan Wang-Erlandsson et al., "A planetary boundary for green water," *Nature Reviews Earth & Environment*, April 2022, Volume 3.
[18] Dieter Gerten et al., "Towards a revised planetary boundary for consumptive freshwater use: Role of environmental flow requirements," *Current Opinion in Environmental Sustainability*, December 2013, Volume 5, Number 6.
[19] See technical appendix for detailed explanation of threshold development.

Chemical and plastic pollution

Global control variable: The planetary-boundaries framework has not defined a control variable for the "introduction of novel entities," as it is referred to in the literature. Given the damage that plastic-waste emissions can cause to aquatic environments, this report—and planetary-boundary research in general—focuses on plastic-waste emissions to aquatic environments as representative of the global "novel entity" boundary (what we refer to as "chemical and plastic pollution" or just "plastic pollution").[20] This report does not quantify other novel entities that make up the planetary boundary, including chemical pollution, heavy metals, and radioactive material, which means that the impact of certain sectors that emit such materials (for example, mining and oil and gas) is likely underrepresented.

Thresholds: Although there is no "official" boundary for plastic-waste emissions to aquatic environments, following the suggestion of leading plastic-waste emissions scientists and research by the United Nations Environment Programme, this report uses 2010 plastic-waste emissions levels as the boundary, which equates to eight metric megatons (Mt) per year.[21] We do not have similar guidance for an "outer" limit, so do not propose a threshold for the zone of uncertainty.

Nutrient pollution

Global control variable: We follow the planetary-boundaries framework, which has defined several control variables for "biogeochemical flows" of nitrogen and phosphorus, the nutrients most likely to cause eutrophication (an overabundance of nutrients that can cause algal blooms), acidification, and anoxic events (a lack of oxygen, which can kill marine life), among other environmental harms. This paper incorporates recent updates to the planetary-boundary science on nutrient pollution and separates nitrogen runoff to surface waters and deposition to terrestrial ecosystems into two control variables.[22] One is based on the risk of eutrophication of surface waters caused by nitrogen runoff; the second is based on the risk of eutrophication and acidification of terrestrial ecosystems caused by atmospheric nitrogen deposition. The boundary for phosphorus pollution was based on the critical concentration of phosphorus in surface waters, which increases the risk of eutrophication and anoxic events.

Thresholds: The global boundary for nitrogen runoff is 55 megatons of nitrogen (Mt N) per year and is based on the total critical N load of surface waters. The boundary for terrestrial deposition is 31 Mt N per year and is based on the total critical N deposition on terrestrial ecosystems. Current research does not propose an "outer" limit, so this paper does not have a threshold for the zone of uncertainty. The boundary for phosphorus is 26.2 megatons of phosphorus (Mt P) per year, with adjustments to get to a boundary of 6.2 Mt P per year and a zone of uncertainty from 6.2 to 11.2 Mt P per year (see technical appendix for details).

Modeling current-state and sectoral contributions

Since the current state of the planetary boundaries has not been systematically updated since 2015,[23] this report starts by modeling where the planet may stand today and defining a sectoral split of contributions to that current state. Each planetary boundary requires a different modeling approach based on available data and modeling techniques. Our modeling of sectoral contributions is similarly heterogenous. While we reflect the latest scientific thinking and published literature on the topic, there are several updates to the 2015 analysis expected to be released over the next year that could provide greater clarity.

[20] This report focuses on plastics as representative of chemical pollution, and by extension on novel entities, because of its widespread importance across regions and sectors and its recognition as a planetary-scale threat; Sarah E. Cornell, Joan Fabres, and Patricia Villarrubia-Gómez, "Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle," *Marine Policy,* October 2018, Volume 96; Linn Persson et al., "Outside the safe operating space of the planetary boundary for novel entities," *Environmental Science & Technology*, January 2022, Volume 56, Number 3.

[21] No quantitative boundary threshold for plastic pollution has been agreed upon in the scientific literature, but a desirable target of maximum plastic-waste emissions to aquatic environments has been proposed at eight Mt per year, the estimated global emissions to the oceans in 2010 that galvanized high-level action on plastic pollution by a variety of stakeholders, including the United Nations. See "Outside the safe operating space," January 2022; Stephanie B. Borrelle et al., "Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution," *Science,* September 2020, Volume 369, Number 6510; and the United Nations Environmental Assembly, 2019.

[22] In contrast to earlier work, the boundaries are now based on the nitrogen surplus (agricultural input minus crop uptake) instead of nitrogen input. This ensures that high-intensity use of nitrogen is not penalized if it is used efficiently to produce crops and highlights areas which apply too little nitrogen, such as parts of Africa, showing potential for more efficient crop production; L. F. Schulte-Uebbing et al., "From planetary to regional boundaries for agricultural nitrogen pollution," *Nature*, October 2022, Volume 610; W. de Vries et al., "Assessing planetary and regional nitrogen boundaries related to food security and adverse environmental impacts," *Current Opinion in Environmental Sustainability*, September 2013, Volume 5.

[23] Will Steffen et al., "The trajectory of the Anthropocene: The Great Acceleration," *Anthropocene Review*, January 2015, Volume 2, Number 1.

'Business as usual' projections using planetary boundaries and cost curve analyses

Finally, to understand the size of the challenge facing the planet, we created a set of models to forecast where the planet may stand in 2030 and 2050 against each planetary boundary we analyzed. We selected these time periods because they align with policy goals in the UN post-2020 Global Biodiversity Framework. Any projection involves assumptions and considerable uncertainty, but understanding the relative size of the challenge is necessary to begin to scope possible solutions, as presented in the cost curve analyses in chapter 3.

To project forward, we used the shared socioeconomic pathways (SSPs), which are alternative scenarios of future development used by the IPCC to model potential climate outcomes through 2100. In this report, we use SSP2, which is a "middle of the road" story line widely regarded as the "business as usual" scenario.[24] In SSP2, social, economic, and technological trends do not shift markedly from historical patterns; development and income are uneven among countries; there is slow progress toward achieving Sustainable Development Goals; fossil fuel use declines slowly; and global population growth is moderate, leveling off in 2070.[25] On top of the SSP2 assumptions, our model includes assumptions for nature protection,[26] bioenergy demand and mitigation policy,[27] trade,[28] and productivity improvements.[29]

Again, each planetary boundary required a slightly different modeling approach due to constraints on available data and modeling techniques. While each model generally adhered to the SSP2 assumptions, there are slight variations.

[24] *Shared Socioeconomic Pathways Overview*, United Nations Economic Commission for Europe (UNECE), May 15, 2019.
[25] A detailed review of how the narrative SSP2 story line was translated into quantitative markers can be found in Oliver Fricko et al., "The marker quantification of the Shared Socioeconomic Pathway 2: A middle-of-the-road scenario for the 21st century," *Global Environmental Change*, January 2017, Volume 42; SSPs and Representative Concentration Pathways (RCPs) integrate but do not perfectly overlap; "Explainer: How 'Shared Socioeconomic Pathways' explore future climate change," Carbon Brief, April 19, 2018.
[26] David Leclère et al., "Bending the curve of terrestrial biodiversity needs an integrated strategy," *Nature,* September 2020, Volume 585.
[27] Jan Philipp Dietrich et al., "MAgPIE 4 – a modular open-source framework for modeling global land systems," *Geoscientific Model Development*, 2019, Volume 12, Number 4.
[28] Christoph Schmitz et al., "Trading more food: Implications for land use, greenhouse gas emissions, and the food system," *Global Environmental Change*, 2012, Volume 22, Number 1.
[29] Jan Philipp Dietrich et al., "Forecasting technological change in agriculture—An endogenous implementation in a global land use model," *Technological Forecasting and Social Change*, January 2014, Volume 81.

Box 3

Tipping points

Many of Earth's natural systems respond incrementally to human pressure up to a point. Planetary-boundary thresholds have been set based on scientists' current best understanding of where these points are.[1] Beyond the thresholds, risk increases in a nonlinear way and may cause sudden, significant, and irreversible damage to the systems that provide a safe operating space for humanity.

Failure to act now could have dire consequences

Where Earth already appears to have gone beyond a planetary boundary, delayed action increases the chances of hitting a tipping point.[2] For example, circulation in the Atlantic is being slowed by an influx of less-dense freshwater from the melting Greenland ice sheet. There are concerns that this could collapse the Gulf Stream, which would affect rains in India, South America, and West Africa, and increase storms and lower temperatures in Europe, threatening the food security of billions of people.[3] Tipping points could also cause a domino effect in which one tipping point cascades into others, compounding the problem.[4] The effects of these impacts may be regressive and most acutely felt by vulnerable local communities and Indigenous Peoples.[5]

There is uncertainty about where precisely a planetary boundary could be and when a tipping point might be transgressed,[6] so it is difficult to accurately model this or define when to act. A prudent course of action would thus be precautionary and preemptive.

We underestimate risk of inaction and therefore overestimate cost of action

Most models (including the cost curves presented in the next chapter) may overestimate the cost of action by failing to account for nonlinear risks, and therefore could underestimate the cost of inaction.[7] This suggests action today may be prudent even if current models suggest a negative ROI and highlights the risk of using constant discount rates for natural capital.

Examples of tipping points in the Earth's natural system caused by climate change

There are at least nine tipping points at which a changing climate could cause abrupt or irreversible change of the Earth's natural systems: Greenland ice sheet disintegration, permafrost loss, West Antarctic ice sheet disintegration, boreal-forest shift, Amazon rainforest dieback, coral reef die-off, Atlantic meridional overturning circulation breakdown, West African monsoon shift, and Indian monsoon shift (exhibit).[8] These tipping points could lead to biodiversity loss, sea level rise, disruption to agriculture, and extreme weather conditions, among other impacts.

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[1] Georgina M. Mace et al, "Approaches to defining a planetary boundary for biodiversity," *Global Environmental Change*, September 2014, Volume 28,
[2] Will Steffen, "Trajectories of the Earth System in the Anthropocene," *Earth, Atmospheric, and Planetary Sciences*, August 2018, Volume 115, Number 33.
[3] David I. Armstrong McKay et al., "Exceeding 1.5°C global warming could trigger multiple climate tipping points," *Science*, September 2022, Volume 377, Number 6611.
[4] Juan C. Rocha et al., "Cascading regime shifts within and across scales," *Science*, December 2018, Volume 362, Number 6421.
[5] *Indigenous peoples and climate change: From victims to change agents through decent work,* International Labour Office, 2017; Liton Chakraborty et al., "Leveraging hazard, exposure, and social vulnerability data to assess flood risk to indigenous communities in Canada," *International Journal of Disaster Risk Science,* December 2021, Volume 12.
[6] Nico Wunderling et al., "Interacting tipping elements increase risk of climate domino effects under global warming," *Earth System Dynamics*, June 2021, Volume 12, Number 2.
[7] Nicholas Stern, "Economics: Current climate models are grossly misleading," *Nature*, February 2016, Volume 530.
[8] For additional information on each tipping point, see Robert McSweeney, "Explainer: Nine 'tipping points' that could be triggered by climate change," Carbon Brief, February 10, 2020.

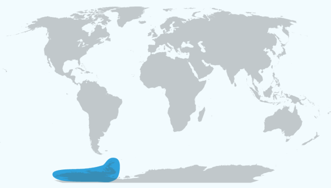
Exhibit

Diverse, climate-driven tipping points put the whole planet at risk.

Ice melt could lead to sea level rise and the release of greenhouse gases.

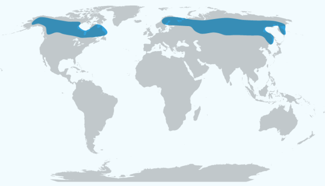
Greenland ice sheet disintegration
Irreversible retreat of the ice sheet caused by rising temperatures

Permafrost loss
Abrupt increase in emissions of CO_2 and methane through the thawing of frozen carbon-rich soils



West Antarctic ice sheet disintegration
Collapse of the ice sheet triggered by persistent grounding-line retreat in one sector, cascading to other sectors

Shifting biomes could lead to regional warming, less rainfall, and collapsing fisheries.

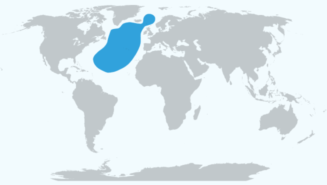


Boreal-forest shift
A shift in boreal forests create expansion into tundra to the north and dieback to the south

Amazon rainforest dieback
Deforestation and hotter, drier conditions cause dieback of the rainforest and a shift towards savannah

Coral reef die-off
Rising temperatures push warm water corals beyond tolerable levels of thermal stress into an alternative state dominated by macroalgae

Changes in circulation could disrupt agriculture and lead to more extreme weather.



Atlantic meridional overturning circulation (AMOC) breakdown
Shutdown of the AMOC caused by an increase influx of fresh water into the North Atlantic

West African monsoon shift
An abrupt change in Sahel rainfall, caused by a shift northwards (wetter) or southwards (drier) into the West African monsoon

Indian monsoon shift
Strengthened monsoon caused by rising CO_2 emissions or a weakening as a result of high aerosol emissions

Source: Carbon Brief; see bibliography

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The current state of planetary boundaries

We find that human activity seems to have gone beyond the safe operating space for humanity (that is, outside of the zone of uncertainty) on at least four boundaries: biodiversity loss, chemical and plastic pollution, nutrient pollution, and GHG emissions.[106] For the two other boundaries—forest cover loss[107] and freshwater consumption—our estimates suggest that the current impact of human activity seems to be in the zone of uncertainty (Exhibit 2).

Terrestrial biodiversity loss stands out—we estimate it is 2.7 times beyond the planetary boundary as currently understood and 1.4 times beyond levels seen in 1970.[108] This is particularly concerning because of feedback loops that exist between biodiversity and the other boundaries. Another standout is the chemical and plastic pollution boundary. We estimate the world economy currently emits 2.6 times the amount of plastic into water sources each year as levels seen in 2010—negatively affecting species, ecosystems, and food webs, and reducing the ability of oceans to sequester carbon.[109]

We find that human activity seems to have gone beyond the safe operating space for humanity.

[106] To better understand where humanity stands against the planetary boundaries, this report updates Steffen et al. (2015) and makes future projections to 2030 and 2050 based on business-as-usual assumptions to assess the planet's trajectory. This report measures the control variables that scientists have aligned on for assessing each boundary. This report excludes analyses of atmospheric aerosol loading and ocean acidification primarily due to a lack of data and ozone depletion since the boundary is stable within limits. For more detail on the analysis, please see the technical appendix and "Planetary boundaries," January 2015.

[107] This report uses a data set from the FAO, focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as the Global Forest Watch (GFW), which classifies any sort of forest degradation as deforestation. Moreover, natural forest conversion to plantation forests is not considered forest cover loss in the planetary boundaries framework because plantation forests still enable land–climate interactions.

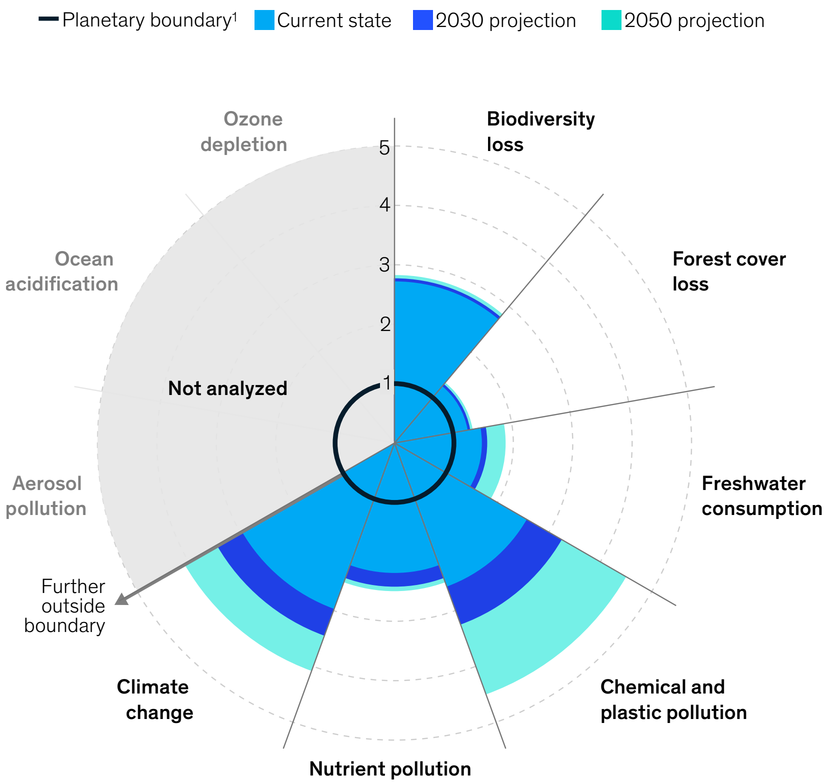
[108] In the marine realm, 56 percent of current fish stocks (this report's measure of marine biodiversity loss) are overfished.

[109] Although there is no official boundary for plastic-waste emissions to aquatic environments, following the suggestion of leading plastic-waste emissions scientists and research by the UNEP, this report uses 2010 plastic-waste emissions to aquatic environments as a reference boundary, which equates to eight Mt per year. See Stephanie B. Borrelle et al., "Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution," Science, September 2020, Volume 369, Number 6510; Sarah E. Cornell, Joan Fabres, and Patricia Villarrubia-Gómez, "Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle," *Marine Policy,* October 2018, Volume 96; and the United Nations Environmental Assembly, 2019.

Exhibit 2

Human activity seems to have pushed the planet two times beyond the 'safe operating space' on at least four boundaries.

Current and projected status against planetary boundaries, multiples beyond planetary boundary[1]



Boundary Control variable		
Biodiversity loss Biodiversity intactness index (BII)[2]	**Chemical and plastic pollution** Plastic-waste emissions to aquatic environments	Aerosol pollution Not analyzed—lack of reliable data
Forest cover loss[3] Forested land as a percent of potential forest cover	**Nutrient pollution[4]** Nitrogen runoff, nitrogen deposition, and phosphorous pollution	Ocean acidification Not analyzed—lack of reliable data
Freshwater consumption Blue-water consumption	**Climate change[5]** Contribution of GHG[6] emissions to warming	Ozone depletion Not analyzed—on path to recovery

Note: Refer to technical appendix section 2 for a detailed analytical approach for each boundary.
[1]This chart only reports the planetary boundary and does not include the looser, outer "zone of uncertainty." Beyond the strict boundary there is a nonzero risk of triggering a "tipping point" (systems collapse).
[2]BII is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.
[3]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions.
[4]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution. The exhibit shows the current state and projections for phosphorous pollution, which is the furthest beyond the boundary of the three.
[5]This report's analysis follows the planetary-boundaries literature to use "radiative forcing," which measures excess Earth system energy and, when positive, causes warming. Radiative forcing is driven in large part by GHG emissions.
[6]Greenhouse gas.
Source: See bibliography

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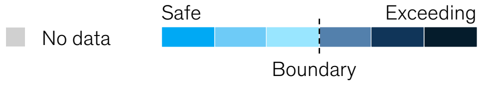
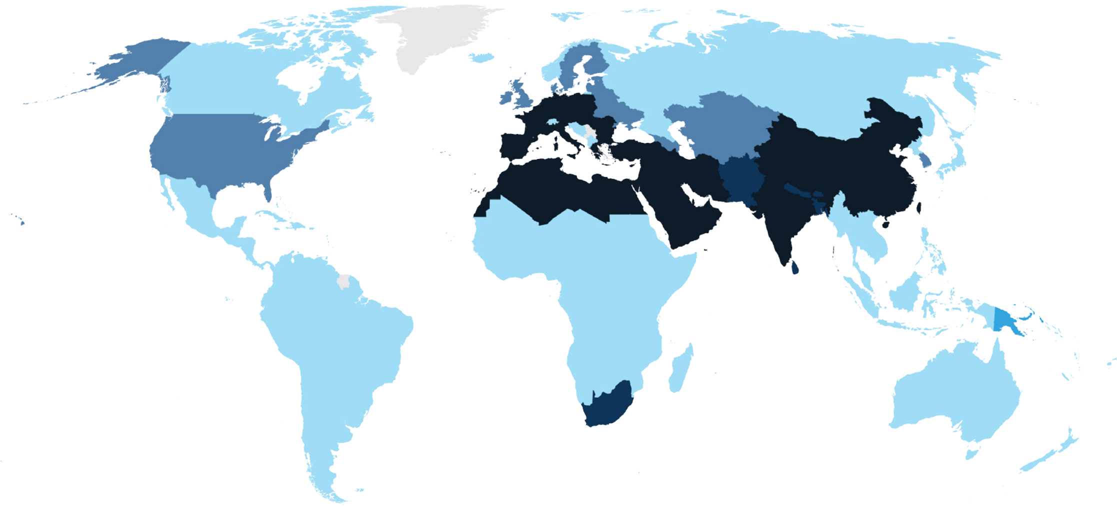
Some planetary boundaries—especially nutrient pollution and terrestrial biodiversity loss—can be assessed locally and globally. For example, nitrogen runoff travels relatively small distances (less than 1,000 kilometers).[110] The nitrogen boundary seems to have been crossed in Europe and Asia (Exhibit 3), and the global average is above the safe limit. But our estimate suggests that 114 countries may have a nitrogen deficit (see Box 4, "How the Netherlands is seeking to tackle its nitrogen crisis").

Exhibit 3

Nitrogen runoff pollution has exceeded the boundary across Europe and large parts of Asia.

Runoff nitrogen pollution compared to surplus boundary





Note: Spatial grain is national boundaries; the boundaries and names shown on maps do not imply official endorsement or acceptance by McKinsey & Company.
Source: See bibliography

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[110] Willem A. H. Asman, Jan K. Schjørring, and Mark A. Sutton, "Ammonia: Emission, atmospheric transport and deposition," *New Phytologist,* 1998, Volume 139, Number 1; D. Fowler et al., "Regional mass budgets of oxidized and reduced nitrogen and their relative contribution to the nitrogen inputs of sensitive ecosystems," *Environmental Pollution,* 1998, Volume 102, Number 1.

Box 4

How the Netherlands is seeking to tackle its nitrogen crisis

The Netherlands is a dense, urbanized country with an intensive and highly productive agricultural sector; the country is consistently one of the world's largest net exporters of agricultural products. Agriculture is the largest nitrogen emitter, contributing almost half of the Netherlands' excess nitrogen. This is predominantly caused by dense dairy operations, with Dutch farms holding four times more animal biomass per hectare than the European Union average.

Excess nitrogen in the Netherlands has a noticeable impact on the local environment. In water, it causes algal blooms that deprive ecosystems of oxygen and kill marine life. In soil, nitrogen-loving plants such as grasses, blackberries, and nettles are outcompeting others, driving biodiversity declines that are cascading through ecosystems and affecting insects and birds.[1] Nitrogen can acidify the soil, preventing roots from absorbing nutrients such as calcium and magnesium, and excess nitrogen in a gaseous state can be harmful to human health.

The Netherlands must now take drastic steps to comply with European legislation on nitrogen.[2] Licenses for nitrogen-emitting activities such as construction are harder to obtain, causing project delays. In 2020, speed limits on Dutch roads were reduced from 130 kilometers per hour (km/h) to 100 km/h to help ease short-term emissions of nitrogen. In June 2022, the Dutch government published spatially explicit nitrogen reduction targets to bring emissions back to levels that ecosystems can handle.[3] In some areas, this means reducing emissions by 70–80 percent,[4] which would involve reducing livestock numbers, potentially by as much as 30 percent.[5]

These actions have roiled farming communities and triggered widespread protests, highlighting that the need for sharp course corrections involves complex trade-offs between lives and livelihoods with large societal costs. Taking proactive action on preserving natural capital, rather than waiting until the consequences are unavoidable, can help avoid situations like the one now facing the Netherlands.

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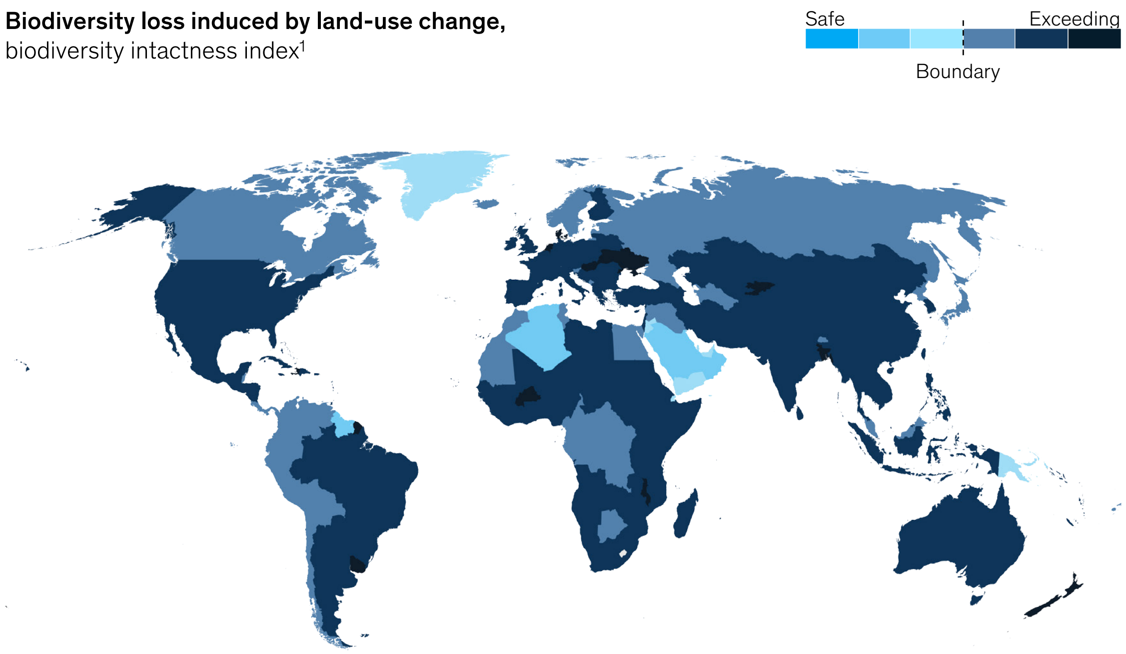
[1] "Stikstof (Nitrogen)," Nederland, World Wildlife Fund, accessed November 17, 2022.
[2] The EU Nitrates Directive (1991) is concerned with the protection of waters against pollution by agricultural nitrate sources. The Ambient Air Quality Directive (2008) limits emissions of NO_2 and other nitrogen oxides; European Commission Nitrates Directive October 11, 2021; "Air quality: Commission refers Bulgaria and Spain to the Court for failing to protect citizens from poor air quality," European Commission, July 25, 2019; Nikolaus Kurmayer, "Germany convicted for breaching EU air quality law," Euractiv, June 3, 2021.
[3] "Nitrogen," Wageningen University & Research, accessed August 22, 2022.
[4] "Startnotitie nationaal programme landelijk gebied (National program for rural areas: Initial memorandum)," Rijksoverheid (Netherlands government), 2022.
[5] Toby Sterling, "Dutch farmers protest plan to curb nitrogen pollution," Reuters, June 22, 2022.

Freshwater use is another variable that remains in what is currently understood to be the zone of uncertainty but can cause devastating issues when exceeded locally. Terrestrial biodiversity loss is a more widespread problem and seems to be beyond what is understood to be the boundary in at least 168 countries (Exhibit 4). Terrestrial biodiversity loss seems to be within the boundary in only 20 countries.

Exhibit 4

Biodiversity loss has exceeded the planetary boundary across most of Earth's terrestrial area.

Biodiversity loss induced by land-use change,
biodiversity intactness index[1]



Note: Spatial grain is national boundaries; the boundaries and names shown on maps do not imply official endorsement or acceptance by McKinsey & Company.
[1]The biodiversity intactness index is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.
Source: See bibliography

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The outlook for planetary boundaries

Business-as-usual projections for 2030 and 2050 suggest the outlook could worsen for all of the planetary boundaries assessed.[111] As an example, our model suggests that phosphorus pollution, one of three control variables for nutrient pollution, may increase from 2.3 times what is understood to be the boundary today to 2.7 times the boundary in 2050. Phosphorous pollution can cause eutrophication and toxic algal blooms in water sources, killing fish and plants because of a lack of oxygen and making water undrinkable for humans. On the climate change boundary, previous research has shown that a business-as-usual approach to climate change could potentially leave the planet beyond the safe operating space for humanity in 2050.[112]

The 2050 projections form the basis of the cost curves outlined in chapter 2. Each cost curve uses the difference between the 2050 projection and the boundary as the total abatement goal.

Sectoral contributions toward planetary boundaries

Each sector of the economy has a different impact on natural capital and can implement unique mitigation opportunities. To inform the potential for sectoral action, we first estimate sectoral contributions to the planet's current position against each planetary boundary (Exhibit 5). This analysis only considers direct impacts, rather than indirect ones manifesting themselves throughout an industry's entire value chain, even though those impacts are also critical.

Food systems (crop and livestock agriculture) appear to be having the largest impact on the planet and are the largest contributing sector in five out of the nine planetary boundary control variables assessed. Our midpoint estimate is that crop agriculture accounts for 72 percent of freshwater consumption, 61 percent of nitrogen runoff pollution, and 32 percent of terrestrial biodiversity loss. We estimate that livestock agriculture is the largest contributor to biodiversity loss (53 percent) and phosphorus pollution (51 percent)[113] and is the second-largest contributor for nitrogen runoff and deposition. We included food grown for livestock under crop agriculture.

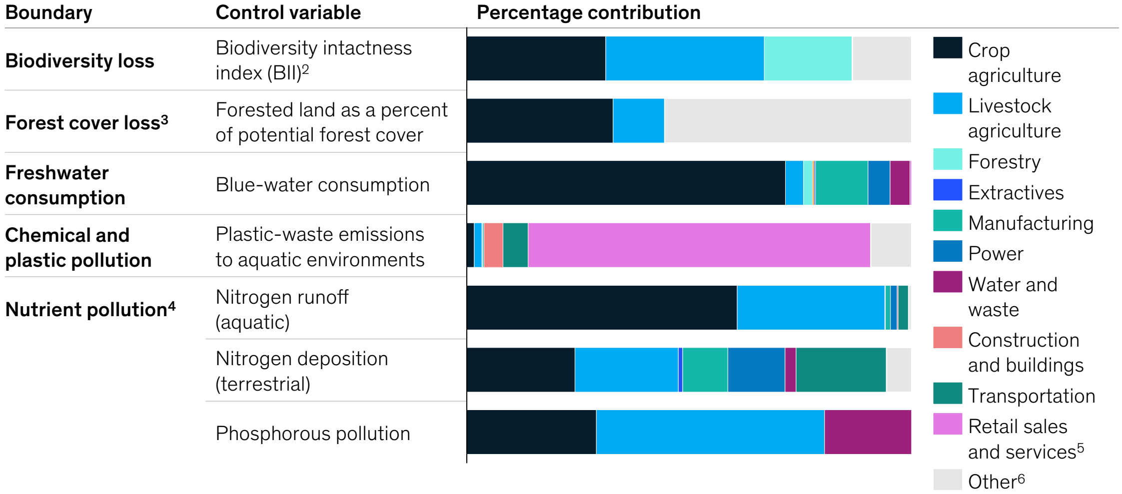
The retail sales and services sector—which includes retail, accommodation and food services, IT, finance, insurance, professional and support services, education, health, and entertainment—accounts for 77 percent of chemical and plastic pollution (as measured by plastic-waste emissions to aquatic environments), according to our midpoint estimates. Previous McKinsey research has shown that the power sector and industry (including the manufacturing and extractives sectors) contribute the most to the GHG emissions that drive climate change.[114]

[111] Business-as-usual projections were constructed using the assumptions that underlie the middle-of-the-road SSP (Shared Socioeconomic Pathways) scenario, or SSP2, as well as the Model of Agricultural Production and its Impact on the Environment (MAgPIE 4) model. Since each planetary boundary used a different underlying data set, each business-as-usual projection differed slightly in its assumptions. A detailed review of each projection by planetary boundary can be found in the technical appendix. Comprehensive overviews of SSP2 and MAgPIE 4 can be found in *Shared Socioeconomic Pathways Overview,* United Nations Economic Commission for Europe (UNECE), May 15, 2019, and Jan Philipp Dietrich et al., "MAgPIE 4 – a modular open-source framework for modeling global land systems," *Geoscientific Model Development,* 2019, Volume 12, Number 4.
[112] "Climate math," April 2020.
[113] This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste that is lost to the environment (manure that is left over once manure has been processed or used for other agricultural applications); Fei Lun et al, "Global and regional phosphorus budgets in agricultural systems and their implications for phosphorus-use efficiency," *Earth System Science Data*, 2018, Volume 10; Sanna Lötjönen, Markku Ollikainen, and Esa Temmes, "Dairy farm management when nutrient runoff and climate emissions count," *American Journal of Agriculture Economics*, February 2020, Volume 102, Number 3.
[114] "Climate math," April 2020.

Exhibit 5

Agriculture is the largest contributor to exceeding planetary boundaries, as currently understood, followed by retail sales and services.

Sectoral contributions[1] toward each planetary boundary, % on relative scale



Note: Analysis focuses on five of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Greenhouse-gas emissions are excluded because they are well covered in other reports. Refer to technical appendix section 2 for a detailed analytical approach for each boundary.

[1]Sectoral contributions are calculated based on direct operations and do not account for upstream or downstream impacts (for example, construction contributes to biodiversity loss primarily through the purchase of materials, not directly).

[2]The biodiversity intactness index (BII) is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.

[3]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions. Report assumes no forestry-induced forest cover loss because that sector converts primary forest to secondary and plantation forest, which still conserves total forest cover.

[4]Nitrogen runoff: global nitrogen runoff contributing to surface water eutrophication risk; nitrogen deposition: global nitrogen deposition contributing to terrestrial ecosystem eutrophication and acidification risk; phosphorus pollution: global phosphorus pollution contributing to surface water eutrophication risk. This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.

[5]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.

[6]This category includes biodiversity and forest loss attributed to grassland, peatland, bare land, and shrubland on primary forest which is not directly attributable to sectoral activities, as well as a very small contribution from urban land use.

Source: See bibliography

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Our estimates also show that there are three cases in which an individual sector contributes enough to exceed a planetary boundary on its own. Livestock agriculture contributes 112 percent of the phosphorus portion of the identified nutrient pollution boundary,[115] crop agriculture contributes 105 percent of the identified freshwater consumption boundary, and other services contributes enough plastic pollution to exceed 2010 levels of plastic-waste emissions to aquatic environments by 198 percent (Exhibit 6).

We measured the impact of each sector's direct operations—that is, the activities conducted by companies in that sector, not the activities conducted by their suppliers or customers. However, each sector is interrelated, and a sector's largest impact may occur upstream or downstream of its direct operations. For example, large buyers of agricultural products, such as textile manufactures, may appear to have a relatively small impact on natural capital simply because their impact primarily occurs through the agricultural products used in production. This is important because the challenge of mitigating impacts is a wider value chain responsibility. Companies may need to look beyond their direct operations much as companies now measure and act on Scopes 1, 2, and 3 carbon emissions.

We also did not analyze secondary impacts beyond an activity's direct footprint. This has implications for interpreting results for the extractives sector. For instance, mining has been shown to increase deforestation up to 70 km beyond mining lease boundaries, causing 12 times more deforestation than within the lease alone.[116] Our estimates of extractives' contribution to land-use change and biodiversity loss may thus be substantial underestimates.

Continued depletion of natural capital could trigger extreme changes to the planet, undermining the conditions on which society and the economy have come to rely.

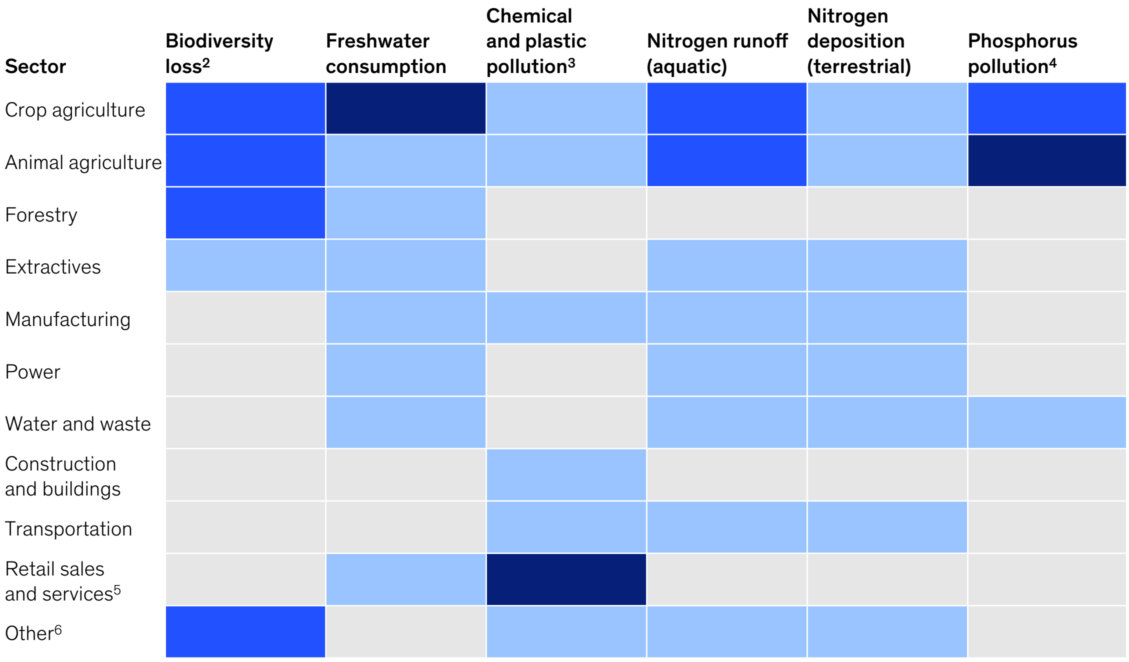
[115] Ibid.
[116] Laura J. Sonter et al., "Mining drives extensive deforestation in the Brazilian Amazon," *Nature Communications*, October 2017, Volume 8, Number 1013.

Exhibit 6

In three instances, a single sector contributes to overshooting the planetary boundary as currently understood.

Proportional contribution[1] of individual sectors toward planetary boundaries, % of boundary from individual sector

< 33% 33–100% > 100%



Note: Analysis focuses on four of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Greenhouse-gas emissions are excluded because they are well covered in other reports. Forest cover loss is not included in this chart because the sector analysis looks at contribution to forest loss since 2000, so it cannot be linked to the boundary in this case. Blanks were not analyzed. Refer to technical appendix section 2 for detailed analytical approach for each boundary and sector.
[1]Sectoral contributions are calculated based on direct operations and do not account for upstream or downstream impacts (for example, construction contributes to biodiversity loss primarily through the purchase of materials, not directly).
[2]The biodiversity intactness index (BII) is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.
[3]Control variable shown is plastic-waste emissions to aquatic environments.
[4]This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.
[5]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
[6]This category includes biodiversity and forest loss attributed to grassland, peatland, bare land and shrubland on primary forest which is not directly attributable to sectoral activities, as well as a very small contribution from urban land use.
Source: See bibliography

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3 How companies can address impacts on nature

Our research suggests that companies have the potential to shift the world's trajectory on natural capital and usher in a return to a safe operating space by 2050. And they could do so through a set of targeted actions that use existing technologies and that in many cases could contribute to earnings.

In this chapter, we assess the effect of 47 potential corporate actions, or levers, to mitigate the loss of natural capital across five planetary boundaries: biodiversity loss, forest cover loss, freshwater consumption, chemical and plastic pollution, and nutrient pollution. We exclude the boundary for greenhouse-gas emissions because it is covered in other reports McKinsey has published.[117]

The midpoint results of our analysis suggest that corporate action could potentially get the planet back within three of the planetary boundaries: forest cover loss, freshwater consumption, and nutrient pollution. The sized levers could also address 48 percent of the projected overage of the boundary for biodiversity (getting close to a pre-1970 level) and 60 percent of the identified boundary for chemical and plastic pollution. This analysis demonstrates that corporate action, using technologies and approaches available today, could make a meaningful contribution to addressing the challenge of the planetary boundaries, although corporate action alone is not sufficient. "Whole of society" levers, such as nature conservation, and new technologies, such as novel enzymes that can break down plastic and technologies to extend the shelf life of foods, could help close the remaining gaps.

Twelve corporate actions with an estimated net-positive ROI of around $700 billion could potentially deliver about 45 percent of the abatement potential we identify. The 12 include regenerative-agriculture techniques, food waste reduction, and implementing new delivery models to reduce plastic production (for instance, returnable and reusable container programs). Taken together—and if fully implemented—these 12 levers could achieve an annual benefit of around $700 billion, net of costs. Four other levers are low cost but have potentially high impact, delivering 8 percent of the identified mitigation potential at a net cost of around $15 billion per year, according to our estimates. These four are precision agriculture for cropland, regenerative agriculture in pastures, recycling construction plastic, and mechanical recycling. A further 20 levers,[118] representing 47 percent of the abatement potential, are ROI negative with today's technologies and no pricing of externalities. We estimate that these levers could be achieved at a net cost of up to $1.5 trillion per year. As markets and technologies mature, the ROI of those actions could increase.

Corporate action on nature also has meaningful overlap with climate action (see Box 5, "The nature–climate nexus"). Nine of the 47 levers identified have significant abatement potential for both carbon and other planetary boundaries. Together, these nine levers could provide

[117] See "The net-zero transition," January 2022; "Climate math," April 2020; *Agriculture and climate change,* April 2020.
[118] We exclude 11 other higher-cost levers in the top-line ROI numbers, such as the use of nitrogen inhibitors in cropland and desalination, because these provide mitigation above what is needed to address the freshwater and nutrient boundaries and do not address other boundaries. They may have local applications, however.

15 metric gigatons (Gt) of CO_2-equivalent (CO_2e) abatement per year, or about 40 percent of annual emissions in 2020. They include eight agricultural levers, such as regenerative and precision agriculture, as well as switching to solar and wind power. They could address 64 percent of projected freshwater consumption, 44 percent of projected nutrient pollution, and 5 percent of projected biodiversity loss. Four of the 13 we did size are excluded from top-line numbers because they are expensive and go beyond what was needed to address the five planetary boundaries we analyzed. While we did not size CO_2 potential for the 34 other levers, many of them could also have a net climate benefit.

Of course, demonstrating a potential for abatement does not ensure its realization. Any given lever represents a change in the way companies operate—and, by extension, in the way people consume their products and services. The abatement potential we present assumes that each opportunity is pursued systematically and completely across the world; that there is collaboration and coordination between upstream and downstream partners (for instance, between farmers and the buyers of agricultural products); and that policy makers create enabling conditions.

This chapter starts with a review of our approach to constructing cost curves for planetary boundaries and then moves on to a discussion of the overall abatement potential and economics of the 47 corporate levers and an in-depth review of specific levers and sector-level actions. It concludes with a discussion of action beyond the corporate sphere that will be required to fully address the planetary boundaries, including whole-of-society actions and new technologies.

Box 5

The climate–nature nexus

Addressing climate change and protecting nature are widely understood to be mutually supporting goals—the causes are similar, negative outcomes are mutually reinforcing, and efforts to address one will generally benefit the other.[1] In fact, protecting, managing, and restoring natural capital provides a cost-effective pathway to both sequester carbon and increase climate resilience.[2] Action to address nature builds on the carbon-mitigation activities that companies are already pursuing. Companies can tackle climate-related and nature-related issues together or, at a minimum, understand the impact on natural capital while addressing climate.

Nature will help determine the trajectory of the net-zero transition

There is a risk that if nature deteriorates further, the world will not be able to achieve its climate goals.[3] For instance, vast stores of irrecoverable carbon depend on the preservation of nature ecosystems such as mangroves, peatlands, marshes, and old-growth forests, which contain more than 139 billion tons of CO_2. The ocean floor also contains carbon-rich sediments that, if disturbed, could release additional carbon.[4] If this carbon were released into the atmosphere, it would likely be impossible for humanity to avoid the worst climate outcomes.[5]

[1] Hans-Otto Pörtner et al., “Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change,” Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), June 24, 2021.
[2] “Why investing in nature is key to climate mitigation,” McKinsey, January 25, 2021.
[3] “Exponential roadmap for natural climate solutions,” Conservation International, accessed November 10, 2022.
[4] Julien Claes, Duko Hopman, Gualtiero Jaeger, and Matt Rogers, “Blue carbon: The potential of coastal and oceanic climate action,” McKinsey, May 2022.
[5] “Irrecoverable carbon,” Conservation International, accessed November 10, 2022.

Overlapping benefits

Investing in carbon mitigation can help the environment through recovery of natural systems[6] and by helping mitigate one of the key drivers of extinction risk.[7] In the opposite direction, investing in natural capital can sequester carbon, via protection of irrecoverable carbon sinks (stores of carbon in nature that are vulnerable to release from human activity and, if lost, could not be restored by 2050[8]), the acceleration and derisking of carbon mitigation pathways,[9] and improved climate resiliency.[10] Current programs such as REDD+ are constructed precisely to take advantage of these synergies.[11] We estimate that scaling carbon markets could address 7 percent of the biodiversity loss challenge.

Natural climate solutions (NCS)—"conservation, restoration, and improved land management actions that increase carbon storage or avoid greenhouse gas emissions"—are already playing a meaningful role in emissions reduction.[12] Of the $632 billion of annual spending on climate mitigation or adaptation from 2019 to 2020, $36 billion was invested in nature.[13] And estimates show that NCS is a lower-cost way to provide around one-third of the climate mitigation needed to reach a 1.5° or 2°C pathway by 2030[14]—close to 7.0 metric gigatons (Gt) of CO_2 and up to 11.7 $GtCO_2$ per year[15]—including through innovative blue carbon initiatives.[16]

There are also operational benefits for companies: many of the same team members who currently focus on reducing emissions could help identify and implement opportunities to reduce company impacts on natural capital. Companies can also use the same business intelligence assets, investment channels (for example, in credits), reporting tools, and other assets.

The need for an integrated strategy

Despite this synergy, there are sufficient differences between carbon- and nature-related actions that they cannot be viewed as substitutes. The overlap between biodiversity hot spots and carbon-rich areas is just above 40 percent, meaning that it will not be enough to focus only on carbon and hope to protect natural capital, or vice versa.[17] And some actions that are beneficial to carbon sequestration can damage natural capital, such as the planting of non-native trees.[18] And even then, the interactions between climate and nature goals are complex: for example, non-native plants have been shown to have the unexpected effect of reducing the carbon sequestration potential of the ecosystem.[19] The key is that actions taken with both systems in mind are more resilient and effective than actions that consider only carbon emissions or other dimensions of natural capital independently.

[6] Carolina Soto-Navarro, "Mapping co-benefits for carbon storage and biodiversity to inform conservation policy and action," *Philosophical Transactions of the Royal Society B*, January 2020, Volume 375, Number 1794.
[7] Mark Urban, "Accelerating extinction risk from climate change," *Science*, May 2015, Volume 348, Number 6234; Cristian Roman-Palacios and John Wiens, "Recent responses to climate change reveal the drivers of species extinction and survival," *PNAS*, February 2020, Volume 117.
[8] "Irrecoverable carbon," accessed November 10, 2022.
[9] *Nature and net zero*, a joint report from World Economic Forum and McKinsey, May 2021.
[10] *Step up climate change adaptation or face serious human and economic damage*, United Nations Environment Programme, January 14, 2021.
[11] "REDD+," United Nations Environment Programme, accessed August 5, 2022.
[12] "Natural climate solutions," The Nature Conservancy.
[13] Baysa Naran et al., *Global landscape of climate finance 2021*, Climate Policy Initiative, October 2021.
[14] *Nature and net zero*, May 2021.
[15] Lera Miles et al., *Nature-based solutions for climate change mitigation*, United Nations Environment Programme, 2021.
[16] "Blue carbon," May 2022.
[17] The overlap is a bit more salient for irrecoverable carbon, as less than 14 percent of Earth's land area contains 75 percent of its irrecoverable carbon and provides habitat for 91 percent of its terrestrial vertebrate species. "Mapping co-benefits for carbon storage and biodiversity," January 2020; "Irrecoverable carbon," accessed August 5, 2022.
[18] Liz Kimbrough, "Article against single species, non-native tree plantations finds wide support," Science: The Wire, October 16, 2021.
[19] L. P. Waller et al., "Biotic interactions drive ecosystem responses to exotic plant invaders," *Science*, May 2020, Volume 368, Number 6494.

Our approach

Consistent with previous McKinsey applications of cost-curve analyses, this chapter for the first time applies an economic lens to the question of what it will take to bring the planet back to a safe operating space for humanity, focusing on corporate actions across five planetary boundaries.[119] For clarity, we report our estimates as averages or midpoint values rather than ranges, even while many of our estimates contain varying ranges. The analysis does not include any measure of the enormous intrinsic value of natural capital and natural systems,[120] nor does it include a risk adjustment to account for potential economic impacts stemming from further depletion of natural capital. While the choice of which levers to implement may also rely on noneconomic considerations, we believe that an evaluation of marginal returns is a helpful place to start the discussion on which levers to implement. Nevertheless, there are meaningful limitations to this analysis (see Box 6, "Limitations of this analysis").

Process to select levers

This report takes a broad approach to identify an initial set of levers. Constructing cost curves for a broader set of planetary boundaries is, in some ways, more complex than constructing them for greenhouse-gas emissions due to the breadth of disciplines involved. By opting for a broad approach, we necessarily limit the depth to which we can explore individual abatement opportunities. Still, we hope this analysis can be useful to enable comparison, discussion, and action by applying a consistent approach across planetary boundaries, sectors, and regions.

This report uses a bottom-up process to identify almost 900 lever ideas from various sources, including peer-reviewed articles, external industry experts, internal knowledge experts, and corporate and industry reports, in addition to our experience serving a wide range of companies. Three guiding principles were used to refine the ideas into a final list of levers:

Include only actions that corporate leaders could implement and that do not have a significant impact on output. This report sizes only levers that nonfinancial corporations could implement directly, without meaningfully affecting their overall output. This principle therefore excludes actions that must be implemented by policy actors (for example, subsidy reform), financial actors (for example, green-financing initiatives), and consumers (for example, global demand reduction).[121] The principle also excludes actions that could be beneficial to one dimension of the environment but reduce output and therefore negatively affect other dimensions. For example, planting water-efficient tree varieties is excluded as a water-saving lever because it could decrease the supply of in-demand tree varieties and potentially require an increase in forestry land use to achieve the same level of output, thus negatively affecting biodiversity.

Focus on high-level, global actions that have significant impact. The levers are defined broadly by design. They are meant as a starting point to encourage future analysis at a more granular sector, region, or company level. Smaller-scale actions that may be important in some contexts are either included within the high-level levers or excluded from consideration. For example, optimizing the timing of transportation traffic to minimize interference with nature could mitigate biodiversity loss,[122] as could the use of wildlife corridors, but the impact

[119] Our framing for this report draws heavily on Version 2 of the global greenhouse-gas abatement cost curve, which was published in 2013, building on the original 2007 publication. More recent work has expanded the cost curve approach to many specific regions and sectors and also focused on what it will take to make the net-zero transition. We expect that the planetary-boundary cost curves will follow a similar maturation process over time. See. "Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement cost curve," McKinsey, September 1, 2013; Per-Anders Enkvist, Tomas Nauclér, and Jerker Rosander, "A cost curve for greenhouse gas reduction," *McKinsey Quarterly*, February 1, 2007; "The net-zero transition: What it would cost, what it could bring," McKinsey, January, 2022; for more, see McKinsey's Insights on Sustainability.
[120] "Valuing nature conservation," McKinsey, September 22, 2020.
[121] We discuss these actions as enablers for the quantified corporate levers both in this chapter and in chapter 5.
[122] Ellen Damschen et al., "Ongoing accumulation of plant diversity through habitat connectivity in an 18-year experiment," *Science*, September 2019, Volume 365; Joshua Tewksbury et al., "Corridors affect plants, animals, and their interactions in fragmented landscapes," *PNAS*, September 2002, Volume 99.

Box 6

Limitations of this analysis

The cost curves in this chapter are based on a large set of assumptions. While we expect our estimates to be reasonable given the information available, they contain considerable uncertainty. We expect that McKinsey and others will address these limitations in future iterations of planetary-boundary cost curves.

— Our analysis excludes levers that have a small overall impact on the planetary boundaries. Specifically, we excluded levers that cannot be scaled to a global level and levers where full implementation would have a negligible impact on the planetary-boundary control variable.

— Our analysis excludes levers that do not affect planetary-boundary control variables. For example, the control variable for chemical and plastic pollution is plastic-waste emissions to aquatic environments, so our analysis does not include levers that mitigate pollution from other "novel entities" that make up the planetary boundary, including heavy metals and radioactive material. Similarly, the biodiversity intactness index (BII) metric for biodiversity uses the direct spatial footprint of land use, so it does not capture the impact of activities that improve biodiversity in areas outside of a company's direct footprint. The extractives sector is especially underrepresented in our analysis due to its small direct footprint and the exclusion of pollutants common to mining.

— Some levers are excluded due to their negative impact on other planetary boundaries or due to mixed scientific findings to date. Since each planetary boundary represents a distinct system, we believe that it would be prudent to conduct more detailed analysis before implementing these levers at a global scale. Examples include plastic incineration, replacement of plastic with paper, and forest fire mitigation using clear-cutting. Although we excluded such levers, our analysis does not include systematic attention to second-order impacts on other aspects of the environment, socioeconomic considerations, or local communities. Therefore, any implementation of these levers must include a detailed analysis of such second-order impacts.

— Our analysis does not include emerging technologies that have not yet been broadly proved in a real-world context. Many of these technologies may become more feasible over the next 30 years and could play a major role in solving the nature crisis.

— Regional granularity is limited. Our analysis accounts for where levers can technically be implemented at the country level. A greater level of subnational precision may yield different results. Specific regional and local strategies should assess the feasibility and impacts of each lever before implementing. Similarly, the global analysis means that cost estimates do not account for regional variations, instead using the cost to implement in the United States and Europe, where estimates are more readily available.

— Abatement potential of specific levers may be larger than stated. Levers have been sized to be mutually exclusive, but each lever may have a larger abatement potential if sized independently. In general, we maximize the abatement potential of lower-cost levers before considering overlapping levers, which artificially reduces the abatement potential of higher-cost levers. We have also limited implementation of levers to avoid negative impacts on output (for example, adding trees to cropland only up until the point where that does not affect production). In these cases, the true potential may be higher.

— Costs are estimated in current dollars and exclude enabling capital. Cost sizing does not account for future changes in global commodities pricing. It also does not estimate variations in cost per year into the future, which would allow for the application of a discount rate. This analysis includes estimates of net marginal changes in operating and capital expenditure but does not include costs related to investing in new technologies, building new supply chains, and other enablers of the transition.

— Our analysis does not include a ramp-up period or assumptions around the speed of learning and adoption. All levers are technically feasible today, but ramp-up times may vary, which could affect cost estimates and total abatement potential.

— Abatement potential and costs are not risk adjusted. The analysis excludes both potential benefits associated with disaster avoidance and possible risks associated with implementation of the levers. For instance, reducing oil extraction would implicitly reduce the risk of oil spills, thus abating a potential environmental impact and providing some risk-adjusted cost benefit. We also exclude risk adjustment for nonlinear risks, which are beyond the scope of this report.

— The levers are not comprehensive. They are the result of a bottom-up identification process undertaken with an extensive network of experts. The cost curves should be taken as an initial library that can and should be expanded and refined over time, not as a comprehensive list of all possible levers a corporation can implement.

For further details on the assumptions and sources used in the construction of each lever, please refer to the technical appendix of this report.

cannot be reliably quantified at a global scale using the BII metric. Such levers could still be extremely effective and important in some regions or situations.

Choose the most realistic and effective actions, as supported by the available data and science. Data availability and quality vary across planetary boundaries, as do the maturity and agreement of available science for sizing levers. The final list of levers includes actions with the most support and acknowledgment in scientific literature. In many cases, we exclude lever ideas from quantification either because we could not identify available data or because available science showed conflicting assumptions. We also exclude levers that would have meaningful adverse social impacts.

Approach to estimating costs

In addition to estimating each lever's abatement potential, this report estimates the net return (net cost or value opportunity) for each lever by assessing the lever's incremental cost or savings potential relative to the business-as-usual alternative. For levers that include net new processes or capital, where there is no business-as-usual alternative, the lever cost is equivalent to the total cost of implementation. The net costs and savings are calculated in today's dollars (2022) based on three components: (1) incremental capital expenditures required to implement the lever, calculated by dividing total incremental capital expenditure by the lifetime of the capital; (2) incremental operating expenditures required to implement the lever; (3) incremental operating savings resulting from implementing the lever. We report midpoint estimates based on maximum feasible adoption of each lever. The costs are calculated using industry reports or academic articles that define implementation costs primarily in the United States and Europe, and estimates represent the cost or savings from implementing the lever in 2022. Because this report uses 2022 costs, the analysis does not apply a discount rate to cost estimates, nor does it consider any cost improvements due to learning rate improvements or other efficiencies. Future analyses that include such estimates could help refine this cost estimate.

The cost estimates represent the annual cost to get the world within the planetary boundaries for water consumption, forest cover loss, and nutrient pollution, and the total identified abatement potential for biodiversity loss and chemical and plastic pollution. Since the identified levers for water consumption and nutrient pollution exceed the planetary boundary, the total cost excludes the costliest levers that would get the planet above and beyond the planetary boundary. For example, if all lower-cost freshwater levers were implemented, the world would not need to invest in desalination, so the desalination lever is excluded from the total cost. Since these costs do not include sufficient levers to fully address biodiversity loss and chemical and plastic pollution, or three other planetary boundaries, the overall cost of addressing all planetary boundaries is likely higher.

While the cost of action is significant, the cost of inaction is likely much higher. With half of all economic activity moderately or highly dependent on natural capital, the cost of losing those resources is many orders of magnitude higher than what is needed to address nature-related crises, even on a risk-adjusted basis.[123] This analysis does not account for these risks and therefore implicitly overstates the costs of acting now.

[123] *Nature risk rising: Why the crisis engulfing nature matters for business and the economy*, World Economic Forum, January 2020.

Estimating the abatement potential across five planetary boundaries

The results of our analysis suggest that corporate action could play a significant role in returning the planet to a safe operating space for humanity. Below, we have illustrated the full potential of the corporate levers we identified against the 2050 forecast and five planetary boundaries (Exhibit 7). The results, reported throughout the report as global averages or the midpoint of high and low estimates, suggest that corporate action could get the world back within the boundaries for forest cover loss, freshwater consumption, and nutrient pollution. The sized levers could also address 48 percent of the projected overage of the boundary for biodiversity (getting close to a pre-1970 level) and 60 percent of the identified boundary for chemical and plastic pollution.

As previously noted, closing the gap at a planetary level does not mean that nature degradation will be addressed in every locale. Rather, it only means that human activity is unlikely to trigger a planetary tipping point.

Each sector can contribute against the projected 2050 gap to the planetary boundary (Exhibit 8). Of all sectors, our estimates suggest that agriculture seems to have the greatest opportunity to address projected overages in the biodiversity, freshwater, and nutrient planetary boundaries by 2050. Agriculture levers account for 72 percent of the total identified improvement in biodiversity loss, addressing 35 percent of the projected global overage, according to our analysis. Agriculture levers could also bring the world entirely within the planetary boundary for forest cover loss, address 82 percent of the gap to the freshwater consumption boundary, and address 94 percent of the gap for nutrient pollution.

While agriculture has a large direct footprint, its role can be taken in a broader context: action from downstream sectors could be critical in enabling the agriculture sector to change. Food manufacturers, for example, can choose to source food outside of regions where deforestation is used to create farmland, and consumers can help drive pressure to do so.[124] As we note later in this chapter, reducing or eliminating food waste may be a critical step toward reducing the agriculture sector's footprint.

Action by retail sales and services sectors (including retail, accommodation and food services, IT, education, health, and entertainment) could help shift the economy on chemical and plastic pollution. To achieve the chemical and plastic pollution mitigation potential shown in Exhibit 8, the economy can both reduce plastic production and limit pollution of existing plastic by adopting circular-economy practices to increase reuse and recycling.[125] Retail sales and services can also contribute significantly across other boundaries through efficiency improvements.

Outside of agriculture and retail sales and services, the remaining sectors have significant opportunity to mitigate impacts on the planetary boundaries, even while their footprints are smaller. The use of sustainable forestry techniques to improve working forest ecosystems will be critical to mitigate biodiversity loss. Infrastructure and capital improvements, including in green energy and desalination, can significantly reduce demand for freshwater. Decarbonization efforts can reduce nitrogen oxide emissions, while improvements in wastewater treatment reduce nitrate and phosphate leakage into the environment.

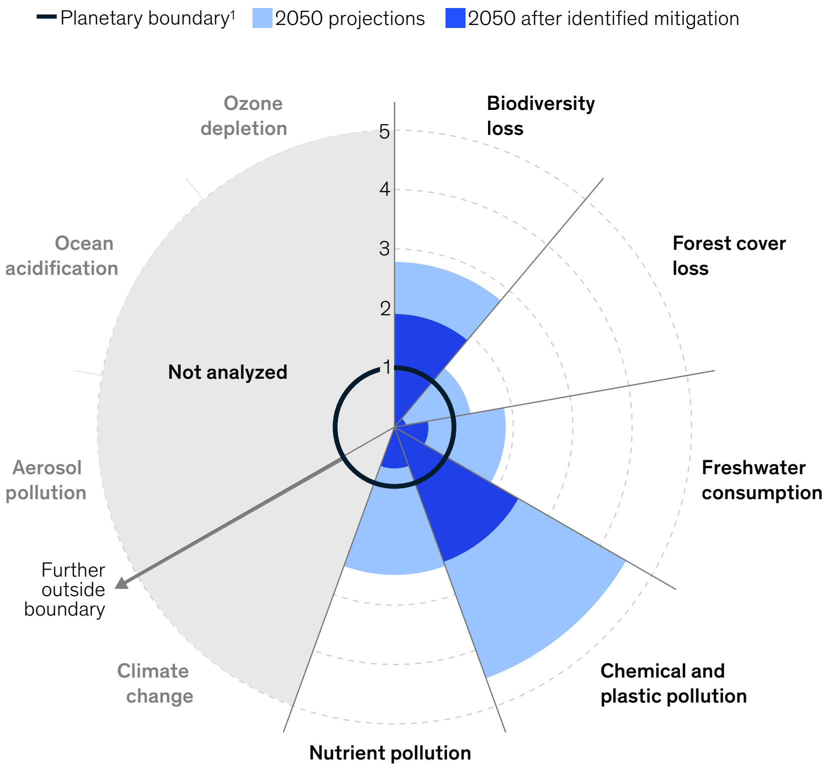
While corporate action can make a meaningful contribution, it cannot fully address the planetary boundaries alone. At the end of this chapter, we discuss two broad categories of actions that can fill the gap: whole-of-society levers and new technologies.

[124] Erasmus Ermgassen et al., "Addressing indirect sourcing in zero deforestation commodity supply chains," *Science Advances*, April 2022, Volume 8, Number 17.
[125] *Breaking the plastic wave*, Pew Charitable Trusts, July 2020.

Exhibit 7

Corporate action could potentially return the planet to within the boundary on at least three planetary boundaries.

Projected status and mitigation potential against planetary boundaries,
multiples beyond planetary boundary[1]



Boundary Control variable		
Biodiversity loss Biodiversity intactness index (BII)[2]	**Chemical and plastic pollution** Plastic-waste emissions to aquatic environments	Aerosol pollution Not analyzed—lack of reliable data
Forest cover loss[3] Forested land as a percent of potential forest cover	**Nutrient pollution[4]** Nitrogen runoff, nitrogen deposition, and phosphorous pollution	Ocean acidification Not analyzed—lack of reliable data
Freshwater consumption Blue-water consumption	Climate change Contribution of greenhouse-gas emissions to warming	Ozone depletion Not analyzed—on path to recovery

Note: Refer to Technical Appendix section 2 for detailed analytical approach for each boundary.
[1]This chart only reports the planetary boundary and does not include the looser, outer “zone of uncertainty.” Beyond the strict boundary there is a nonzero risk of triggering a “tipping point” (systems collapse).
[2]BII is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.
[3]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions.
[4]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution. The exhibit shows the current state and projections for phosphorous pollution, which is the furthest beyond the boundary of the three, while mitigation is assessed as an average of the three.
Source: See bibliography

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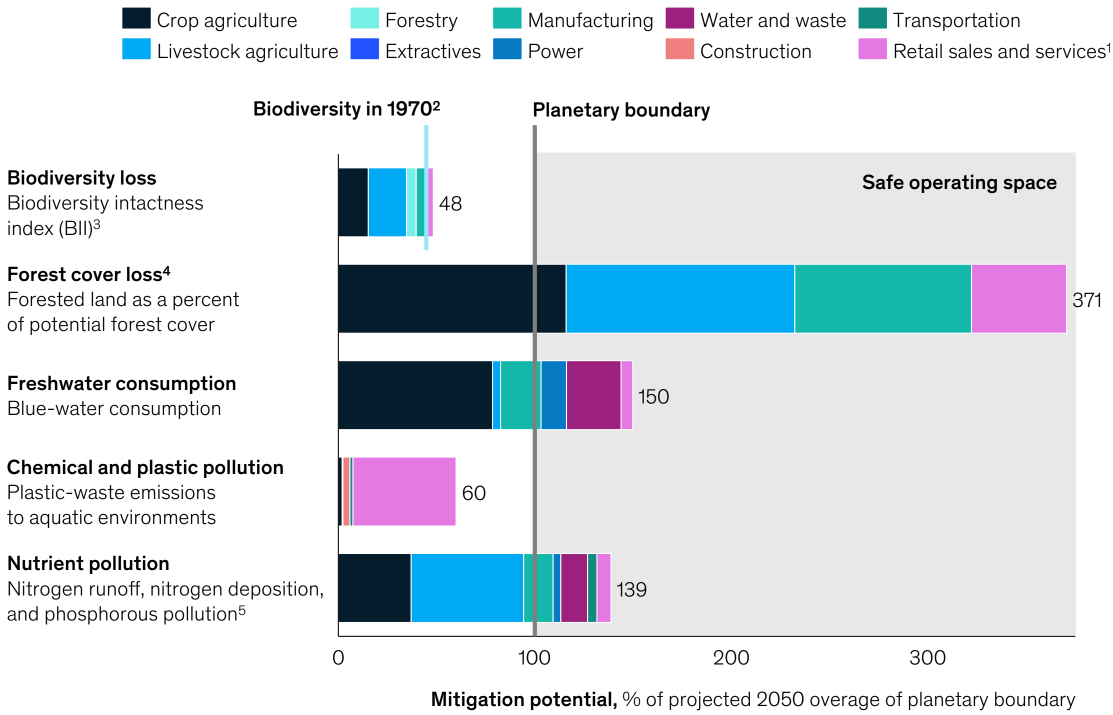
Exhibit 8

Agriculture and retail sales and services seem to have the most abatement potential, though all sectors have a role to play.

All sectors, by sector



Note: Analysis focuses on five of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Greenhouse-gas emissions are covered in other reports and not recreated here. See "The net-zero transition: What it would cost, what it could bring," McKinsey, January 2022; "Climate math: What a 1.5-degree pathway would take," *McKinsey Quarterly,* April 2020; and *Agriculture and climate change,* McKinsey, April 2020. Refer to technical appendix section 3 for a detailed analytical approach for each boundary and sector.

[1]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.

[2]In the literature, the biodiversity intactness index (BII) zone of uncertainty ranges from 10 to 70 percent loss. However, this is subject to a great deal of debate and uncertainty, so the report uses the 1970-level of BII loss to contextualize a potential zone of uncertainty.

[3]BII is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.

[4]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions. Report assumes no forestry-induced forest cover loss because that sector converts primary forest to secondary and plantation forest, which still conserves total forest cover.

[5]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution, all weighted equally. This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.

Source: See bibliography

McKinsey & Company

Almost half of the estimated abatement potential could potentially provide a positive return on investment

Based on our estimates (and subject to the limitations mentioned in our methodology section), 12 levers would have a net-positive ROI in 2022 dollars. If fully implemented, these levers could deliver around 45 percent of the total identified mitigation potential, which would amount to an annual benefit of around $700 billion, net of costs.[126] These levers include switching to regenerative agriculture, reducing food waste, and implementing new delivery models (for instance, returnable and reusable container programs) to reduce plastic use. A natural question may be why ROI-positive levers are not widely implemented already (see Box 7, “Barriers to implementing ROI-positive levers at scale”).

Four levers are defined as low cost[127] and could together deliver 8 percent of the identified mitigation potential at a net cost of around $15 billion per year: precision agriculture for cropland, regenerative agriculture in pastures, recycling construction plastic, and mechanical recycling.

Twenty levers are estimated to be ROI negative in current dollars and, if fully implemented, could deliver around 55 percent of the identified mitigation potential at an annual cost, net of savings, of up to $1.5 trillion.[128]

— Thirteen levers are defined as moderate cost and could together deliver 32 percent of the identified mitigation potential at a net cost of around $1.1 trillion per year. These include agroforestry, biological pest control, drip irrigation, water-efficient manufacturing techniques, and biodegradable plastic for packaging.

— Seven levers are defined as high cost and could together deliver 15 percent of the identified mitigation potential at a net cost of around $370 billion per year. These include the use of manure management, mine reclamation, and wastewater treatment.

Eleven other higher-cost levers, such as the use of nitrogen inhibitors in cropland, desalination, and decarbonizing the transport sector, could provide mitigation above what is needed to address the freshwater and nutrient boundaries (and do not address other boundaries) and are excluded.

These rough ROI estimates are bound to change over time. New technologies can reduce costs, and new policies and new investor expectations could encourage greater accounting of nature impacts. Conversely, costs may be higher, or returns lower, due to localized challenges in implementing levers or slow adoption. One limitation of our analysis is that the underlying models do not account for the cost of negative externalities or include an assessment of nature risk.[129] If such measures were included, ROI levers that are currently negative could become more attractive.

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[126] This report defines ROI in net terms for each lever, meaning that the reported figures include estimates of both costs and savings. Hence, ROI-positive levers are defined as levers where the estimated capital and operational savings exceed capital and operational costs on an annual basis. The net costs and savings are calculated as incremental to business as usual, are calculated in today’s dollars (2022), and represent the maximum feasible adoption for each lever using available technologies.

[127] The cutoff between moderate and high cost is defined for each boundary: biodiversity loss: $500.0/ha, one-third the average agriculture operational cost in the United States; freshwater consumption: $0.9/m^3$, the average municipal price of water in the United States; chemical and plastic pollution: $22.0/kg, the average cost of plastic production that results in 1 kg of plastic pollution to aquatic environments; and nutrient pollution: $1.0/kg nitrogen runoff, the average cost of nitrogen fertilizer production. The cutoff between low and moderate costs is defined as 10 percent of the medium to high cutoff.

[128] These figures represent a lower bound to the overall cost of getting the world within planetary boundaries, given that the sized levers do not completely address biodiversity loss and plastic pollution, nor do they include the other unsized boundaries.

[129] Financial markets typically do not value nature or externalities that negatively affect nature unless they are associated with a defined asset value or cash flow. Economic models also typically undervalue or fail to value nature due to several interconnected market failures: the benefits of natural capital are often public goods that are nonexcludable and nonrivalrous, the costs and benefits of nature are external to actors who conserve or degrade nature, and discount rates underestimate the value of long-term ecosystem stability compared to economic returns from short-term natural asset consumption. The immense complexity of interdependent and dynamic natural systems also poses a challenge. For a deeper discussion of these issues, see *Financing nature,* 2020; and *The economics of biodiversity: The Dasgupta review*, February 2021.

Box 7

Barriers to implementing ROI-positive levers at scale

One might expect that if a lever is "in the money," corporates would already be implementing the lever at scale. In reality, while there is at least limited adoption of all levers enumerated above, there are many nonfinancial barriers that can limit uptake.

— *Knowledge gaps.* While a solution might be available, implementing agents might not be aware of it. Farmers, for example, must understand what regenerative agriculture is and learn how to integrate it into their practices.

— *Preferences.* Even if implementing agents are aware of a solution, they may be hesitant to embrace new technologies or processes and prefer current solutions to seemingly riskier new solutions. This is especially true when a large proportion of revenue is dependent on an existing practice or when it is difficult to experiment. To return to the example above, even farmers who believe that regenerative agriculture works may hesitate to try a new practice without a proven case from a trusted source.

— *Financing constraints.* High upfront capital costs can limit implementation of ROI-positive levers, especially in regions that are already resource constrained. In higher-income contexts, corporate leaders may choose not to invest in ROI-positive levers that do not meet or exceed set hurdle rates.

— *Delayed payback period.* Some levers, while ROI positive once fully implemented, may not deliver positive returns for several years. Regenerative agriculture, for example, could cause yields to decline in the short term even though it would reduce input needs and be ROI positive in the long term.[1] Resources would be needed to bridge that payback period.

— *Infrastructure and technical constraints.* In some cases, implementing levers at a global level requires supporting infrastructure. For example, implementing mechanical recycling on a global scale would require waste collection and transportation infrastructure. Depending on the regional context, standing up the supporting infrastructure could require additional financial resources or broader governmental support.

— *Policy.* Existing regulations, subsidies, or other incentives may contribute to maintaining the status quo. For example, when the cost of fertilizer is subsidized, the financial benefit of reduced fertilization using soil tests is significantly lower.[2]

[1] Raj Kumar Jat et al., "Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic Plains of South Asia: Yield trends and economic profitability," *Field Crops Research*, August 2014, Volume 164.
[2] For example, see "USDA announces plans for $250 million investment to support innovative American-made fertilizer to give US farmers more choices in the marketplace," United States Department of Agriculture, March 11, 2022.

Planetary-boundary cost curves highlight the levers to achieve abatement potential

To illustrate the results of our analysis, we constructed nature mitigation cost curves that mirror marginal abatement cost curves (MACCs) used in the context of greenhouse-gas emissions.[130] The cost curves depict each technical mitigation "lever" as a bar on the chart. The width of each lever is specified by the lever's maximum mitigation potential (while also ensuring that the levers do not overlap), and the height of each lever represents its unit cost.[131] The levers are organized from lowest unit cost—which can be negative, representing a positive return on investment—to highest unit cost. There is significant uncertainty for each individual lever for both cost and abatement potential.

Examining the mitigation potential of 47 levers

The five cost curves (Exhibits 9–13) show the full mitigation potential of 47 levers against each planetary boundary assessed and the cost or value opportunity of each lever. Many levers appear to have impacts across multiple boundaries, meaning that they address multiple dimensions of natural capital at the same time for the same overall cost. Each planetary boundary represents a different dimension of natural capital, so the mitigation potential and unit cost metrics differ for each cost curve.

Biodiversity loss

The cost curve for biodiversity loss (Exhibit 9) shows the cost and mitigation potential for bringing the world within the current planetary boundary of 0.9 on the biodiversity intactness index (BII). A BII score of 1.0 is equivalent to preindustrial, or pre-1750, levels of biodiversity, so 0.9 is equivalent to 10 percent biodiversity loss (specifically, functional biodiversity) from preindustrial levels. A score of 0.8, or 20 percent biodiversity loss, is similar to what is seen in 1970. By implementing the levers identified, the world could potentially close 48 percent of the projected gap to the boundary.

There are two main categories of levers that could be used to mitigate biodiversity loss. The first category is levers that reduce land-use intensity and improve biodiversity while maintaining current levels of production, like agroforestry, regenerative agriculture, and sustainable forestry. In general, we measure the improvement potential of these levers by taking the difference between an average-global-intensity BII score and a low-intensity BII for that land-use type.[132] The second category of levers would change the land use itself, including plant-based alternatives, reduced food loss and waste, and advanced seed technology (and products that enhance yield). When a lever implies converting land from agriculture use to another use or inversely avoiding land conversion to agriculture, this report assumes that the biodiversity improvement would correspond to the difference in BII between the current land-use type and a mature secondary forest. The largest levers to mitigate biodiversity loss are as follows:

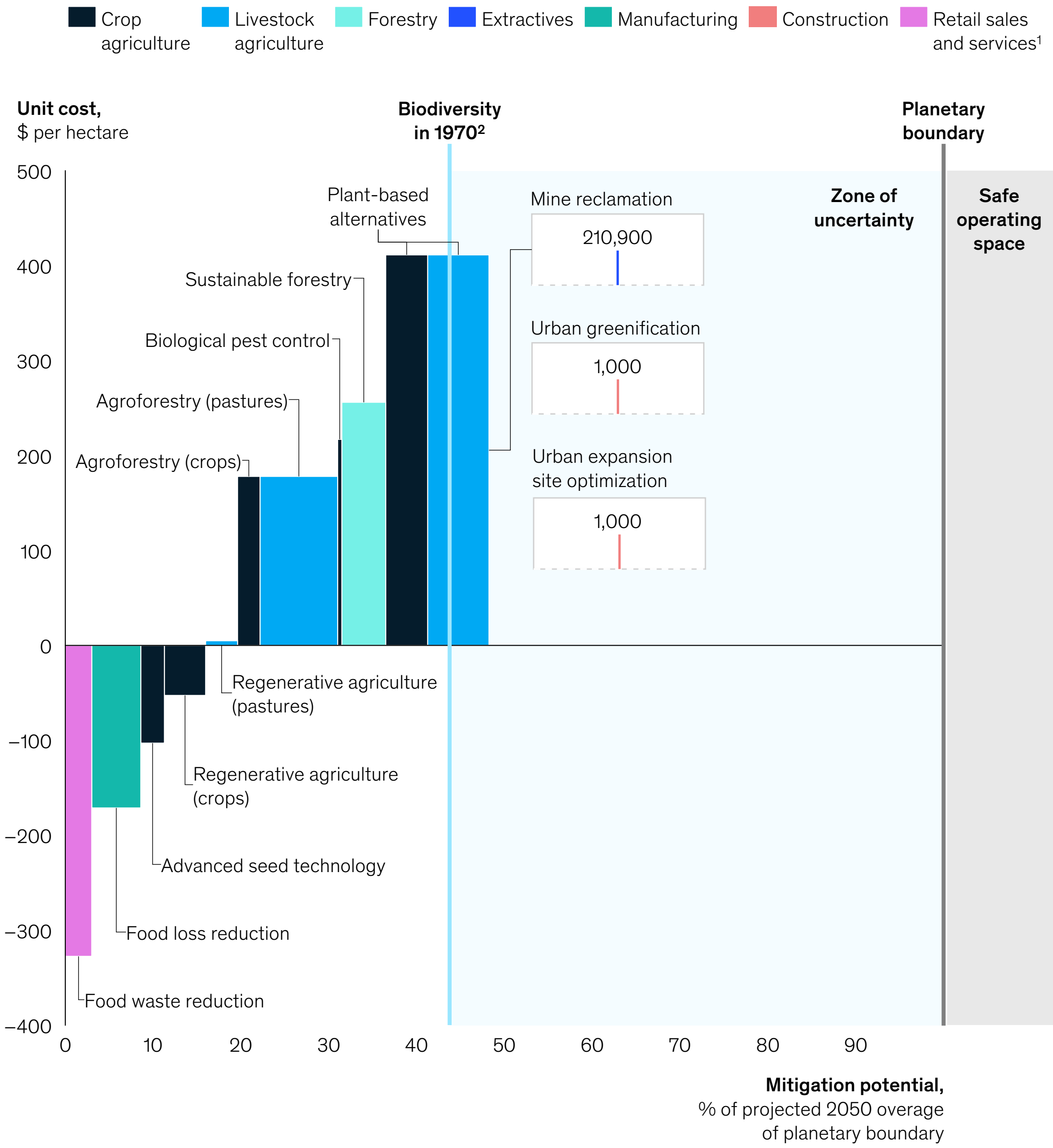
— **Agroforestry** (11 percent abatement potential; net cost of $320 billion[133]) includes adding trees to cropland and pastureland. Agroforestry could be implemented around agricultural land to create conservation buffers such as hedgerows and riparian buffers, or could be incorporated into agriculture land among crops or animals. We assume this lever can be implemented in areas with low above-ground biomass and that tree density can increase to the median density in the region or biome.

[130] "A cost curve for greenhouse gas reduction," February 1, 2007.
[131] The cost of abatement is calculated from a societal perspective (excluding taxes and subsidies). This allows for comparisons in opportunities, but it also means that the costs calculated are different from the costs that companies may actually see, as companies would also factor in taxes, subsidies, and different interest rates into their calculations. Therefore, the cost of each lever cannot be used to determine switching economics between investments, nor used to forecast prices for credits or offsets. The cost of each opportunity also excludes transaction and program costs to implement the opportunity at a large scale, as these are highly dependent on local-level implementation decisions.
[132] "The biodiversity intactness index," October 27, 2021.
[133] All cost and net opportunity values throughout the chapter are rounded estimates.

Exhibit 9

Reducing food waste and implementing innovative farming techniques could have the greatest impact on mitigating biodiversity loss.

Corporate levers to mitigate biodiversity loss, volumes represent lever mitigation potential



Note: Refer to technical appendix section 3 for detailed analytical approach for each boundary and sector.
[1]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
[2]Biodiversity loss is calculated using the biodiversity intactness index (BII), which is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments. In the literature, the BII zone of uncertainty ranges from 10 to 70 percent loss. However, this is subject to a great deal of debate and uncertainty, so the report uses the 1970-level of BII loss to contextualize a potential zone of uncertainty.
Source: See bibliography

McKinsey & Company

— **Plant-based alternatives** (12 percent abatement potential; net cost of about $35 billion), by increasing the availability of plant-based substitutes to limit meat consumption, would reduce the amount of land required for agriculture. Although this switch affects the agricultural sector's baseline, implementation of the lever would require cross-sectoral action by agriculture and sectors that sit downstream of agriculture, especially the retail sales and services sector (which includes food service, grocery stores, and other large buyers of agricultural products). We estimate the mitigation potential for plant-based alternatives by using survey data on the percentage of respondents who would switch to plant-based alternatives if there were no price difference between meat and plant-based alternatives (20 percent), while cost is based on the current (2022) price premium for plant-based alternatives (see the technical appendix for additional details).[134] A shift in demand to plant-based alternatives could reduce demand for agricultural land and potentially allow some land to rewild.

— **Measures to reduce food loss and food waste** (9 percent abatement potential; net value opportunity of $150 billion) could improve biodiversity by reducing the quantity of land needed for agriculture. Food loss occurs largely in the manufacturing sector, between harvest and retail, while food waste occurs in the retail sector and at the consumer level. We assume that corporate action can abate food loss across manufacturing, and we assume that corporations can reduce food waste from the food service and retail sectors but cannot address consumer food waste. Following a McKinsey analysis on food loss and waste, we assume a 60 percent reduction in both food loss and food waste is possible.[135]

— **Regenerative-agriculture practices** (8 percent abatement potential; net value opportunity of about $65 billion) could be applied on cropland and pastureland. On cropland, we define regenerative or conservation agriculture to include cover crops and no-tillage practices. On pastureland, we define regenerative agriculture to include rotational grazing practices to manage soil and vegetative health. For both cropland and pastureland, we use a proprietary geospatial model to determine, at a ten-by-ten-kilometer level of granularity, where regenerative-agriculture practices can be applied globally.

— **Sustainable forestry** (5 percent abatement potential; net cost of about $300 billion), including variable thinning, buffers, subsoiling, and multispecies reforestation, could improve biodiversity in commercial forestry areas from pre-harvest to harvest and planting. We assume that these forestry management practices can be implemented in plantation forests but require a positive cost. We find that implementing these four practices could add approximately $250 per hectare per year to current costs.[136]

— **Advanced seed technology** (3 percent abatement potential; net value opportunity of about $20 billion), which includes genetically modified crops and other yield-enhancing technologies, could reduce the overall amount of land needed for agriculture by improving yields. Our estimates for this lever assume an increase in genetically modified crop adoption to current US levels in countries that currently implement some level of genetically modified crops. We consider only seed technology that does not negatively affect other planetary boundaries, excluding seed technology that results in increased

[134] Vivid Economics Alternative Proteins Model, November 2022.
[135] Moira Borens, Sebastian Gatzer, Clarisse Magnin, and Björn Timelin, "Reducing food loss: What grocery retailers and manufacturers can do," McKinsey, September 7, 2022.
[136] Mila Bristow, J. Nichols, and Jerome Vanclay, "Mixed-species plantations: Prospects and challenges," *Forest Ecology and Management*, September 2006, Volume 233; Yuhao Feng et al., "Multispecies forest plantations outyield monocultures across a broad range of conditions," *Science*, May 2022, Volume 376, Number 6596; Erkki Lähde, Olavi Laiho, and Timo Pukkala, "Variable-density thinning in uneven-aged forest management—a case for Norway spruce in Finland," *Forestry*, December 2011, Volume 84, Number 5; Johan Sonesson et al., "Costs and benefits of seven alternatives for riparian forest buffer management," *Scandinavian Journal of Forest Research*, December 2020, Volume 36; Manisha Parajuli et al., "Logging operations and soil compaction," *Land-Grant Press*, March 14, 2022.

chemical usage on cropland due to the negative impact on biodiversity in fields where it is implemented.

Forest cover loss

The cost curve for forest cover loss (Exhibit 10) shows the cost and mitigation potential for bringing the world within the current planetary boundary of less than 25 percent forest cover loss compared to potential forest cover. If fully implemented, three categories of levers, already addressed above, could far exceed what is needed to return to within the boundary for forest cover loss by reducing land needed for agriculture. Importantly, we assume that either this newly available land will mitigate future deforestation due to agriculture, or the available land will be reforested to create new secondary forest.

An important caveat, discussed in chapter 2, is that the forest cover loss metric used in this report considers only the quantity of forest cover, not the quality of forest. By this definition, secondary and plantation forests are both considered forest cover even though these types of forest have vastly different biodiversity potential. This highlights the importance of levers that consider all boundaries. For example, while secondary forest is equivalent to primary forest for the forest loss metric, the two forest types are not equivalent for the biodiversity metric.

Freshwater consumption

The freshwater consumption cost curve (Exhibit 11) shows that corporate action has the potential to get the world back within the safe operating space for humanity on freshwater consumption on a global basis.

Three levers can mitigate biodiversity loss and freshwater consumption by reducing agriculture land and, as a result, reducing water used for irrigation: plant-based alternatives (19 percent abatement potential), food loss and food waste reduction (17 percent abatement potential), and advanced seed technology (9 percent abatement potential). Below are four additional levers:

— **Drip irrigation** (30 percent abatement potential; net cost of about $35 billion) saves water by reducing irrigation water lost to evaporation. Our estimate assumes that 31 percent of current cropland could fully convert from surface irrigation practices to drip irrigation. Where drip irrigation is implemented, we assume that consumptive water use decreases by 76 percent.[137] The positive cost of drip irrigation reflects the capital and operating expenses required to make the switch, and the expected water savings are based on the average global cost of water for agriculture. As with many other cost-positive levers, however, current barriers are limiting drip adoption. In the United States, for example, while the agriculture industry has excess capacity of drip irrigation equipment, farmers are not switching due to water subsidies and other external factors.[138]

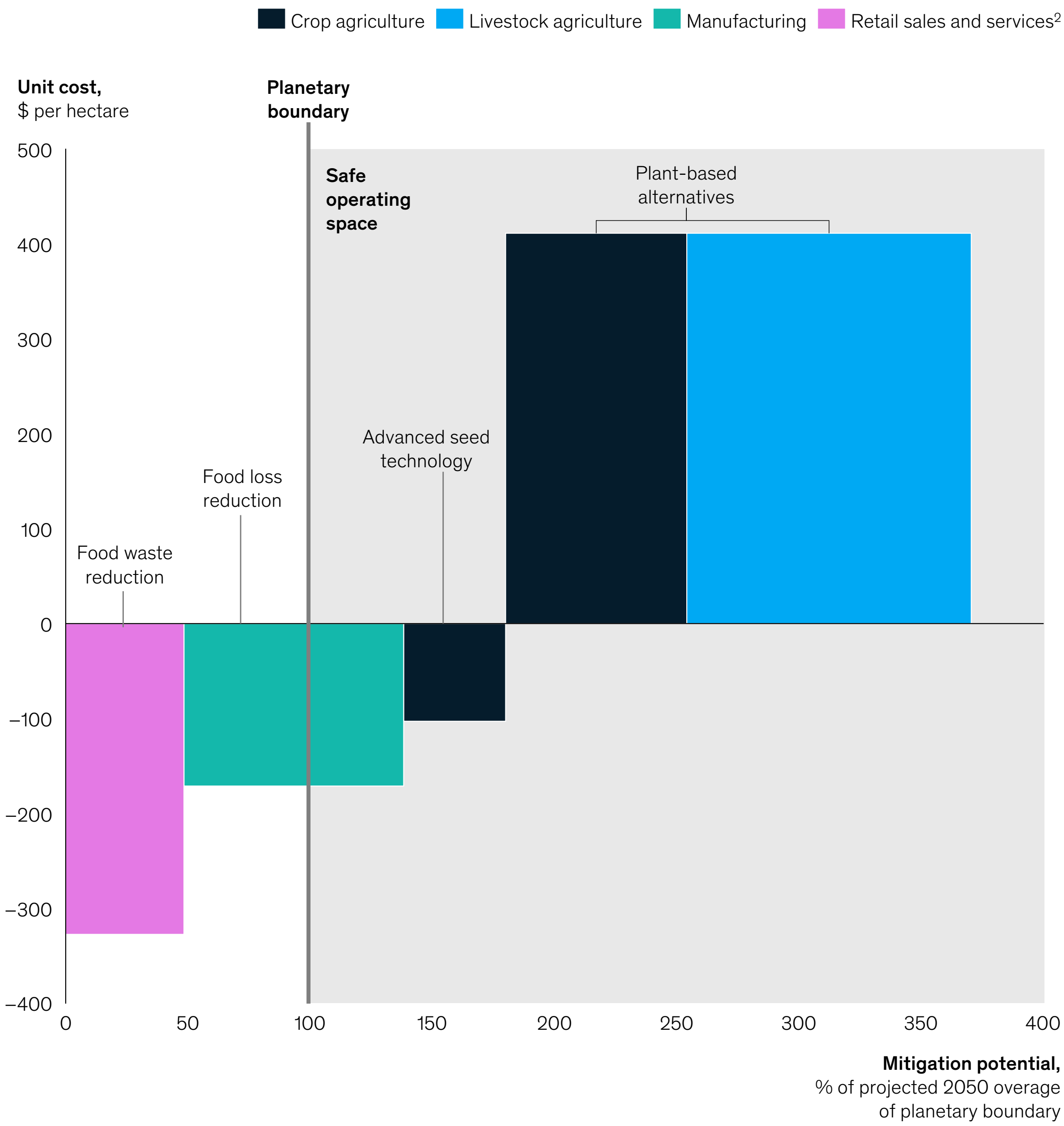
— **Water-efficient agriculture** (19 percent abatement potential; net value opportunity of about $40 billion) is defined as using the most water-efficient seeds and farming methods for each crop. Depending on the crop, this includes selection of optimal seeds and farming practices such as alternate-furrow irrigation that mitigate freshwater loss and provide economic savings through reduced water consumption. We assume water-efficient practices can generate water consumption savings of 3 to 33 percent, depending on the crop, and that this lever can be applied in dry regions prone to drought.

[137] We apply this assumption primarily in Korea, Madagascar, the Sahel, and South Asian basins (Ganges, Indus, and Mahanadi), and also in temperate regions in Argentina, Brazil, Europe, North America, South Africa, and the Yangtze basin. See Jonas Jägermeyr et al., "Integrated crop water management might sustainably halve the global food gap," *Environmental Research Letters*, February 2016, Volume 11, Number 2; Jonas Jägermeyr et al., "Water savings potentials of irrigation systems: Global simulation of processes and linkages," *Hydrology and Earth System Sciences*, July 2015, Volume 19.
[138] Seth Siegel, "How drip irrigation can change the world: Adoption is still low for a technology that saves water, reduces use of fertilizer and increases agricultural yield," *Real Assets Adviser*, June 2017, Volume 4, Number 6.

Exhibit 10

Food waste reduction and food loss reduction are low-cost levers to mitigate forest cover loss.

Corporate levers to mitigate forest cover loss,[1] volumes represent lever mitigation potential



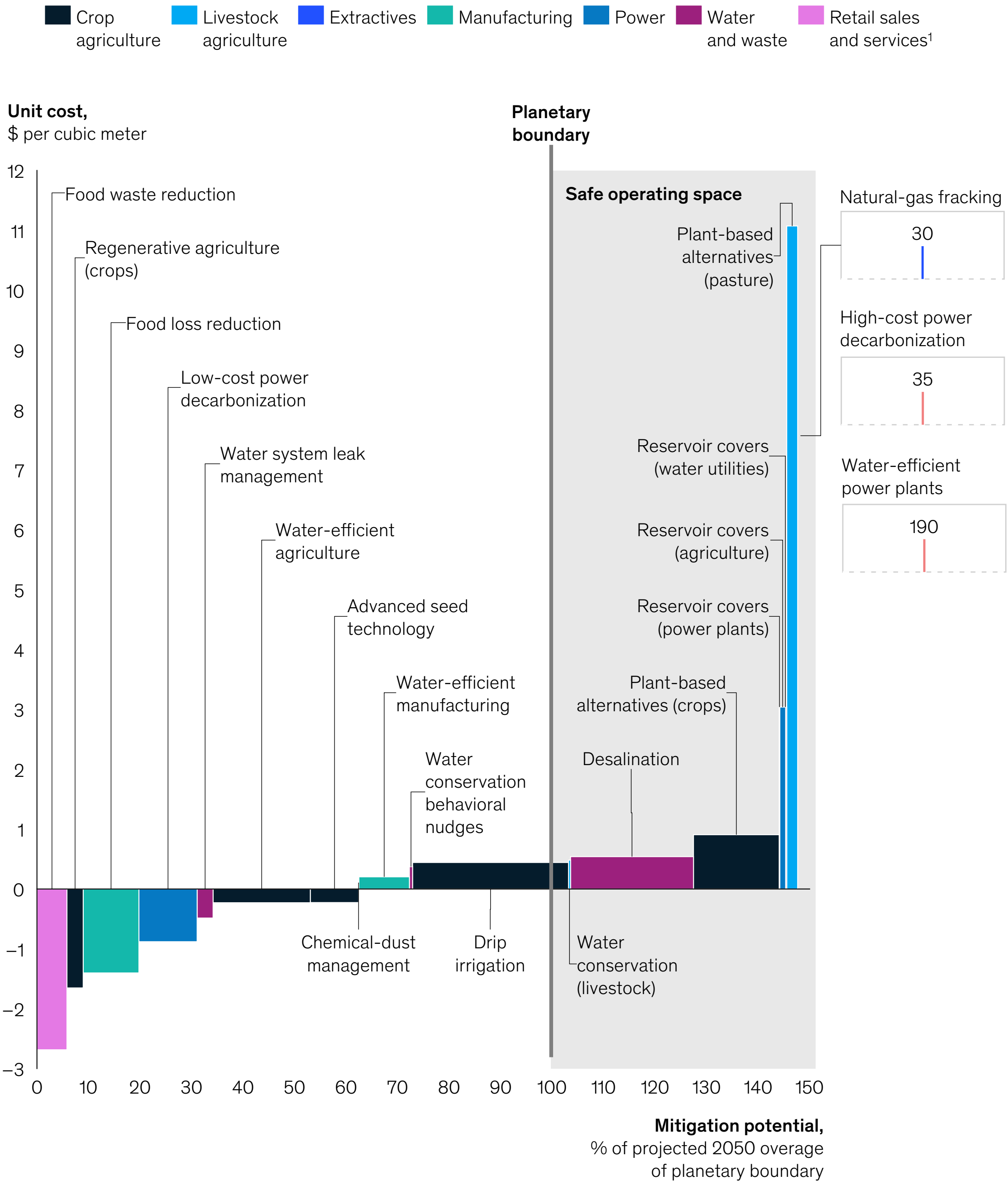
Note: Refer to technical appendix section 3 for detailed analytical approach for each boundary and sector.
[1]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions. Report assumes no forestry-induced forest cover loss because that sector converts primary forest to secondary and plantation forest, which still conserves total forest cover.
[2]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
Source: See bibliography

McKinsey & Company

Exhibit 11

The crop agriculture sector has the single largest potential to mitigate freshwater consumption, compared with other sectors.

Corporate levers to mitigate freshwater consumption, volumes represent lever mitigation potential



Note: Refer to technical appendix section 3 for detailed analytical approach.
[1]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
Source: See bibliography

McKinsey & Company

— **Low-cost power decarbonization** (11 percent abatement potential; net value opportunity of about $95 billion[139]) represents switching from fossil fuel–based power to wind and solar power. While carbon-based power sources consume significant quantities of water, renewables such as solar and wind consume almost none. Our assumptions about adoption of renewables and the cost of adoption are derived from McKinsey's latest report on climate change.[140]

— **Water-efficient manufacturing techniques** (10 percent abatement potential; net cost of about $20 billion) could improve consumptive water efficiency across manufacturing subsectors. We assume a 1 percent improvement in manufacturing efficiency based on process and capital improvements that require relatively low investment, after accounting for lower water spend.

One caveat to the global cost curve is that sustainable levels of freshwater consumption are also critical at a local level. Companies could consider regional and local variability in the areas they operate to ensure localities do not exceed the boundary in any given water basin. The Science Based Target Network's methods on freshwater consumption and pollution align with this point by focusing on local water basins.[141]

Chemical and plastic pollution

The chemical and plastic pollution cost curve (Exhibit 12) shows that corporate action could mitigate 60 percent of the projected 2050 overage of the identified boundary of eight metric megatons (Mt) of plastic-waste emissions to aquatic environments per year (which is equivalent to 2010 levels).[142]

Our analysis includes only levers that do not have a significant negative impact on other planetary boundaries. Plastic highlights the importance of addressing the planetary boundaries holistically, because potential levers to replace plastic with alternative materials come with their own challenges. A recent McKinsey report finds that plastics have a lower total GHG contribution than currently available alternatives in several applications and help reduce food waste from spoilage, while the use of alternatives such as paper could increase demand for wood products and have a negative impact on biodiversity.[143] Because of this, we largely exclude levers related to replacing plastics with alternative materials.

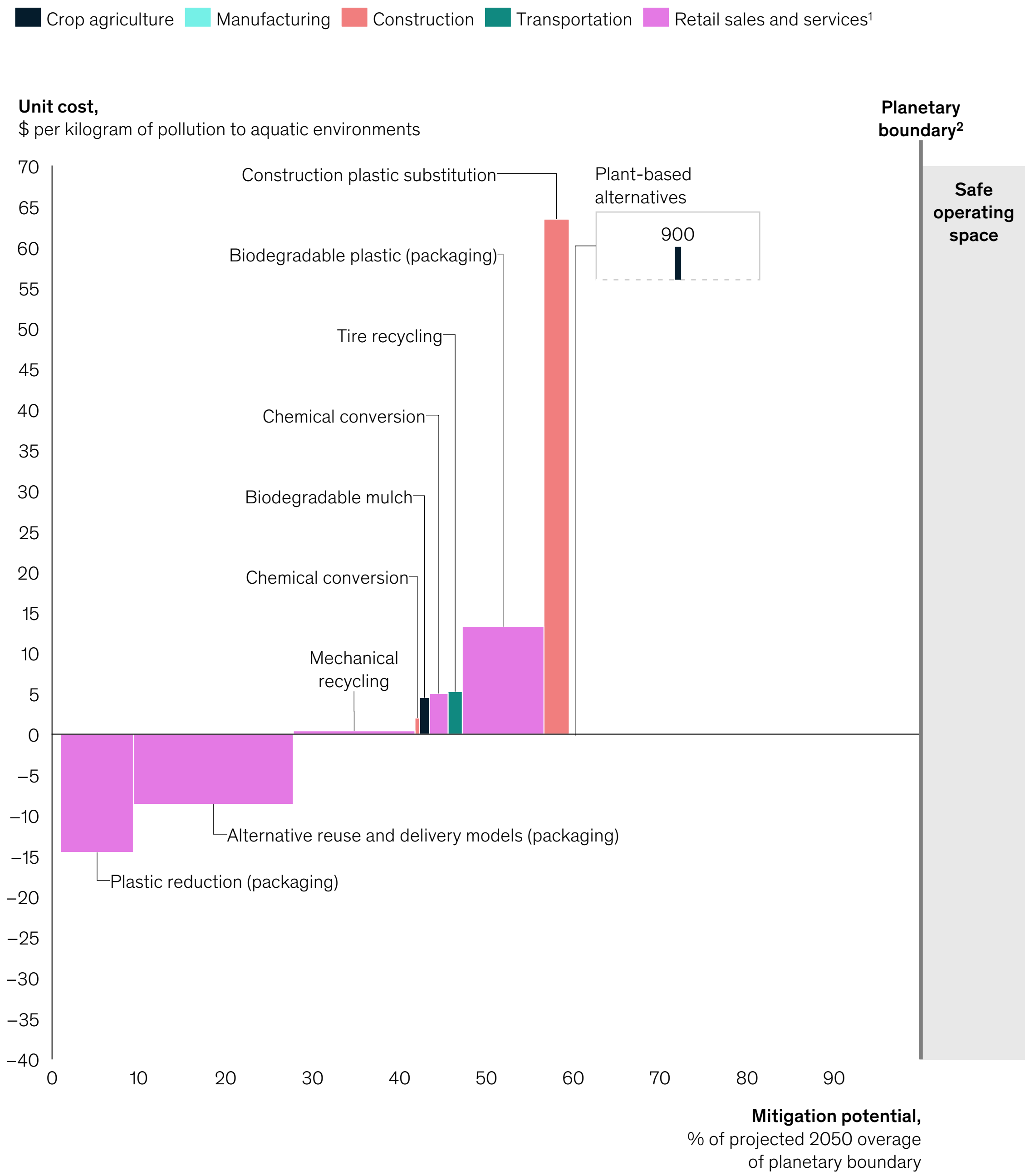
Instead, we focus primarily on four types of levers: alternative delivery models, expanded recycling, improvements in recycling, and reduced plastic in packaging. The mitigation potential for each of these levers represents the full potential of implementing the actions under a system-change scenario.[144]

[139] Cost is based on estimates from McKinsey Global Energy Perspective, updated May 2022. Estimates are forward looking, accounting for future returns over the lifetime and using future forecasts for electricity and gas prices. Actual returns may vary due to the complex and volatile global environment and local variation. Companies may experience higher prices today because of exceptionally high demand and elevated gas prices, among other factors.
[140] "The net-zero transition," January 2022.
[141] *Technical guidance for Step 3: Measure, set & disclose – initial freshwater SBTs (draft for public comment),* Science Based Targets Network, September 2022.
[142] Although there is no "official" boundary for plastic-waste emissions to aquatic environments, following the suggestion of leading plastic-waste emissions scientists and research by the UNEP, this report uses 2010 plastic-waste emissions to aquatic environments as a reference boundary, which equates to eight metric megatons per year. See "Predicted growth in plastic waste," September 2020; "Marine plastic pollution as a planetary boundary threat," October 2018; United Nations Environmental Assembly, 2019.
[143] "Climate impact of plastics," McKinsey, July 2022.
[144] Winnie Lau et al., "Evaluating scenarios toward zero plastic pollution," *Science*, July 23, 2020, Volume 369.

Exhibit 12

Corporate levers involving lowered plastic use in packaging could help to mitigate plastic-waste emissions.

Corporate levers to mitigate plastic-waste emissions to aquatic environments,
volumes represent lever mitigation potential



Note: Refer to technical appendix section 3 for detailed analytical approach. Food waste reduction, food loss reduction, and advanced seed technology are low-cost levers not included on the cost curve, but account for less than 1 percent of overall mitigation potential combined.
[1]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
[2]Although there is no "official" boundary for plastic-waste emissions to aquatic environments, following the suggestion of leading plastic-waste emissions scientists and research by the United Nations Environment Programme (UNEP), this report uses 2010 plastic-waste emissions levels as the boundary, which equates to 8 million tons per year.
Source: See bibliography

McKinsey & Company

The largest levers are the following:

— **Alternative delivery models for packaging** (18 percent abatement potential; net value opportunity of $45 billion) includes switching from single-use plastics to bulk sales and other low-plastic methods of delivering products, which can mitigate plastic pollution while providing net savings to the companies using the services.

— **Mechanical recycling** (14 percent abatement potential; net cost of about $2 billion) through open-loop and closed-loop processes can reduce plastic pollution by keeping existing plastic in circulation, thereby reducing virgin-plastic production in the long run. Costs include the capital investment and operating costs associated with sorting and recycling plastics.

— **Compostable bioplastic** (9 percent abatement potential; net cost of about $35 billion), while relatively expensive today, could reduce the amount of plastic pollution in aquatic environments while providing many of the same benefits as virgin plastic. Based on published literature, we assume bioplastics can replace some plastics, including food service disposables, carrier bags and films, laminated products, and hygiene products.[145] The average incremental cost of compostable bioplastic using polylactic acid (PLA) feedstock instead of ethanol feedstock is approximately $0.80 per kilogram.[146]

— **Plastic reduction** (8 percent abatement potential; net value opportunity of about $35 billion) estimates the potential of eliminating plastic without substitution by reducing the amount of plastic in packaging. If fully implemented, the lever would represent a net savings opportunity through lower plastic requirements.

— **Construction plastic substitution** (3 percent abatement potential; net cost of about $50 billion) includes replacing plastic building materials with nonplastic alternatives. Specifically, we assume that foam building insulation can be replaced with nonplastic alternatives.

Nutrient pollution

Corporate action could close the gap to the current planetary boundary for nutrient pollution (Exhibit 13). The current nutrient pollution boundary comprises three distinct boundaries—terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution. For simplicity, we show a single cost curve that assigns equal weights to each component of the boundary. The identified levers close the gap across each of the three boundaries. Levers to mitigate nutrient pollution extend across most sectors to address both solid and liquid pollution from fertilizers and animal waste as well as gaseous nitrogen oxides from combustion in the power, transport, and manufacturing sectors.

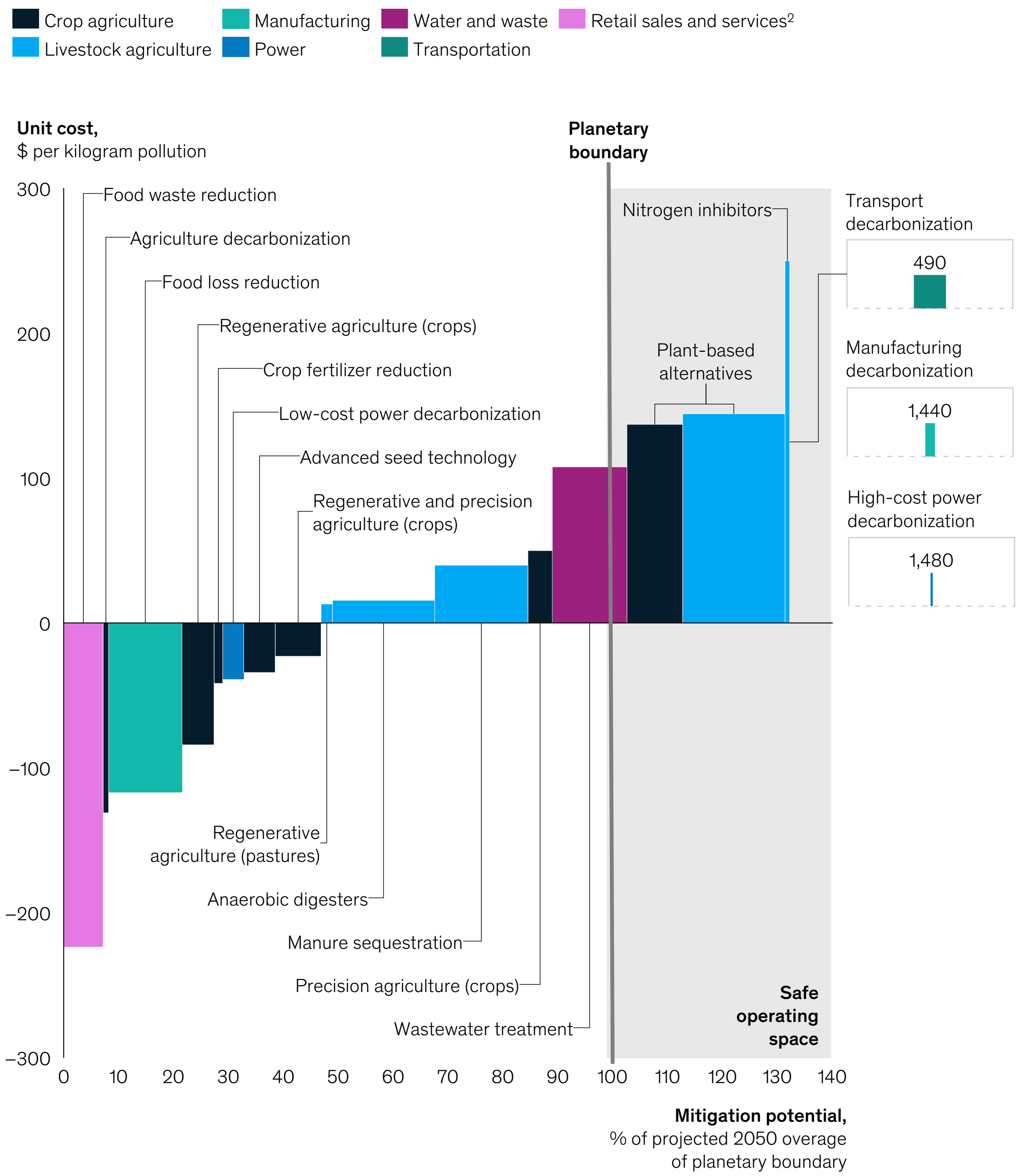
To avoid double counting, we assume that three strategies could mitigate nutrient pollution in crop agriculture: regenerative agriculture, precision agriculture, and reduction of fertilizer overapplication by soil testing. As described previously, we use a proprietary model to determine, at a ten-by-ten-kilometer level of granularity, where regenerative-agriculture (specifically, no-till) practices can be applied. We assume that precision agriculture can be applied only in countries defined by the World Bank as high or upper-middle income, due to high capital requirements. In the remaining countries, we assume that fertilizer reduction can be implemented where regenerative agriculture is not feasible and where nitrogen use is above median levels.

[145] Ibid.
[146] Shabnam Sanaei and Paul Stuart, "Systematic assessment of triticale-based biorefinery strategies: Techno-economic analysis to identify investment opportunities," *Biofuels, Bioproducts and Biorefining*, 2018, Volume 12; Claudia Wellenreuther, André Wolf, and Nils Zander, "Cost competitiveness of sustainable bioplastic feedstocks – a Monte Carlo analysis for polylactic acid," *Cleaner Engineering and Technology*, February 2022, Volume 6.

Exhibit 13

All sectors of the economy have a role to play in addressing nutrient pollution.

Corporate levers to mitigate nutrient pollution,[1] volumes represent lever mitigation potential



Note: Refer to technical appendix section 3 for detailed analytical approach.
[1]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution, all weighted equally. This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.
[2]Includes retail, accommodation and food services, IT, finance and insurance, professional and support services, education, health, and entertainment.
Source: See bibliography

McKinsey & Company

The largest levers include the following:

— Three levers to mitigate biodiversity loss could also mitigate freshwater consumption by reducing agriculture land and, as a result, nutrient pollution on agriculture land. Plant-based alternatives (29 percent abatement potential), food loss and food waste reduction (21 percent abatement potential), and advanced seed technology (6 percent abatement potential) are described in greater detail above.

— **Anaerobic digesters** (19 percent abatement potential; net cost of about $15 billion) could reduce manure leakage on large farms through collection and conversion of manure to alternative products. Due to high capital costs, we assume anaerobic digesters are applicable only on large farms in high-income countries. The positive cost reflects the capital investment required, but some case studies find evidence of positive ROI for anaerobic digestion.[147]

— **Manure sequestration** (17 percent abatement potential; net cost of about $25 billion) includes the implementation of barriers to limit manure contamination of surrounding areas. We assume that denitrification barriers can remove nitrates in manure by up to 66 percent. To avoid double counting in livestock agriculture, we assume manure sequestration using liners can reduce nitrate and phosphate leakage from manure on small farms, and that anaerobic digesters can reduce manure leakage on large farms in high-income countries.

— **Wastewater treatment** (14 percent abatement potential; net cost of about $170 billion) includes implementation of phosphorus- and nitrogen-removal processes in municipal wastewater. We assume that this lever can be implemented in all regions where phosphates and nitrates from waste contribute to nutrient pollution. However, the cost of implementation is very high, requiring investment in expensive water treatment infrastructure.

— **Precision agriculture** (12 percent abatement potential; net value opportunity of $20 billion where implemented with regenerative agriculture, net cost of about $10 billion where implemented on its own) and tech-enabled practices could reduce overapplication. In high-income regions, precision agriculture can limit nutrient pollution by optimizing fertilizer application at a granular level.

— **Low-cost power decarbonization** (4 percent abatement potential; net value opportunity of about $95 billion) by switching to wind and solar energy can reduce nutrient pollution by limiting nitrogen oxide pollution from combustion.

Identifying key contributions that sectors can make to mitigate the loss of natural capital

Every sector of the economy has a role to play. In the following section we focus first on agriculture and then, more briefly, discuss important levers across all sectors analyzed in chapter 2. More work will be needed to provide sector-specific deep dives into each of the cost curves.

Agriculture

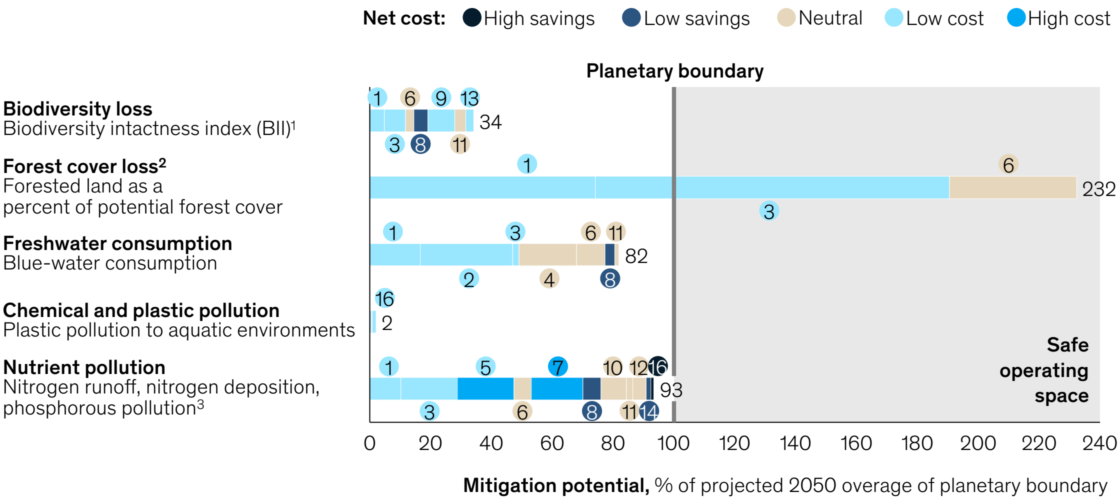
Agriculture alone could play a significant role in addressing the planetary boundaries (Exhibit 14). It appears to have the greatest potential of any sector to mitigate biodiversity loss, forest cover loss, freshwater consumption, and nutrient pollution.

[147] Arpit Bhatt and Ling Tao, “Economic perspectives of biogas production via anaerobic digestion,” *Bioengineering*, July 14, 2020; Juliana Vasco-Correa et al., “Economic implications of anaerobic digestion for bioenergy production and waste management,” Ohioline, June 15, 2018.

Exhibit 14

Agriculture appears to have the largest direct role to play in addressing the planetary boundaries.

Corporate levers to address planetary boundaries, volumes represent lever mitigation potential



Top levers to address planetary boundaries

1. Plant-based alternatives (crop impact)
2. Drip irrigation
3. Plant-based alternatives (pasture impact)
4. Water-efficient agriculture
5. Anaerobic digesters
6. Advanced seed technology
7. Manure sequestration
8. Regenerative agriculture (crops)
9. Agroforestry
10. Regenerative and precision agriculture (crops)
11. Regenerative agriculture (pastures)
12. Precision agriculture (crops)
13. Agroforestry (crops)
14. Crop fertilizer reduction
15. Biodegradable mulch
16. Agriculture decarbonization
17. Nitrogen inhibitors (pastures)
18. Biological pest control
19. Water conservation practices (livestock)
20. Reservoir covers (agriculture)

Note: While all lever mitigation potential is shown on the chart, trackers are omitted for levers with small mitigation potential. Analysis focuses on five of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Greenhouse-gas emissions are covered in other reports and not recreated here. See "The net-zero transition: What it would cost, what it could bring," McKinsey, January 2022; "Climate math: What a 1.5-degree pathway would take," *McKinsey Quarterly,* April 2020; and *Agriculture and climate change,* McKinsey, April 2020. Refer to technical appendix section 3 for detailed analytical approach for each boundary and sector.

[1]The biodiversity intactness index (BII) is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.

[2]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions.

[3]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution, all weighted equally. This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.

Source: See bibliography

McKinsey & Company

The previous section covered the mitigation potential and cost of the 14 largest agriculture levers shown in Exhibit 14. To summarize, these levers can be grouped into three categories. First, there are process-related agriculture levers that the sector can implement directly, including water-efficient techniques, regenerative agriculture, and agroforestry. These levers require relatively low cost and, in some cases, generate positive returns. Second, there are capital-intensive levers that the sector can implement directly, including drip irrigation, anaerobic digesters, manure sequestration, and precision agriculture. These levers require upfront capital, and some (for example, agriculture decarbonization) can yield positive returns today, while others (such as precision agriculture) could decline in cost over time. Finally, some levers could require collaboration between the agriculture sector and other sectors. The largest lever in this category is switching to plant-based alternatives, which would require collaboration across the value chain, from farmers to food retailers. Together, these three categories of levers account for more than 95 percent of the agriculture sector's abatement potential.

Outside the top 14, the agriculture sector could implement smaller levers, which will be important on a smaller or more localized level. For example, biological crop protection uses biological agents to replace synthetic pesticides, fungicides, and herbicides. Biodegradable mulch and films can replace plastic-based mulch to control weeds, minimize erosion, and limit evaporative water loss.

Nonagricultural sectors

While agriculture appears to have the largest land footprint, other sectors could also be critical in closing the gap (Exhibit 15).

For nonagricultural sectors, the largest levers across the board are food waste reduction and food loss reduction, which, as discussed in the previous section, could contribute to mitigating biodiversity loss, forest loss, freshwater consumption, and nutrient pollution through their impact on agriculture land. We sized the lever based on the actions that corporations—specifically food manufacturers, food retailers, and food service providers—could take to reduce wasted food through improved planning, inventory management, and other smaller initiatives. The other major biodiversity lever outside of agriculture is sustainable forest management in the forestry sector, which includes biodiversity-enhancing practices such as variable thinning, buffers, subsoiling to decrease soil compaction, and multispecies forestry.

Action across nonagricultural sectors could also mitigate freshwater consumption. Decarbonization action, especially in the power sector, may have particular impact. Switching to renewable-energy sources that are less water intensive than fossil fuels could greatly reduce water consumption, for example. Continued efficiency improvements across manufacturing, water and waste, and mining can together mitigate a significant portion of overall water consumption.

To mitigate chemical and plastic pollution, retail sales and services sectors can make changes in how plastic is used. Improved plastic recycling and plastic reduction (primarily in packaging) are low-cost actions that help limit the amount of new plastic produced each year—and thus reduce the amount of plastic polluting aquatic environments.

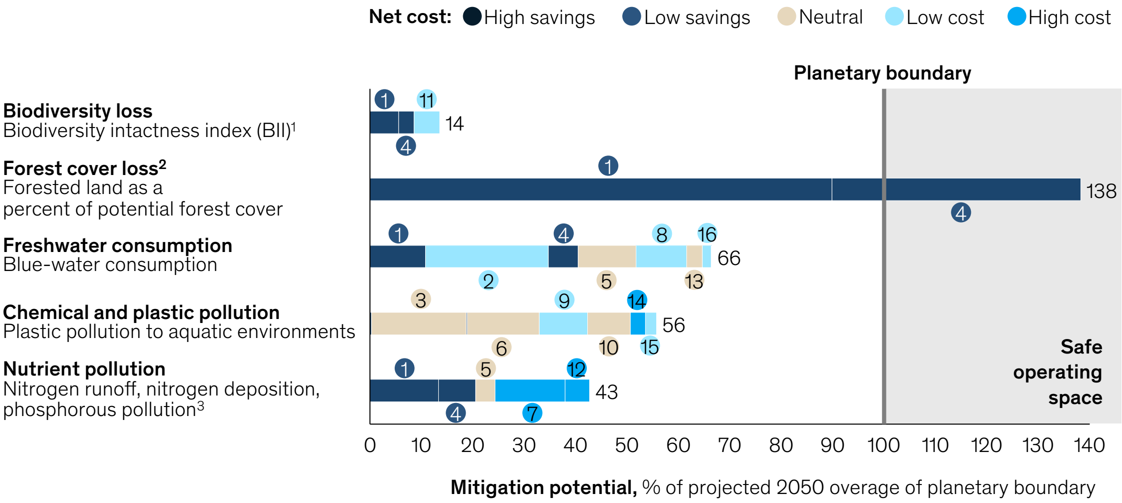
To mitigate nutrient pollution, two major types of actions could have an impact. First, the water and waste sector could improve waste management through updated and new wastewater treatment facilities that reduce the impact of physical waste leakage into the environment. Second, the transport, power, and manufacturing sectors could switch to electric alternatives to reduce nitrogen oxide pollution resulting from combustion.

Two features of our analysis—the global scale and the choice of control variables—yield results that emphasize some sectors over others. The remaining sectors, even while not heavily emphasized in this analysis, may nonetheless have significant potential to mitigate nature loss.

Exhibit 15

Besides agriculture, all other sectors can also take action to address the planetary boundaries.

Corporate levers to address planetary boundaries, volumes represent lever mitigation potential



Top levers to address planetary boundaries

Forestry
- 11 Sustainable forestry

Extractives
- 23 Natural-gas fracking
- 24 Chemical-dust management
- 28 Mine reclamation
- 1 Food loss reduction
- 8 Water-efficient manufacturing
- 17 Manufacturing decarbonization

Power
- 5 Low-cost power decarbonization
- 18 Reservoir covers (power plants)
- 19 High-cost power decarbonization
- 27 Water-efficient power plants

Water and waste
- 2 Desalination
- 7 Wastewater treatment
- 13 Water system leak management
- 20 Water conservation nudges
- 22 Reservoir covers (water utilities)

Construction and buildings
- 14 Construction plastic substitution
- 21 Construction plastic recycling
- 25 Urban greenification
- 26 Urban expansion site optimization

Transportation
- 12 Transport decarbonization
- 16 Tire recycling

Retail sales and services
- 15 Chemical conversion
- 6 Mechanical recycling
- 3 Alternative delivery models
- 4 Food waste reduction
- 9 Biodegradable plastic (packaging)
- 10 Plastic reduction (packaging)

Note: While all lever mitigation potential is shown on the chart, trackers are omitted for levers with small mitigation potential. Analysis focuses on five of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Greenhouse-gas emissions are covered in other reports and not recreated here. See "The net-zero transition: What it would cost, what it could bring," McKinsey, January 2022; "Climate math: What a 1.5-degree pathway would take," *McKinsey Quarterly,* April 2020; and *Agriculture and climate change,* McKinsey, April 2020. Refer to technical appendix section 3 for detailed analytical approach for each boundary and sector.

[1]The biodiversity intactness index (BII) is an estimated percentage of the preindustrial (pre-1750) number of species that remain and their abundance in any given area, given the prevalence of human impact in that area. BII does not extend to marine environments.

[2]This report uses a data set from the Food and Agriculture Organization (FAO), focusing on deforestation since 2000, and defines deforestation as a persistent conversion of forest to any other land use. This differs from other databases, such as Global Forest Watch, which classifies any sort of forest degradation as deforestation. Natural forest conversion to plantation forests is not considered forest cover loss in the planetary-boundaries framework because plantation forests still enable land–climate interactions. Report assumes no forestry-induced forest cover loss because that sector converts primary forest to secondary and plantation forest, which still conserves total forest cover.

[3]Nutrient pollution includes three separate control variables: terrestrial nitrogen deposition, nitrogen surface water runoff, and phosphorus pollution, all weighted equally. This report's calculation for phosphorus pollution attributed to livestock agriculture includes both runoff and leaching from pastureland and excess manure waste.

Source: See bibliography

McKinsey & Company

The extractives sector, composed of mining and oil and gas, is underemphasized due to both its small direct footprint and impacts that are not captured in the control variables used. Nevertheless, extraction activities appear to have an outsize impact on ecosystems both within their direct footprint and in surrounding areas.[148] For biodiversity, choice of mine location, extraction method, and rehabilitation processes could all have a significant impact on local biodiversity, in both terrestrial and marine contexts. To mitigate impact on freshwater and novel entities, petroleum extraction and mining companies could improve global adoption of stringent waste management practices to limit the leakage and impact of toxic pollutants.

The power and manufacturing sectors could also help mitigate impacts not captured by the control variables used. Freshwater use in power and manufacturing is often very high, even while consumptive use is much lower. Reduced water use, implementation of enhanced water treatment, and improved sourcing to mitigate impact on water-constrained areas can reduce freshwater use. These sectors may also have the potential to mitigate the emissions of novel entities other than plastics. Finally, manufacturing subsectors could also increase circularity to reduce raw-material requirements and improve efficiency through efforts such as increasing scrap recycling in steel production. We did not size these levers due to their variability across subsectors, and because their primary impact on nature is through second-order effects, but our omission should not be taken to mean these levers will not be important for mitigating impacts to natural capital.

The transport sector may also be underemphasized, especially with respect to its impact on biodiversity loss. For land transport, equipment, routes, and timing of work all affect biodiversity—and the choice of transport and optimization of routes and timing could mitigate impacts on natural capital, even where the impacts are not captured by the spatially defined BII metric. For marine transport, similar measures could affect a wide array of marine life.[149] Improved ballast management, a measure that is implemented in marine transport today, limits the spread of invasive species that threaten biodiversity.

The buildings and construction sector could implement nature-positive practices, especially when expanding into previously wild areas. For example, the placement and construction of roads could affect biodiversity by disrupting animal migration and natural habitats.

Finally, the fishery sector, while generally outside the scope of this report, could play a critical role in defining whether the world can address marine biodiversity loss. A critical lever for the fishery sector is effective implementation of fishing limits—something that is often outside the control of individual companies. However, actions such as bottom-trawling reduction, onshore fish farming, lab-grown fish, and next-generation fish feed in aquaculture are levers within corporate control that can mitigate the sector's impact on marine biodiversity.

Beyond corporate action that is possible today, additional actions would be required to fully address the planetary boundaries

This analysis demonstrates that, although corporate action could make a meaningful contribution to addressing the planetary boundaries, that action alone is not sufficient. Both whole-of-society levers and new technologies would be needed to close the remaining gaps.

'Whole of society' actions

Several additional actions could help fill the gap between what corporate actions can do directly and our current understanding of where the planetary boundaries are:

Maximize diet shift. In the levers above, we estimate the mitigation potential of shifting to resource-light diets by evaluating the expected transition to plant-based meat and dairy, assuming cost parity between the two. The total potential of the world switching to resource-

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[148] "Mining drives extensive deforestation in the Brazilian Amazon," October 18, 2017.
[149] "Green corridors: A lane for zero-carbon shipping," McKinsey, December 21, 2021.

light diets could be much larger, although the optimal mix of animal and non-animal sources of nutrition involves other trade-offs, such as emissions. Just as an indication of the scale, we consider the impact of half the world switching to fully plant-based diets. If meat, dairy, and egg production decreased by 50 percent, global land required for agriculture could decrease by more than one-quarter.[150] This shift could close 28 percent of the gap to the planetary boundary for biodiversity, either through reduced expansion of agriculture land through 2050 or by allowing existing agriculture land to rewild.[151]

Expand conservation. One major action that could meaningfully address multiple planetary boundaries is setting aside more land and sea for conservation. The UN Convention on Biological Diversity's "30 by 2030" proposal calls for the protection of 30 percent of our planet's surface area by 2030, nearly doubling the amount of conserved land and national waters.[152] We estimate that doubling conservation could require an additional operating expenditure of $20 billion to $45 billion a year,[153] depending on the conservation scenario, but could also reduce atmospheric CO_2 by 0.9–2.6 gigatons annually, create a significant number of jobs, and protect or generate $300 billion to $500 billion in GDP.[154]

Expand circular-economy practices. The transition to a circular economy could provide benefits across most planetary boundaries, most significantly by mitigating plastic pollution through the design of products for reuse and through improved implementation of reuse, substitution, recycling, and waste management practices. Under aggressive assumptions, a system-level transition to a circular economy could reduce approximately 80 percent of plastic pollution into aquatic and terrestrial systems. External estimates suggest that this shift would require the private and public sectors to take risks amounting to more than $100 billion per year by 2040.[155] In the more immediate term, while plastic production is expected to remain high, improved plastic-waste management could address the 80 Mt of mismanaged plastic waste each year.[156] Building out a fully functional waste management system, especially in emerging economies, would be costly and in the range of $560 billion to $680 billion over ten years, according to McKinsey estimates, but will be critical in the short term to reduce plastic pollution.[157]

Mainstream and grow carbon credits. Although there is some controversy around the use of carbon credits[158] (despite guidance that direct emissions avoidance and reduction by corporations "must" be the priority[159]), the expansion of carbon credits, if strictly guided by science and implemented in a way that is also beneficial to nature, could help mitigate biodiversity loss through additional conservation and reforestation efforts. Our estimates suggest that reforestation of pastureland and avoided deforestation from carbon credits could mitigate more than 7 percent of the projected biodiversity loss overage by 2050.[160]

New technologies could reduce costs and provide new levers to address planetary boundaries

The levers defined in this report are based on technologies that are already commercialized (or nearly so) and therefore do not address the full set of technologies that will be available during the next decades. Many of these new and emerging technologies could help fill the remaining gap in the abatement needed to bring the world back to a safe operating space

[150] Hannah Ritchie and Max Roser, "Land use," Our World in Data, 2013.
[151] This estimate does not account for potential double counting with other sized levers presented on the cost curve.
[152] The current protection figures of 16 percent on land and 17 percent of national waters include IUCN categories only—excluding other effective area-based conservation measures. The target would also imply a significant increase in the 2 percent of international waters that are protected today.
[153] "Valuing nature conservation," McKinsey, September 22, 2020.
[154] Ibid.
[155] "Evaluating scenarios toward zero plastic pollution," July 23, 2020.
[156] "Addressing the challenges of plastic waste: Circularity and leakage," McKinsey, September 2, 2022.
[157] Ibid.
[158] "Why investing in nature is key to climate mitigation," January 25, 2021.
[159] "About us," Taskforce on Scaling Voluntary Carbon Markets.
[160] This estimate does not account for potential double counting with other sized levers presented on the cost curve.

for biodiversity loss and chemical and plastic pollution. New technologies may also help bring down the cost of some existing levers; for instance, chemical conversion to reduce plastic waste currently has a high cost to implement, due in part to the extremely high temperatures required, but new catalysts could decrease the temperature required, which could reduce the cost.[161]

Research attention and early-stage funding have already identified many opportunities for technologies not yet included on the cost curves above, and several emerging technologies show great promise.

Forestry and agroforestry. Many relevant technologies are emerging. For example, robotics for automated nurseries could help bring down the cost of trees.[162] Drones can help with advanced planting.[163] And remote sensing and machine learning technologies could be used to monitor forest health and wildfires.[164] Tree genetics and climate-smart forestry practices could also help increase carbon uptake of forests.[165] These technologies could reduce costs, create alternative revenue streams (for example, through carbon sequestration), and further address biodiversity loss.

Alternative food sources. Plant-based proteins[166] are already included in the cost curves, but further or faster advances in meat replacements could create cost savings and scale for lab-grown protein (and fats). Alternative protein fermentation could also alter the food chain dramatically, freeing up land for other use, such as conservation or renewable-energy production.[167] There has also been progress on alternative proteins for animal feed that use single-cell protein production from manure, insect-based feed, and fish-meal alternatives.[168] Although only demonstrated in experiments to date, emerging technologies could create starch via non-plant routes (for example, from CO_2), replacing a host of ingredients and further reducing demand for agricultural land.[169]

Technologies are also emerging that specifically address ocean-based food sources, can enhance carbon sequestration, and adapt to ocean acidification. Kelp, seaweed, and other products and processes show promise on both fronts and are becoming more popular.[170]

Food waste. Reducing food waste would reduce pressure on land use and help nonagricultural companies limit their upstream impacts. Specific levers include shelf-life extension (for example, through biodegradable films and hydrogels) and sensors and monitors in the supply chain.[171] External estimates highlight that the global market for smart packaging, including foods, pharmaceuticals, and other products, could exceed $26 billion by 2024.[172]

Chemical and nutrient pollution. In agriculture, technologies that enhance nitrogen uptake in plants via microbes or genetic traits could reduce nitrogen runoff and deposition.[173]

[161] "Converting plastic waste into fuel," *Harvard Science in the News*, June 30, 2021.
[162] "How automation is transforming greenhouses and nurseries," March 31, 2020.
[163] "Touch the sky to plant trees," July 25, 2020.
[164] "Forest health monitoring using hyperspectral remote sensing techniques," October 9, 2020; examples of wildfire monitoring include Technosylva and AEM. See "What we do," Technosylva, accessed November 11, 2022; "Wildfire risk management," AEM, accessed November 11, 2022.
[165] "Enhanced photosynthetic efficiency for increased carbon assimilation," March 9, 2022.
[166] "Make room for alternative proteins: What it takes to build a new sector," McKinsey, March 25, 2022.
[167] *The protein problem*, November 17, 2021; "The fermentation flurry in plant-based food," February 2021.
[168] "Production of single cell protein from manure as animal feed by using photosynthetic bacteria," December 2019; "Alternative aquaculture feeds," June 5, 2019.
[169] Tao Cai et al., "Cell-free chemoenzymatic starch synthesis from carbon dioxide," *Science*, September 23, 2021, Volume 373.
[170] Karen Filbee-Dexter and Thomas Wernberg, "Substantial blue carbon in overlooked Australian kelp forests," *Scientific Reports*, July 23, 2020, Volume 10.
[171] "Rethinking barrier films, food waste and the circular economy," October 12, 2021; "Can gene editing reduce postharvest waste," January 1, 2021.
[172] Dirk Schaefer and Wai Cheung, "Smart packaging: Opportunities and challenges," *Procedia CIRP,* June 27, 2018, Volume 72.
[173] Ignacio Ciampitti et al., "Redefining crop breeding strategy for effective use of nitrogen in cropping systems," *Communications Biology,* August 16, 2022, Volume 5.

In transportation, a host of technologies[174] that already address carbon emissions, such as battery-electric vehicles and fuel cells, can also reduce NOx emissions. In mining, technologies that reduce the need for water, such as thickeners and filters, could also reduce pollution.[175] In manufacturing and power, improvements in technologies such as selective catalytic reduction and selective noncatalytic reduction can convert nitrogen oxides into nontoxic chemicals and potentially address other pollutants, such as sulfur oxides and carbon monoxide.[176]

Plastic waste. Novel enzymes show promise to degrade plastics in a matter of days, versus much longer time periods.[177] While this solution does not address the more immediate collection problem, it holds promise for helping reduce plastic pollution and leakage from landfills.

Beyond traditional mechanical recycling, chemical recycling technologies including chemolysis, hygrothermal recycling, and gasification provide new opportunities for plastic reuse.[178] Sorting technology for plastics could also improve the efficiency and effectiveness of all recycling methods. Examples include optical sensors, chemical tracers, digital watermarks, and AI-enabled robotic methods.[179]

Freshwater consumption and wastewater management. Agricultural water usage could be reduced with IoT sensors that indicate when to water crops, as well as through the development of new and novel precision agricultural methods such as gravity-based micro-irrigation.[180] In manufacturing, technologies such as magnetic separators, catalysts, and forward osmosis could be applied to a variety of processing techniques and reduce water consumption and wastewater pollution.[181] Biological-based chemical manufacturing may also reduce wastewater discharge and combustion emissions compared with traditional manufacturing methods.[182] In the power sector, novel adsorbents and absorbents could address fouling, scaling, and corrosion, reducing the impact of contaminants and increasing the ability of power plants to cycle water use for cooling.[183] Advances in evaporative wet- and dry-cooling technology, such as radiative cooling, could also reduce water usage.[184] More broadly, emerging technologies such as algal, electrochemical, and membrane separation may also improve municipal wastewater filtering[185] and reduce the cost differential between freshwater withdrawals and reuse.

[174] "Why the automotive future is electric," McKinsey, July 7, 2021.
[175] "FLSmidth advancing towards zero water waste in tailings by 2030," *Mining Magazine*, October 10, 2022.
[176] Selective catalytic reduction uses equipment at the end of a process line to convert NO_x into N_2 and H_2O with the aid of ammonia injections in the gas stream and a catalyst chamber. Selective non-catalytic reduction injects a reagent (for example, urea or ammonia) into the exhaust gas stream without the presence of a catalyst to capture NO_x. See Alon Khabra, Gad Pinhasi, and Tomer Zidki, "NO_x and SO_x flue gas treatment system based on sulfur-enriched organic oil in water emulsion," *ACS Omega,* February 2021, Volume 6.
[177] Hongyuan Lu et al., "Machine learning-aided engineering of hydrolases for PET depolymerization," *Nature*, April 27, 2022, Volume 604.
[178] Chemolysis is the use of a chemical agent such as methanol or glycol, or just water, to break down plastic material into monomers. Hydrothermal recycling uses water at an elevated pressure and temperature to cut long-chain hydrocarbon bonds into plastics to produce oils and chemicals. Gasification is a high-temperature and high-pressure environment where oxygen or steam is in contact with the feed material to produce synthesis gas that can be converted into monomers. See "Rethinking plastics in a circular economy," Economist Impact, 2021.
[179] Sreeparna Das, "Recycling: What's ahead in advanced sorting technology," *Plastics Technology*, September 20, 2022.
[180] Abdul Salam, "How wireless technologies can help farmers save water," *Fast Company*, August 14, 2022.
[181] "Innovative solutions in the process industry for next generation resource efficient water management," Inspire Water, 2020.
[182] "Bright future for the bio-based chemical industry," ACME-Hardesty, accessed November 13, 2022.
[183] Amy Childress et al., *Power sector technology roadmap*, National Alliance for Water Innovation, 2021.
[184] Ablimit Aili et al., "Reduction of water consumption in thermal power plants with radiative sky cooling," *Applied Energy*, November 15, 2021, Volume 302.
[185] *Technology opportunities for improved nutrient removal from human waste*, RTI Innovation Advisors, August 2020.

4 A road map for corporate action

Companies are facing a large number of challenges, from talent retention to macroeconomic pressures, geopolitical instability, and supply chain pressures, just to name a few. But taking action on nature is not another burden. Companies can start their journey by understanding their footprint and implementing ROI-positive actions that address both climate and natural capital. There is also an opportunity for companies to build a distinctive identity around their efforts to address impacts on natural capital.

While there has been an increasing focus on how to define corporate road maps to climate action, the playbook for corporate action on nature is still in development. Some companies are starting to acknowledge dimensions of nature such as biodiversity loss, for example, but very few have set quantified targets.

Given all the demands facing companies in a broadly challenging environment, it can be difficult to know where to begin. This chapter defines a set of actions—mirroring efforts companies are already taking on climate and building on available work from leading scientific, business, and academic groups[186]—that can help corporate actors move forward on immediate, no-regret actions and plan for more actions in the future.

The challenge: Companies are still learning what to do

Companies are still in the early stages of committing to a broad set of nature-related goals (Exhibit 16). A recent McKinsey review of the Global 500 companies[187] shows that most companies have climate-related targets (83 percent) or at least acknowledge climate change (an additional 15 percent).[188] Across other dimensions of nature, however, targets and acknowledgments are far lower.

For instance, although 51 percent of companies acknowledge biodiversity loss in some way, only 5 percent of those have set quantified targets (see Box 8, "Examples of current corporate nature targets"). Other dimensions of nature, such as nutrient pollution, show up even less frequently in public acknowledgments. This may not be surprising: corporate understanding of nature is still largely nascent.

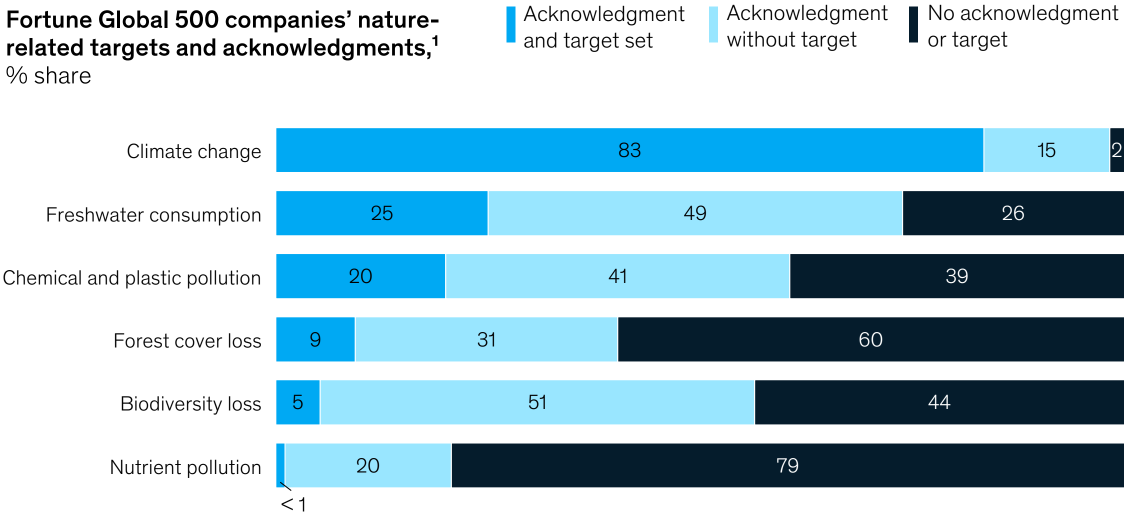
As we note in the next chapter, there is no standardized approach to measuring natural capital and ecosystem services.[189] Many companies may not know what steps to take beyond simply acknowledging the challenge of nature degradation, and limited understanding of how to engage might prevent them from making quantified commitments.

[186] This chapter pulls the best thinking from TNFD's LEAP framework (Locate, Evaluate, Assess, Prepare), the SBTN's five-step process (Assess, Interpret & Prioritize, Measure Set Disclose, Act, Track), WBCSD's Nature Action program, and Business for Nature's synthesized approach (ACT-D: Assess, Commit, Track, Disclose), as well as academic guidance on how businesses can avoid "greenwashing." See *The TNFD nature-related risk and opportunity management and disclosure framework*, June 2022; "SBTN interim targets," Science Based Targets Network, accessed November 13, 2022; "Nature action," World Business Council for Sustainable Development (WBCSD), accessed November 13, 2022; "High-level business actions on nature," Business for Nature, accessed November 13, 2022; Joseph William Bull et al., "Analysis: The biodiversity footprint of the University of Oxford," *Nature*, April 20, 2022.
[187] "Where the world's largest companies stand on nature," September 13, 2022.
[188] This review includes 460 of the Global 500 companies, because there was not sufficient public information to determine the goals of 40 companies.
[189] *The TNFD nature-related risk and opportunity management and disclosure framework*, June 2022.

Exhibit 16

Corporate targets are common for climate change but far less common for other dimensions of nature.

Fortune Global 500 companies' nature-related targets and acknowledgments,[1]
% share



Note: Analysis focuses on six of the nine planetary boundaries. For two planetary boundaries (ocean acidification and atmospheric aerosol loading), an absence of reliable data prevented analysis, while the analysis excludes ozone depletion since it is on a path to recovery. Figures may not sum to 100%, because of rounding.
[1]Includes 460 of the Fortune Global 500 companies. A target is defined as a company having set a quantified, time-bound, and outcome-oriented target across the entire organization. A commitment to spend a certain dollar amount without a target outcome or time period did not count as a target. An acknowledgment means that a company refers to that dimension of nature and either acknowledges its importance or reports ad hoc steps or initiatives it has taken to mitigate impacts, without specifying a concrete goal.
Source: See bibliography

McKinsey & Company

Among companies that have nature-related targets, most tend to focus solely on climate. The same McKinsey review highlighted that 16 percent of the Global 500 have set targets against three or more dimensions of nature, and no company has targets against the six dimensions.[190]

Four actions that could guide corporate efforts on nature

Several actions could guide corporate efforts to move forward on immediate, no-regret initiatives. The four actions are: (1) assess the company's nature footprint, (2) identify a set of possible actions to address those impacts, (3) commit to initial targets and integrate them into a portfolio of initiatives, and (4) monitor, verify, and, on a voluntary basis, disclose outcomes. In parallel, companies will need to build organizational capabilities and align key stakeholders to ensure the successful implementation of the nature strategy. These actions echo a step-by-step approach called ACT-D outlined by Business for Nature (see Box 9, "The ACT-D approach").

Such actions would require an iterative test-learn-refine approach. As companies monitor their progress and learn, they could refine their approach and test new levers. They could also integrate new technologies and the latest scientific thinking and respond to changes in market conditions, regulatory and consumer expectations, and more.

[190] "Where the world's largest companies stand on nature," September 13, 2022.

Box 8

Barriers to implementing ROI-positive levers at scale

Companies vary significantly in the extent and ambition of their nature targets. A wide variety of companies have already set ambitious goals:

— **L'Oréal** has developed more than 15 targets for 2030 for "managing water, respecting biodiversity, and preserving natural resources" based on the planetary-boundaries framework.[1]

— **Walmart** has committed to protect, restore, or improve the management of at least 50 million acres of land and one million square miles of ocean by 2030, among other detailed and metric-based nature goals.[2]

— **Kering**, inspired by the goals of the Convention on Biological Diversity (CBD), has committed to having a net-positive impact on biodiversity by 2025 by regenerating and protecting an area at least six times its physical footprint.[3]

— **Teck Resources** has committed to conserve or restore at least three hectares for every one hectare that its mining activity affects.[4]

— **Ørsted** has committed to ensuring that all of its projects commissioned from 2030 and on have a net-positive impact on biodiversity as well as targets on circular resource use and sourcing sustainable biomass.[5]

[1] *L'Oréal for the Future*, L'Oréal, 2020.
[2] *Sustainability*, Walmart, 2022.
[3] *Biodiversity strategy: Bending the curve on biodiversity loss*, Kering, 2020.
[4] "Becoming nature positive," Teck, 2022.
[5] *Green energy for the planet and its people*, Ørsted, 2021.

Box 9

The ACT-D approach

Business for Nature has developed a step-by-step guide for corporations looking to take action on nature. The ACT-D approach (assess, commit, transform, and disclose) was developed in collaboration with organizations the Science Based Targets Network (SBTN), the Taskforce on Nature-related Financial Disclosures (TNFD), the Nature Capital Protocol, and the World Business Council for Sustainable Development (WBCSD), among others.[1]

1. *Assess:* "Measure, value and prioritize your impacts and dependencies on nature to ensure you are acting on the most material ones."

2. *Commit:* "Set transparent, time-bound, specific, science-based targets to put your company on the right track towards operating within the Earth's limits."

3. *Transform:* "Avoid and reduce negative impacts, restore and regenerate, collaborate across land and seascapes, shift business strategy and models, and advocate for policy ambition."

4. *Disclose:* "Track performance and prepare to publicly report material nature-related information throughout your journey."

[1] "High-level business actions on nature," Business for Nature, accessed November 13, 2022.

Action 1: Assess your nature footprint

A nature footprint establishes the types and magnitude of a company's impact on nature, as well as potential impacts on company values and dependencies. The footprint has two parts: first, assessing which dimensions of nature a company has the most impact on,[191] and second, measuring that impact, including potential value impacts and dependencies (Exhibit 17).

A footprint assessment can include both a company's direct operations, analogous to Scope 1 GHG emissions, and the upstream and downstream impacts of those operations, analogous to Scopes 2 and 3 for GHG emissions. Thus, a grocery store would assess direct impacts caused by the grocery's operations, such as in-store food waste, the upstream impact of sourcing food, including agricultural land-use and transportation, and the downstream impacts, including consumer waste. A baseline is defined as impact in the year against which the business will set targets. It is relevant for nature impacts that are cumulative over time, such as carbon emissions, biodiversity loss, land use change, and plastic emissions.[192]

To meaningfully guide decision making, companies could identify their most significant material impacts and dependencies. Tools such as the Natural Capital Protocol can help companies assess value impacts and dependencies,[193] while SBTN's Assessment Method defines materiality as it relates to what nature needs and can help companies "identify which environmental issues to set targets on, for which parts of the business."[194] Organizations such as the Science Based Targets initiative (SBTi) suggest acceptable baseline years for carbon target setting,[195] and SBTN has released a similar methodology for nature impacts.[196]

Companies can select metrics that broadly address a company's impact across its footprint (see Box 10, "How to start measuring a company's nature footprint"). Numerous metrics are already available for measuring a company's nature impact across all aspects of nature.[197] What is important is choosing the best ones for a company's particular operations. Organizations such as SBTN are developing consolidated methods that include guidance on selecting metrics.[198] They have already published methods for freshwater use and pollution, with interim methods for other dimensions of nature.[199]

Action 2: Identify a set of actions

Companies can identify a set of potential activities, or levers, that could reduce impacts on nature and potentially improve company performance. For each company-specific lever, companies could identify the abatement potential, impact timelines, sources of financing, and possible returns, among other factors. Actions could go beyond direct operations to include partnering with suppliers and buyers to address impacts within a company's value chain and even partnering with outside organizations and other key stakeholders to address broader challenges. The "mitigation hierarchy" can also provide guidance on the priority order of actions to take (see Box 11, "Using the mitigation hierarchy to guide corporate actions").

As identified in chapter 3, a range of ROI-positive activities can improve operational efficiency and reduce dependencies. Companies would need to assess the company-specific ROI potential of these and other levers and might choose to tackle ROI-positive levers first. In all cases, companies would need to keep sight of the abatement potential of each lever and what it could take to address the company's overall nature footprint.

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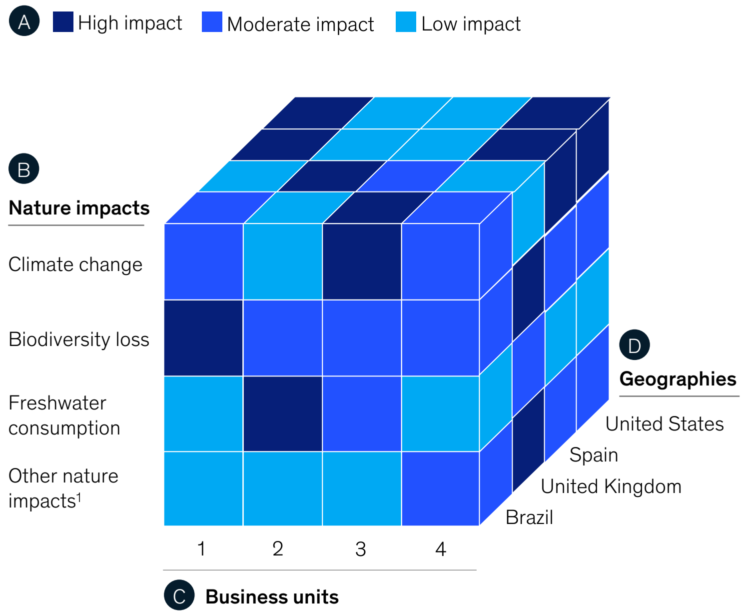
[191] The Sector Materiality Tool created by SBTN provides an assessment for upstream and downstream materiality. See *Technical guidance for Step 1: Assess and Step 2: Prioritize*, September 2022.
[192] Nature impacts that are "flows" (as opposed to cumulative "stocks") need only be balanced at the local level and include freshwater consumption and nutrient pollution (although nutrient pollution may be severe enough to require remediation).
[193] *Natural capital protocol*, Natural Capital Coalition, 2016.
[194] *Technical guidance for Step 1: Assess and Step 2: Prioritize*, September 2022.
[195] *How-to guide for setting near-term targets*, Science Based Targets, December 2021.
[196] Guidance is based on when data are available and how representative a baseline is of company operations. Guidance varies by sector. See *Science-based targets for nature,* September 2020.
[197] *The TNFD nature-related risk and opportunity management and disclosure framework*, June 2022.
[198] *Technical Guidance for Step 1: Assess and Step 2: Prioritize*, September 2022.
[199] "SBTN interim targets," accessed November 13, 2022.

Exhibit 17

To determine material impacts, a company can break down their footprint by business unit, geography, and dimension of nature, among other divisions.

Example materiality assessment



(A) Best practice is to determine materiality thresholds at the outset of the footprinting exercise and to include direct operations and upstream and downstream impacts.

(B) Companies can include metrics that are most material for the company but should assess the materiality of each planetary boundary.

(C) Companies may choose to pilot a small number of working units before rolling out programs to the entire company.

(D) Companies may split the assessment along dimensions that make the most sense for their operations—for example products, business units, industrial processes, inputs to operations, geographies, or other splits. The key is to assess impacts on nature along "working units" that can meaningfully drive action at the company.

[1] Could adhere to planetary boundaries (forest cover loss, chemical and plastic pollution, nutrient pollution) and include other metrics that are relevant to the company, such as hazardous waste.
Source: See bibliography

McKinsey & Company

Companies can identify a set of potential activities, or levers, that could reduce impacts on nature and potentially improve company performance.

Box 10

How to start measuring a company's nature footprint

While a comprehensive nature footprint can be extremely complex, requiring unique analytic assets and capabilities, companies could start by focusing on the operations that have the largest impact and by gathering the data required to determine best practices. The table below outlines how companies could start against each of the planetary boundaries. The list below is not exhaustive; specific metrics will vary from one company to another depending on what types of impacts are material and where the company operates. The Science Based Targets Network (SBTN) will release its first iteration of science-based targets for nature in early 2023, including initial target-setting resources on freshwater and land,[1] which will guide organizations on how to measure freshwater consumption and forest cover loss.

Planetary boundary	**Examples of how to begin**	**Material sectors for direct operations[2]**
Biodiversity loss	The critical measure for terrestrial biodiversity impact is the area of land converted to commercial use by ecosystem type.[3] An approach implemented by the University of Oxford used the Exiobase3 database and ReCiPe methodology to use CO_2 emissions, land use, and pollutants to estimate biodiversity loss.[4]	All
Forest cover loss	Geospatial tools, such as Global Forest Watch, and company real-estate records can be used to determine land use, which can then be compared to other databases to measure the type and extent of forest loss. We are not aware of a global database to track seabed loss.	Agriculture, forestry
Freshwater consumption	SBTN has released methods for freshwater use, measuring baseline withdrawals in terms of volume per unit of time (for example, three cubic meters per year), defined using primary data such as water meters.[5]	Agriculture, manufacturing, power, water, and waste
Climate change	Greenhouse Gas Protocol established a methodology for footprinting by calculating equivalent CO_2 emissions for each greenhouse gas emitted.[6] The Science Based Targets initiative (SBTi) provides additional guidance by sector. Available guidance covers Scopes 1, 2, and 3 emissions.	All
Nutrient pollution	Nitrogen: The Nitrogen Footprint Tool—developed at the University of Virginia in conjunction with the US Environmental Protection Agency (EPA) in 2009—has been piloted at five other universities in the United States.[7] The primary metric tracked was kilograms of nitrogen by use (for example, food production). It has also been used at the University of Melbourne.[8] Phosphorus: There is no standard method for a corporation to calculate a phosphorus footprint. Research has been done to mimic the methods and data sources used for nitrogen.[9]	Agriculture, transportation, water, and waste
Chemical and plastic pollution	There is no standard method for a corporation to calculate its plastic footprint.[10] Initial metrics may include kilograms of total plastic waste and percent of plastic contents recycled.	Transportation, construction, power, and other services

[1] "Public consultation on technical guidance for companies," Science Based Targets Network, accessed November 13, 2022.
[2] Sector materiality is based on sector-level contributions outlined in chapter 2. Materiality for individual companies may vary significantly based on specific operations and upstream and downstream partners.
[3] Land use can be used to calculate impact on biodiversity loss using metrics such as the biodiversity intactness index (BII). See *Biodiversity Intactness Index*, Natural History Museum, 2022.
[4] "Analysis: The biodiversity footprint of the University of Oxford," April 20, 2022.
[5] *Technical guidance for Step 3: Measure, set & disclose – initial freshwater SBTs (draft for public comment),* Science Based Targets Network, September 2022.
[6] *A corporate accounting and reporting standard*, Greenhouse Gas Protocol, 2005.
[7] Elizabeth A. Castner et al., "The Nitrogen Footprint Tool network: A multi-institution program to reduce nitrogen pollution," *Sustainability*, April 2017, Volume 10, Number 2.
[8] Xia Lang et al., "The nitrogen footprint for an Australian university: Institutional change for corporate sustainability," *Journal for Cleaner Production*, volume 197, June 29, 2018.
[9] Jana E. Compton et al., "The U.S. consumer phosphorus footprint: Where do nitrogen and phosphorus diverge?," *Environmental Research Letters*, October 13, 2020, Volume 15, Number 10.
[10] Julien Boucher et al., *Review of plastic footprint methodologies*, IUCN, 2019.

Box 11

Using the mitigation hierarchy to guide corporate actions

The mitigation hierarchy, outlined in the International Finance Corporation's Performance Standard 6, provides guidance on the priority order companies should take in identifying and implementing actions to reduce their impact on nature.[1] The classic mitigation hierarchy constitutes the four points below:

— *Avoid:* Plan projects to avoid negative impacts, including by changing site locations, altering the development of a project, or limiting the area of impact.

— *Reduce:* Reduce the impacts of ongoing projects by improving the efficiency of operations, reducing resource demands, or altering the timing of projects during migratory or breeding seasons.

— *Restore:* Regenerate habitats back to the pre-project state if a project is unable to avoid or minimize impact. This is already a norm in some industries; for example, in many jurisdictions, mining companies are required to restore damage.[2] Restoration is further down on the mitigation hierarchy in part because even high-quality restoration efforts are unlikely to fully return an area to its former state.[3]

— *Offset:* Take action to balance negative impacts by restoring and protecting habitats that are off-site from the project. Some organizations, such as the Science Based Targets Network (SBTN), do not include offsets in their mitigation hierarchy[4] due to challenges such as nature's lack of fungibility, discussed below.

Companies can apply the mitigation hierarchy beyond direct operations and influence stakeholders upstream and downstream of their direct operations. Addressing nature impacts requires action along the entire value chain (exhibit).[5] This may include switching suppliers to those with lower impacts on nature. Companies may also want to act in tandem with their sector peers, suppliers, and customers to eliminate leakage and ensure holistic impact.

The Convention on Biological Diversity's goal is to halt and reverse nature loss by 2030 and achieve a full recovery by 2050.[6] Achieving that goal may require an additional step in the mitigation hierarchy, conducted in parallel, to invest directly in nature. Examples include investing in green growth opportunities, efforts to undo past harm, and nature credits. Some organizations, such as Business for Nature and SBTN, also include another, parallel "transform" step in the mitigation hierarchy, calling for companies to conduct broader advocacy on nature-related efforts, including through system-level collaboration with government stakeholders and others.[7]

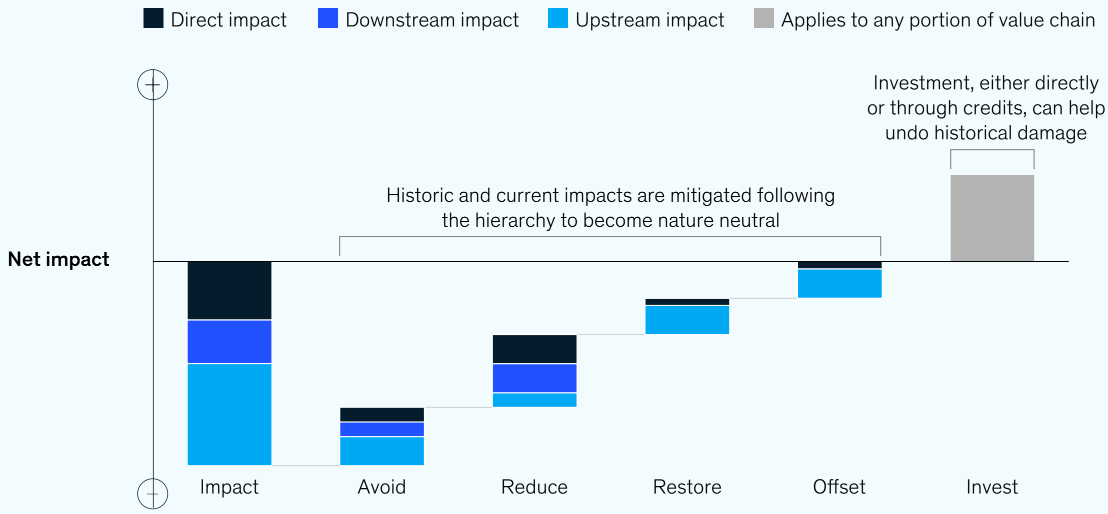
[1] IFC's definition underpins a traditional approach to the mitigation hierarchy, though there has also been more recent work done by the CBD to adapt the mitigation hierarchy into a proactive conservation hierarchy. See *International Finance Corporation's guidance note 6*, January 1, 2012; *The conservation hierarchy*, 2020.
[2] Carl Grant et al., *Mine Rehabilitation: Leading Practice Sustainable Development Program for the Mining Industry*, Commonwealth of Australia, September 2016.
[3] For this reason, SBTN's version of the mitigation hierarchy, the "AR3T" framework (avoid, reduce, regenerate, restore, and transform), divides restoration actions into those that improve the ecosystem functions within the existing land uses ("regenerate") from actions that fully reestablish natural cover in places previously converted ("restore"). See Susan C. Cook-Patton et al., "Protect, manage, and then restore lands for climate mitigation," *Nature Climate Change*, November 18, 2021; Joe Atkinson et al., "Terrestrial ecosystem regeneration increases biodiversity and reduces its variability, but not to reference levels: A global meta-analysis," *Ecology Letters*, May 12, 2022, Volume 25, Number 7.
[4] "SBTN interim targets," Science Based Targets Network, accessed November 13, 2022.
[5] Ibid.
[6] Harvey Locke et al., *A nature-positive world: The global goal for nature*, 2021.
[7] SBTN's version of the mitigation hierarchy, the "AR3T" framework (avoid, reduce, regenerate, restore, and transform), includes transformation as a key step to undertake in parallel. See "SBTN interim targets," accessed November 13, 2022, "High-level business actions on nature," Business for Nature, accessed November 13, 2022.

'Watch out' on using offsets

Similar to greenhouse-gas (GHG) emissions, many companies will be unable to mitigate their nature impacts through operational changes alone. Therefore, companies may need to rely on some form of offsets to address their residual impact on nature (and GHG) after other actions are taken. Since nature is not fungible in the same way that carbon is, it is very rarely possible to perfectly offset damage in one area by protecting another. Even where one-to-one offsetting is possible, to date it has not stopped biodiversity loss overall.[8] Offsets can also be problematic as they may provide incentives for delayed action and can shift efforts to the Global South.[9] As part of a nature-positive strategy, companies can instead invest in nature's recovery (for example, through credits as covered in chapter 4).[10]

Exhibit

We have identified examples of different scope impacts and which step of the mitigation hierarchy is best placed to address them.



Source: See bibliography

McKinsey & Company

[8] Existing offset schemes for biodiversity have been shown to be largely ineffective at halting biodiversity loss. See Sophus O. S. E. zu Ermgassen et al., "The ecological outcomes of biodiversity offsets under 'no net loss' policies: A global review," *Conservation Letters*, July 17, 2019, Volume 12, Number 6.

[9] Biodiversity offsetting schemes almost never achieve a net-neutral impact due to leakage. The other approach is to invest in non-like nature—for example, "offset" a farm in Iowa by investing in rainforest, but that runs into issues of comparing non-like nature assets, a process that is inherently subjective. See Tom Dowdall, "Science-based net-zero targets: 'Less net, more zero,'" Science Based Targets, October 7, 2021.

[10] An analogy can be drawn with decarbonization efforts: a company that is "neutral" may account for negative impacts primarily through offsetting and investment, whereas a "net zero" company will maximize its efforts to avoid and reduce negative effects from its operations before pursuing restoration or offsetting levers. A study of the biodiversity footprint of the University of Oxford outlines how approaches largely based on avoidance can vary significantly in cost and impact versus those largely based on offsets. See Joseph William Bull et al., "Analysis: The biodiversity footprint of the University of Oxford," *Nature Comment*, April 2, 2022.

Addressing current impacts. Selecting and prioritizing a set of levers to address a company's footprint is a complex optimization problem. Companies would first need to identify a set of potential levers across the mitigation hierarchy.[200] They would then need to identify where in the company's operations those levers could be implemented and determine the costs, potential returns, sources of funding, abatement potential, and impact timeline for each. Levers could range from minor changes in operations and sourcing to fully divesting business units. Further complexity is added by the fact that each parameter will vary across the company's operational footprint and may address multiple dimensions of nature at once.

Once a company has gathered the necessary data, lever prioritization may start with levers that are ROI positive, while also following the mitigation hierarchy to prioritize efforts that avoid and reduce impacts over those that restore and offset damage already done.[201] The optimization exercise could be subject to a cost ceiling or other parameters, such as timing or ambition, but in general the goal would be to maximize the abatement potential of the strategy while minimizing costs (or maximizing returns). Many prioritization technologies are emerging that use techniques such as integer linear programming,[202] artificial intelligence,[203] and even conceptual advances that include the mitigation hierarchy in spatial prioritization.[204]

A company could assess multiple alternative scenarios and pathways to achieve its nature goals. For example, a forestry company might identify a set of sustainable-forestry techniques such as sustainable deforestation, variable thinning, and buffer maintenance, and identify the nature impacts and associated costs of implementing each lever across different geographies or business units. An optimization program could then identify the mix of techniques that best matches various scenarios. Programs could include, for example, how to minimize negative biodiversity impacts, how to achieve a desired impact by a certain target date, or how to achieve the maximum possible impact given a specific budget in a specific time frame. Different companies could use a different set of criteria for optimization based on their specific targets and needs across dimensions of nature.

Avoiding future negative impacts. In addition to the actions companies would take to address their footprint, companies could ensure that future decision making is at least neutral in its impact on nature, potentially by including the costs of either offsetting or remediating any negative impacts on nature in financial models.[205] Companies may consider escalating the internal cost for each stage of the mitigation hierarchy to create incentives for earlier action. For guidance on costs, companies could look to local experts, academics, or nongovernmental organizations (NGOs) engaged in restoration and conservation activities.

Undoing past impacts. Companies could also begin to take action to address their historical cumulative impacts on nature. Investing in nature's recovery could constitute part of corporate nature-positive efforts.[206] For example, Microsoft has committed to be carbon negative by 2030 and, by 2050, to "remove from the environment all the carbon the company has emitted either directly or by electrical consumption since it was founded in 1975."[207] For other planetary boundaries, such as biodiversity, this could involve restoration, rewilding,

[200] The levers identified in chapter 2 can help provide a starting point for companies to generate an initial list of levers to address both immediate operations and upstream and downstream impacts. However, companies would need to work with experts to identify additional levers and calculate the feasibility, costs, and abatement potential for levers in line with their own situation.
[201] Companies could also choose to add a weighting that prioritizes levers based on the mitigation hierarchy. See *A cross-sector guide for implementing the Mitigation Hierarchy*, Cross Sector Biodiversity Initiative, 2015.
[202] Jeffrey Hanson et al., "Prioritizr: Systematic conservation prioritization in R," September 17, 2022, distributed by CRAN.
[203] "The Captain Project: Conservation prioritization through artificial intelligence," Python Package Index, August 2022.
[204] Kendall R. Jones et al., "Spatial analysis to inform the mitigation hierarchy," *Conservation Science and Practice*, April 9, 2022, Volume 4, Number 6.
[205] Such costing exercises can feed a "shadow P&L" that better accounts for a true cost of nature. See Gold Standard, "Carbon pricing: Setting an internal price on carbon," blog entry by Gabriel Kuettel, October 14, 2022; *Shadow price of carbon in economic analysis: Guidance note*, World Bank, November 12, 2017.
[206] *How business and finance can contribute*, October 2022.
[207] *Official Microsoft Blog*, "Microsoft will be carbon negative by 2030," blog entry by Brad Smith, January 16, 2020.

and conservation efforts.[208] Emerging markets for biodiversity and nature credits, outlined in chapter 3, could help streamline investments in nature's recovery.

Financing a nature strategy. Financing for levers that are ROI positive can take advantage of traditional channels, while financing for more expensive levers may need to rely on newer approaches as discussed in chapter 5. For instance, linking a bond or debt issuance to sustainability goals can help companies achieve a better interest rate than would otherwise be possible.[209] Such linking mechanisms can either pay out a premium if a company reaches its goals or charge a penalty if the company does not.[210] Other green debt products include impact bonds, green bonds, low-interest green loans, and sustainability-linked loans.[211] There are also new green-credit facilities, including thematic equity funds and diversified sustainability funds.[212]

Companies could also self-fund investments in nature by implementing "internal costs of nature," as Colgate-Palmolive has done for water[213] and as many other companies have done for carbon.[214] These internal costs, if implemented as a charge, could fund company-led activities to address their nature footprint and, simultaneously, help discourage further impacts.

Still, financing the transition to a nature-positive future will require more resources than are currently available. This means that a range of public- and private-sector institutions will need to help fill the gap. For example, governments could increase incentives by reallocating harmful subsidies,[215] implementing payments for ecosystem services, and setting clear expectations for companies. Public financial institutions could consider implementing new standards that would help direct funding toward nature-positive activities.[216] And private financial institutions could potentially create new financial products and set the bar for nature-related performance.[217]

Fundamentally, the world will need to close the gap between investor expectations for net-zero emissions and investor expectations for other dimensions of nature. As we have noted in other publications, companies that address climate and other natural-capital impacts in their operations can benefit through increased resilience in the long term, making them a better long-term investment.[218]

Action 3: Commit to initial targets and integrate them in business operations
Based in part on the levers identified, companies could set initial targets for nature and integrate them into a broader portfolio of initiatives. This portfolio would constitute a set of clearly defined and prioritized actions that could help a company address its current impact,

[208] For "flows," such as pollutants and water usage, this remediation is not necessary—companies should target balance. But for stocks, such as carbon and biodiversity loss, remediation is imperative.
[209] Research by ING has found that issuers of green bonds save, on average, between one and ten basis points, while CBI research has found that green bonds are typically oversubscribed compared with their vanilla counterparts. See "The corporate premium in green finance," June 9, 2021; *Green bond pricing in the primary market H1 2021*, September 2021.
[210] For example, Louis Dreyfus Company B. V. renewed its $750 million revolving credit facility to include a sustainability-linked interest rate measured against environmental outcomes. Key metrics were CO_2 remissions, electricity consumption, water usage, and solid waste sent to landfill. See "Louis Dreyfus Company announces its first sustainability-linked revolving credit facility," May 28, 2019.
[211] Sustainability-linked loans increased in volume by 168 percent in 2019 to a total volume of $122 billion. See *Mobilizing private finance for nature*, World Bank, September 28, 2020.
[212] Overall, securitized products represented 25 percent of the total green bond market. See *Green bonds: The state of the market 2018*, Climate Bonds Initiative, March 6, 2019.
[213] *Colgate Palmolive Company – water security 2021*, CDP, 2021.
[214] "The state of internal carbon pricing," February 10, 2021.
[215] *A multi-billion-dollar opportunity: Repurposing agricultural support to transform food systems*, Food and Agriculture Organization of the United Nations, 2021; *Financing nature*, 2020.
[216] There are many avenues to integrate risk assessments into financing decisions, including (1) positive screening; (2) negative screening; (3) environmental, social, and governance (ESG) engagement, activism, and divestment; (4) ESG integration into business-as-usual risk management processes; and (5) the adoption of norms and standards that address impacts to biodiversity. See *Financing nature,* 2020.
[217] A total of 111 financial institutions managing more than €16.3 trillion in assets have committed to set targets on their impacts on nature. See the Finance for Biodiversity Pledge website, accessed October 30, 2022.
[218] "Does ESG really matter—and why?," *McKinsey Quarterly*, August 10, 2022.

decision-making criteria to avoid further negative impacts, and, in some cases, actions meant to remediate past damage.

Companies may look to organizations such as SBTN for guidance on how to set time-bound, science-based, and quantitative targets in line with the planetary boundaries. Companies may also choose to make their nature commitments public, which provides an opportunity to build an identity around nature commitments. Nimbleness and flexibility are the name of the game, particularly in today's evolving environment, so company approaches may evolve over time.

Setting a vision. In setting targets, a company could set an ambition and vision: Does the company want to completely address its impact on nature to align with the goals outlined in the CDB—that is, halting and reversing nature loss by 2030 and full recovery by 2050?[219] If so, its targets would need to ensure that company actions contribute to a measurable net gain in the extent and diversity of nature by those two dates. Other targets could include being the sector leader on nature or setting ambitions that align with upcoming regulations or a corporate strategy oriented around green-business building.[220]

Companies may also make a strategic choice to define their nature strategy to align with how they want to differentiate themselves in the market. For instance, a beverage company might want to outperform its peers on measures of freshwater consumption, or an agricultural player may want to lead the way on biodiversity protection.

Overall, a company's vision may be influenced by such diverse factors as its nature aspirations (for example, to be the leader in its sector), broader macroeconomic conditions, regulatory guidance, economic incentives, and available financing, but would likely be most effective if informed by the best available science.

Setting targets. Ongoing initiatives, led by organizations like SBTN, are working on specific target-setting methodologies based on planetary boundaries that may help set a high level of ambition based on the best available science. Others, such as the World Economic Forum (WEF) and the World Business Council for Sustainable Development (WBCSD), are producing more sectoral-focused guidance.[221]

A company would need to decide how set targets. As mentioned above, for cumulative impacts, or "stocks" (for example, biodiversity loss, land-use change, GHG emissions, and plastic emissions), companies need a baseline against which to measure progress in reducing impacts. Companies may also choose to take positive action and invest in nature's recovery. For more annualized impacts, or "flows" (for example, freshwater consumption or nutrient pollution), companies could set targets in line with local thresholds, where guidance is available.[222]

While science-based targets are under development, companies could take two broad approaches to set targets: a top-down approach or an approach based on setting a nature budget, both of which can be informed by the levers identified. A company using a top-down approach would set a target relative to its nature footprint. This could be a blanket reduction target, such as a percentage impact reduction by 2030 as outlined in the CBD's Target 15.[223]

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[219] Harvey Locke et al., *A nature-positive world: The global goal for nature*, 2021.
[220] In the future, whether the target is ambitious enough will be defined by national and local regulations, certification organizations, and civil society initiatives such as SBTN. This is similar to how corporate carbon efforts are currently assessed.
[221] The World Economic Forum has identified 15 transitions across sectors and is developing roadmaps for the three socio-economic systems that endanger 80 percent of threatened specifies: land-use, built environment, and energy systems. The World Business Council for Sustainable Development is working on a set of sector-specific nature positive pathways. See *The future of nature and business,* World Economic Forum, 2020; "Roadmaps to nature positive," World Business Council on Sustainable Development, accessed November 14, 2022.
[222] For instance, if there is a local basin management agency that has defined a catchment-specific hydrologic or water quality model and locally based thresholds for freshwater consumption, companies should align their targets with those thresholds (whether or not they are legally required to do so). See *Technical guidance for Step 3*, September 2022.
[223] Target 15, although not yet official, sets a goal for companies to reduce negative impacts on nature by at least half and increase positive impacts. See *PRI Blog*, "CBD COP15: What does the global biodiversity framework mean for investors?," blog entry by Gemma James, October 22, 2021.

A company could also use a desired level of overall financial contribution toward a nature strategy to determine its targets (including starting by focusing on ROI-positive activities).

Regardless of the choice of approach or ambition, companies would need to regularly assess and revise their targets based on the latest science and regulations (see Box 12, "Approaches to setting a nature target").

Integrating into business operations. Once a company has identified a set of levers, determined a vision, and committed to an initial set of targets, it can integrate those levers into a broader portfolio of initiatives that are tracked by leadership. This may require assessing internal capabilities to determine whether a company can successfully implement a nature strategy, including assessing organizational structure, company culture, expertise and skills, accountability, and incentives for executives, among other areas. Where deficiencies are recognized, companies may need to develop a plan to build or source the necessary capabilities as part of their overall strategy.

Four organizational steps may be key to successful action on nature:

First, companies could regularly engage a variety of stakeholders. Employees are an important source of ideas and will ultimately be responsible for implementation. Active employee engagement on a company's nature strategy could be an opportunity to drive retention and build company culture. Shareholders and investors would need to be informed of any nature risks the company faces and could be mobilized to approve the resources needed to act. Partners up- and downstream of company operations may hold key insights that could help develop a more robust nature strategy. And local and Indigenous communities that are affected by company operations could be included at all stages of the company's strategy development to ensure adequate consideration of local knowledge and local livelihoods. Mainstreaming the importance of a company's nature efforts can help ensure internal syndication and buy-in.[224]

Second, companies could create accountability and transparency. This could be achieved through measures such as integrating nature-related performance indicators into company dashboards, holding business units accountable against overall targets, and potentially integrating nature targets into executive and management compensation schemes.[225] As noted, 23 percent of companies[226] already set an internal cost of carbon, which can meaningfully change incentives. Many companies do something similar with water.[227] A similar approach could be applied across the dimensions of nature.

Third, companies could build capabilities and finance the effort. Teams that are responsible for efforts on carbon could build new capabilities to cover a broader set of nature topics. These teams could be self-financing business units if they could monetize nature benefits—for example, by issuing credits or through an internal nature-pricing effort.

Finally, companies could view efforts on nature not as ends in themselves but as part of their broader business strategy. An advanced nature strategy can create durable competitive advantage in operations and supply chain planning. Companies could identify the ways in which a nature strategy benefits the company and clearly communicate those benefits throughout the organization.

[224] Olivier Boiral, Marie-Christine Brotherton, and Inaki Heras-Saizarbitoria, "Improving corporate biodiversity management through employee involvement," *Business Strategy and the Environment*, January 10, 2019, Volume 28, Number 5.
[225] Sophus O. S. E. zu Ermgassen et al., "Are corporate biodiversity commitments consistent with delivering 'nature-positive' outcomes? A review of 'nature-positive' definitions, company progress and challenges," *SocArXiv,* July 2022; Martine Maron et al., "Setting robust biodiversity goals," *Conservation Letters*, May 31, 2021, Volume 15, Number 5.
[226] "The state of internal carbon pricing," Februray 10, 2021.
[227] Vania Paccagnan, "Internal water pricing is changing how companies do business," CDP, August 26, 2022.

Box 12

Approaches to setting a nature target

Companies seeking to set a nature target have choices. The exhibit highlights some of the trade-offs between different approaches, although companies might use elements of each approach to design their nature strategies. In doing so, they would need to estimate both the ease of implementation and the degree of positive impact on nature. For example, with current guidance, data, and techniques, is it possible to pursue the chosen approach to setting targets? Is it possible to track and communicate progress against this target? And how likely is the approach to help bring our economy back in line with the planetary boundaries?[1]

As methodologies become more advanced, this comparison of approaches will likely change. For instance, once more companies have disclosed progress, the benchmarking target would become increasingly feasible. The Science Based Targets Network (SBTN) has published interim guidance that can help companies set targets.[2] Several approaches are available:

Top-down approaches are a no-regrets starting point to establish a nature strategy. In some cases, companies may go beyond a 100 percent reduction target to not only reduce current nature footprints but also undo past impacts.

Financial approaches enable companies to use a desired level of financial contribution toward a nature strategy to determine their goal. Budgets are a viable parameter to include, but they do not guarantee sufficient impact to address the planetary boundaries.

Boundary-based targets are goals that are in line with local and global limits. As outlined, companies can start with boundary-based targets where available.

Three main approaches for target-setting vary by ease of implementation and degree of positive impact on nature.

Exhibit

Three approaches for target setting vary by ease of implementation and degree of positive impact on nature.

Average performance against criteria | Low | Medium | High

Approach	Aspiration	Ease of implementation	Degree of positive impact on nature
Top-down	Incremental: Set a blanket target (eg, 10% reduction in impact)[1]	High	Low
	Proposed Convention on Biological Diversity (CBD) Target 15: Target a 50% reduction in impact	Medium	Medium
	Nature neutral: Balance flows (eg, extract only as much as is replenished) and halt depletion of stocks (eg, stop expanding land footprint)	Medium	Medium
	Nature positive: Nature neutral plus efforts to undo past harm	Low	High
Financial	Budget allocation: Determine a budget to allocate toward developing a nature strategy based on ESG[2] budget, peer commitments, industry benchmarks, etc	High	Low
	Net-present-value (NPV) positive actions: Identify levers that are NPV-positive and implement	Medium	Low
	NPV-neutral actions: Implement all levers that are NPV-positive and use savings to invest in NPV-negative levers	Medium	Medium
	Nature price: Develop an internal “cost of nature” to track the value of the nature services used (and potentially the cost of negative externalities)	Low	Medium
Boundary	Global or local boundary: Set goals in line with environmentally informed guidance such as the planetary boundaries or locally defined carrying capacity[3]	Low	High

[1]Companies may also choose to benchmark to set targets, but information needed for benchmarking is not currently available.
[2]Environmental, social, and governance.
[3]Ease of implementation will improve as additional science-based targets for nature are released.
Source: See bibliography

McKinsey & Company

[1] Another consideration for target setting is whether the targets are fair to companies in emerging economies or new entrants that have little to no historic nature footprint. Fairness can be ensured, in part, by setting national level targets for nature that account for differences in historical footprint, which can then translate to goals for local companies. See Martine Maron et al., “Global no net loss of natural ecosystems,” *Nature Ecology & Evolution*, January 2020, Volume 4, Number 1.
[2] “SBTN interim targets,” Science Based Targets Network, accessed November 13, 2022.

Action 4: Monitor and disclose progress
Once a company commits to action, monitoring is critical to ensure tangible, measurable results and to provide insights needed to adjust the strategy. To do so, companies will need to track progress across business units, geographies, and subsidiaries and develop internal monitoring capabilities or outsource to third parties. SBTN encourages the use of open-source and freely available data and tools to aid in transparency.[228]

Voluntary disclosure of company targets and progress against those targets can also help increase transparency and accountability, provide opportunities for intercompany learning, and allow for benchmarking and comparison. The TNFD has developed detailed reporting guidance across four pillars of disclosure:

— Governance: the ways in which the organization's oversight and decision-making functions take nature-related risk and opportunities into account

— Strategy: the integration of actual and potential effects of nature-related risks and opportunities on the organization's business model, strategy, and financial planning

— Risk management: how the organization integrates nature-related risks into its overall risk management approach

— Metrics and targets: quantitative and qualitative performance indicators and aims related to nature-related risk and opportunities, based on nature dependencies and impacts[229]

Best practice is to seek out independent verification to corroborate company-level monitoring and reporting.

These actions would by definition require an iterative test-learn-refine approach. As companies monitor progress and learn, they can refine their approach and test new levers. They can also integrate new technologies and the latest scientific thinking and respond to changes in market conditions, regulatory and consumer expectations, and more. But, as we describe in the next chapter, the enabling conditions would need to be in place for the actions to be truly successful.

[228] *Technical guidance for Step 1: Assess and Step 2: Prioritize*, September 2022.
[229] *The TNFD nature-related risk and opportunity management and disclosure framework*, June 2022.

There is an opportunity for companies to build a distinctive identity around their efforts to address impacts on natural capital.

5 Enabling the nature transition

Companies can do a lot, but they cannot do it on their own. Other stakeholders in both the public and social sectors have a critical role to play to help enable the nature transition. Issues to be addressed include currently evolving regulatory and policy guidance, a lack of standardized metrics and definitions of nature, widely distributed and nonstandard nature-related data, a lack of funding and financial incentives, limited options for investing in nature's recovery, and a shortage of needed "green skills."

In this chapter, we identify three broad sets of enabling actions: First, governments and industries could work together to define a clear set of expectations for corporate nature efforts. Second, there is a need to develop and invest in the infrastructure—data, skills, and opportunities—that companies would need to help inform their actions. While such infrastructure could be an opportunity for new businesses (such as data brokerages), the public and social sectors could play a key supporting role. Third, governments could help expand financing and incentives for action focused on natural capital. This may potentially require cooperation with both public and private financial institutions.

Define clear sustainable organizational strategies

A clear set of policies and expectations can reduce uncertainty, help create a level playing field for all companies, and inspire corporates to act. In this section, we focus on two potential enablers for corporate action and explore whether they could help remove barriers to action. The two enablers are setting industry-wide reporting standards and defining clear national natural-capital strategies.

Clarify accepted metrics and standards
Standard requirements for natural-capital accounting and reporting could help companies identify which metrics are most critical and make company disclosures consistent and comparable.[230]

Some individual corporations have already started reporting a wide variety of metrics,[231] and some governments are implementing natural-capital reporting standards.[232] To increase transparency, governments can consider working together to use industry-led and science-based standards—such as those under development by the TNFD and SBTN—as the basis of national and international reporting standards. The availability of data would likely increase should governments mandate the use of such metrics in corporate reporting. National reporting standards on carbon and corporate social responsibility—such as those seen in

[230] *A short introduction to the GRI standards*, Global Reporting Institute, accessed November 10, 2022.
[231] "Where the world's largest companies stand on nature," September 13, 2022.
[232] For example, the EU Non-Financial Reporting Directive. See "Commission guidelines on non-financial reporting," European Commission, updated June 18, 2019.

China, the United Kingdom, and the United States—have shown that such standards can drive progress against mandated disclosure variables.[233]

In the absence of officially agreed-upon reporting standards, some organizations are stepping in. The TNFD, for example, has published draft disclosures with the aim of coordinating how businesses report nature-related metrics and act on nature-related risks and opportunities. The TNFD intends to coordinate with other relevant organizations and officially release guidance in September 2023.[234] In some cases, certain sectors may require additional technical guidance for areas in which industry organizations have a role to play.[235] Standard reporting, potentially along the lines of new climate reporting requirements in some countries, could help increase corporate accountability for impacts on natural capital and provide incentives for ambitious nature-related targets.[236]

Governments can assist in providing integrated goals and principles

While companies can set ambitious targets on their own, governments can encourage broader corporate action by setting clear guidance for nature-related actions, which can signal to companies what is expected and which outcomes to target.[237] In many cases, this could require national governments to set the requirements on the use and treatment of natural capital and to align to standard reporting guidance.

National targets for the use of natural capital, which have been under discussion as part of the Convention on Biological Diversity (CBD), may prove essential for ensuring greater clarity on a country's sustainability aspirations. Much as the Paris Agreement required countries to set targets for reducing carbon emissions, the CBD's draft post-2020 Global Biodiversity Framework includes an expectation that countries develop national biodiversity strategies and action plans (NBSAPs). These plans translate the targets outlined in the draft post-2020 framework into country-level action. Selected current targets under negotiation include:

- development of biodiversity-inclusive spatial planning to cover 100 percent of land and sea areas
- conservation of at least 30 percent of land and sea areas globally
- restoration of at least 20 percent of degraded freshwater, marine, and terrestrial ecosystems
- 50 percent reduction in the rate of introduction of invasive alien species
- reduction by at least half of nutrients lost to the environment
- reduction of pesticides by at least two-thirds and elimination of discharge of plastic waste to aquatic environments
- nature-based contributions of at least ten gigatons of CO_2e per year to global efforts to mitigate climate change[238]

NBSAPs are meant to integrate national plans "into relevant sectoral or cross-sectoral plans, programs, and policies,"[239] and could help companies define and refine their goals for nature. However, governments have lacked the financial resources, data, and institutional capacity

[233] Benedikt Downar et al., "The impact of carbon disclosure mandates on emissions and financial operating performance," *Review of Accounting Studies*, 2021, Volume 26; Pierre Jinghong Liang, Nicholas Z. Muller, and Lavender Yang, "The real effects of the mandatory CSR disclosure on emissions: evidence from the greenhouse gas reporting program," National Bureau of Economic Research, July 2021; Yi-Chun Chen, Mingyi Hung, and Yongxiang Wang, "The effect of mandatory CSR disclosure on firm profitability and social externalities: evidence from China," *Journal of Accounting and Economics*, February 2018, Volume 65, Number 1.
[234] *The TNFD nature-related risk and opportunity management and disclosure framework*, June 2022.
[235] *Reporting with the Sector Standards*, Global Reporting Institute.
[236] One example is the EU's corporate sustainability reporting directive. See "New rules on corporate sustainability reporting: Provisional political agreement between the Council and the European Parliament," European Council, June 21, 2022.
[237] "Beyond offsetting: Target-based ecological compensation," Threatened Species Recovery Hub, March 11, 2021.
[238] *UN Biodiversity Conference (COP 15)*, United Nations Environment Program (UNEP), 2022.
[239] "What is an NBSAP?," Convention on Biological Diversity, accessed November 11, 2022.

to implement NBSAP commitments,[240] and less-developed countries have called for more support from the developed world.[241]

Jurisdictional approaches (whether international, national, or regional) can also provide greater clarity. Such approaches have been effective in reducing deforestation and land-use emissions,[242] including from soy and palm oil.[243] They have also been used to address overfishing.[244] Jurisdictional approaches can reduce "balloon squeeze" challenges, which occur when a reduction in unsustainable practices in one location leads to the same practices being used elsewhere.

Finally, national and local spatial planning processes could help identify biodiversity-rich areas and guide development decisions.[245] While the data analysis required to complete spatial planning can often be done using existing data sets[246] and can sometimes take advantage of capacity-building and peer-learning opportunities,[247] consultations with local communities and codifying plans into law may require more extensive timelines.[248]

Consider investing in nature-related infrastructure

While clear aspirations and goals can help companies understand what is expected of them, companies also need infrastructure to support decision making on where, when, and how to act. Those data are often hard to come by, requiring expensive and time-consuming primary research. Two areas stand out as potential enablers of corporate action: improving data around the availability of natural capital and improving supply chain traceability. Although these technologies and services may not eliminate the need for primary research, they could provide greater visibility to companies, potentially helping them take action more quickly.

Companies may also need more training to develop a workforce with the broad set of green skills necessary to interpret and use nature-related data to inform decision making. Finally, corporations may need more options to invest in the recovery of natural capital, which scientifically rigorous and well-regulated credit markets could help provide.

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[240] A total of 177 parties have submitted NBSAPs thus far, although the quality and extent of the submissions have varied. See Christina Supples, "CBD Information Document on lessons learned during implementation of the 2011-2020 Strategic Plan for Biodiversity," NBSAP Forum, May 20, 2021; Balakrishna Pisupati and Christian Prip, *Interim assessment of revised national biodiversity strategies and action plans (NBSAPs)*, UNEP-WCMC and Fridtjof Nansen Institute, 2015.
[241] Martine Maron et al., "Global no net loss of natural ecosystems," *Nature Ecology & Evolution*, January 2020, Volume 4, Number 1; Tiina Häyhä et al., "From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?," *Global Environmental Change*, September 2016, Volume 40.
[242] For instance, across countries with tropic forests that are members of the Governors' Climate and Forests (GCF) Task Force, and in Indonesia. See W. Boyd et al., *Jurisdictional approaches to REDD+ and low emissions development: progress and prospects*, World Resources Institute, June 2018; Lex Hovani et al., *Jurisdictional approaches to sustainable landscapes: Berau and East Kalimantan, Indonesia*, Nature Conservancy, 2018.
[243] John Buchanan, *Exploring the reality of the jurisdictional approach as a tool to achieve sustainability commitments in palm oil and soy supply chains*, Conservational International, March 2019.
[244] For instance, in the Pacific Islands region, the Parties to the Nauru Agreement (PNA) include eight Pacific Island countries that cooperatively manage the highly migratory tuna resources of the Western and Central Pacific Ocean. See John N. Kittinger et al., "Applying a jurisdictional approach to support sustainable seafood," *Conservation Science and Practice,* May 2021, Volume 3, Number 5.
[245] "Spatial analysis to inform the mitigation hierarchy," April 2022.
[246] Ibid.
[247] An evaluation of NBSAPs found that existing technical assistance and capacity building provided meaningful support to national planners, although more support is likely needed. As another example, there are a growing number of well-regarded programs that train practitioners in marine spatial planning. See *CBD Information Document on lessons learned*, May 20, 2021; Catarina Frazão Santos et al., "Chapter 30 - Marine Spatial Planning" in *World Seas: An Environmental Evaluation (Second Edition)*, 2019.
[248] The marine spatial planning process in Portugal, which has Europe's fourth-largest exclusive economic zone (EEZ), lasted nearly a decade. See Catarina Frazão Santos et al., "How sustainable is sustainable marine spatial planning? Part II - The Portuguese experience," *Marine Policy*, November 2014, Volume 49.

Increase the availability of data on natural capital

Although data on natural capital are often in the public domain, they are frequently spread across sources and can be difficult to aggregate and use.[249] Efforts to aggregate and synthesize publicly available data using a single set of standards are ongoing and include the TNFD's Nature-related Data Catalyst, which is targeted toward corporate data needs,[250] and the Group on Earth Observations (GEO), an intergovernmental partnership that has built out an extensive database of Earth observations.[251] Data for modeling and interpolating nature-based outcomes can also be part of the solution.[252]

Where primary research is required, new technologies can provide real-time and accurate data both on companies' current impacts on nature and the effectiveness of interventions. For example, ecoacoustics can detect the presence of certain species and monitor the impact of company operations on biodiversity,[253] as can new eDNA techniques.[254] Low-cost sensors can provide real-time data on soil health and help farmers curb fertilizer use,[255] and unmanned aerial vehicles can be used to monitor a variety of nature-related variables, including forest health, at a lower cost.[256]

The success and adoption of new databases and sources of primary data could help companies save time and money as they develop nature strategies. Data availability could also ease the implementation of machine learning and AI techniques in the development of more sophisticated, cost-effective nature strategies.

Improve supply chain traceability

As they are starting to do with GHG emissions, customers and regulators could hold companies accountable not only for the impact their direct operations have on nature but also for impact stemming from their suppliers.[257] While supply chain traceability is not a new phenomenon, companies currently have relatively limited visibility into the origin and environmental impacts of their suppliers.[258]

Equipping companies with more information could require a significant investment in new technologies.[259] Improvements in digital traceability could help companies understand where supplies are coming from in near-real time, increasing responsiveness and adaptability.[260] There could also be room for companies to expand the use of internal and third-party sustainability standards, develop partnerships up and down the supply chain, and invest

249 The Taskforce on Nature-related Financial Disclosures assessed the landscape of nature-related data and analytics in June 2022 and found that data coverage differed across nature categories, there was variance in measurement approach, spatial and temporal biases were present in data, and nature-related data were limited in access and relevance. See *A landscape assessment of nature-related data and analytics availability*, Taskforce on Nature-related Financial Disclosures, March 2022.
250 "TNFD launches Nature-related Data Catalyst," Taskforce on Nature-related Financial Disclosures, July 13, 2022.
251 For more, see the Group on Earth Observations' GEOSS portal; *GEO at a Glance*, Group on Earth Observations, accessed November 14, 2022.
252 Gold Standard offers three approaches to quantifying soil organic carbon levels, two of which use modeling rather than data collection. Another example, Nori, a carbon marketplace, uses a USDA standard methodology to model carbon sequestration. See *Soil organic carbon framework methodology*, Gold Standard, January 2020; "High quality carbon credits with process based modeling," Nori, accessed November 14, 2022.
253 Ecological acoustics (ecoacoustics) is the use of auditory data to study biodiversity. Scientists can use sound recording equipment and signal processing software to assess the structure and health of an ecosystem as well as track the impact of different interventions to promote biodiversity. See Dan Stowell and Jerome Sueur, "Ecoacoustics: acoustic sensing for biodiversity monitoring at scale," *Remote Sensing in Ecology and Conservation,* September 2020, Volume 6, Number 3; Monica Evans, "How acoustic ecology offers insight into forest health," *Landscape News*, March 30, 2022.
254 Philip Francis Thomsen and Eske Willerslev, "Environmental DNA – An emerging tool in conservation for monitoring past and present biodiversity," *Biological Conservation,* March 2015, Volume 183.
255 "Low-cost AI soil sensors could help farmers curb fertilizer use," *ScienceDaily*, December 13, 2021.
256 Simon Ecke et al., "UAV-based forest health monitoring: A systematic review," *Remote Sensing*, July 2022, Volume 14.
257 *Digital traceability: A framework for more sustainable and resilient value chains*, World Economic Forum, September 2021.
258 For example, confectionary players have been developing more sustainable and equitable cocoa sourcing strategies since at least the mid-2000s. Newer technologies are less well covered. See Verina Ingram et al., "The impacts of cocoa sustainability initiatives in West Africa," *Sustainability,* November 2018, Volume 10; Laura Sonter et al., "Mining and biodiversity: Key issues and research needs in conservation science," *Proceedings of the Royal Society,* December 5, 2018, Volume 285, Number 1892.
259 "Mining and biodiversity: Key issues and research needs in conservation science," December 5, 2018.
260 *Digital traceability: A framework for more sustainable and resilient value chains*, September 2021.

directly in sustainability improvements within their supply chains.[261] The development of standard measures of nature impact, as outlined earlier in this chapter, would allow for both the comparability and transferability of accountability within supply chains. There is an opportunity to build on systems and standards developed in the climate space. For example, the Partnership for Carbon Transparency (PACT) sets foundations for standardized emissions data exchanges.[262]

Improvements in supply chain traceability present an opportunity. The WEF estimates that there could be a $515 billion business opportunity in transitioning to more transparent and sustainable supply chains.[263] Technologies include QR codes, Internet of Things (IoT) sensor devices, and blockchain, which can be used by corporations to track a product's impacts on natural capital throughout their supply chains.[264] Beyond traceability, the combination of these technologies can offer efficiency improvements and other benefits.[265] Surveys suggest that customers could be willing to pay more for sustainably sourced products.[266]

While new businesses may fill some of this gap by developing new technologies and services, governments could play an essential role in supporting transparent and sustainable supply chains. Local and national governments could help develop global partnerships with key commodity producing regions, release trade data on sourcing for commodities, introduce mandatory procurement-reporting standards, and fund infrastructure for supply chain logistics.[267]

Address the 'green skills gap'

Having access to good data is important, but companies and governments would also need people with the skills to put those data to use in decision making. Unfortunately, a consistent gap in addressing nature-related crises is in skills and capabilities. As outlined earlier, both the NBSAP process and the scaling of NBS suffer from a lack of institutional capacity and expertise, in both governments and the private sector.[268]

This is part of a broader and growing "green skills gap." Green skills include capabilities such as environmental-impact assessment and accounting, ecosystem management, reverse supply chain engineering, green-energy design and installation, and sustainable finance. While demand for green skills has grown 40 percent between 2016 and 2021, supply has lagged globally.[269]

Investment in skills-based training,[270] outreach to potential workers,[271] and coordination between industry and educational institutions to match curriculum to needs[272] could help meet the need for green skills and ensure that both governments and the private sector have the capacity to address the nature crisis. Furthermore, equipping more workers with green skills could help secure jobs, including during a economic downturn.

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[261] *Financing nature*, 2020.
[262] "Partnership for Carbon Transparency (PACT) sets foundations for standardized emissions data exchange," *World Business Council for Sustainable Development*, June 16, 2022.
[263] *The future of nature and business*, 2020.
[264] *Continuous interconnected supply chain: Using Blockchain & Internet-of-Things in supply chain traceability*, Deloitte, 2017.
[265] For example, IoT devices can automatically scan products and add records to the blockchain. See Vishal Gaur and Abhinav Gaiha, "Building a transparent supply chain," *Harvard Business Review*, June 2020.
[266] *Digital traceability: A framework for more sustainable and resilient value chains*, September 2021.
[267] *The future of nature and business*, 2020.
[268] *CBD Information Document on lessons learned*, May 20, 2021; *Accelerating financing for nature-based solutions to support action across the Rio Conventions*, Commonwealth Secretariat, October 2021.
[269] Karin Kimbrough, "LinkedIn global green skills report shows gap between demand and supply of green talent," *LinkedIn Data at Work*, February 22, 2022; Karin Kimbrough, "Building a sustainable future requires 'green' skills," *LinkedIn Pulse*, March 11, 2021.
[270] *Global green skills report 2022*, LinkedIn Economic Graph, 2022.
[271] "Nature-based jobs and skills Action Plan 2022-2023," NatureScot, 2022.
[272] Jonathan Tomkins, "Closing the green skills gap," *IEMA*, May 28, 2021.

Develop high-quality, voluntary nature and biodiversity credits

As businesses consider how best to address their nature footprint, voluntary credits can help them directly invest in the protection, restoration, and regeneration of nature after they have taken measures to avoid and reduce their impact. Currently, businesses that wish to invest in nature-related endeavors have to source projects to fund, requiring substantial investment in developing nature-oriented expertise and diligence resources to ensure that projects are effective and legitimate. The development of high-quality, verified credits could help a broader set of companies invest in nature.[273]

Credits are economic instruments that help fund actions that result in measurable positive outcomes for the environment, such as increases in the volume and variety of species in an area or the overall health of an ecosystem.[274] Credits are bought and sold on a voluntary basis as an investment in the recovery of natural capital and are distinct from offsets, which generally compensate for damage.[275]

A variety of efforts are under way to help develop credits (Exhibit 18). For example, sustainable-development units are available in New Zealand, and voluntary biodiversity credits are helping to fund the conservation of the Bosque de Niebla cloud forest in Colombia.[276] Companies may also combine carbon and nature-related efforts by purchasing carbon credits that promote broader nature-related outcomes, such as REDD+ credits.[277] The overlap between biodiversity-rich areas and areas with high carbon-storage potential is about 40 percent,[278] suggesting an opportunity for nature-focused and carbon markets to link as well as the need for an additional nature-focused marketplace.[279]

While the overall trend in the development of credit projects is positive, companies still face barriers to investment due to differing standards and the variety of outcomes credits can generate. It is not yet easy to determine the right investment. The creation of a widely accepted verification standard, building on efforts already under way,[280] could help companies reliably source high-quality credits on a global scale and would be a major driver for new investment in natural capital.

[273] A nature credit could also help conservation practitioners secure enough sustained funding to ensure effective and durable conservation. While nature-based solutions are a substantial lever for climate change abatement, many conservation projects, including those in marine ecosystems or in forests with low historical rates of loss, have struggled to access meaningful funding.

[274] Ina Porras and Paul Steele, *Making the market work for nature: How biocredits can protect biodiversity and reduce poverty*, International Institute for Environment and Development (IIED), March 2020. Biodiversity credits are used around the world. Nature credits, although not yet common, seek to capture positive outcomes for both living and nonliving elements of nature. Efforts to conserve biodiversity as a whole also benefit nonliving nature, such as soil, water, carbon, and other ecosystem services. See Jeremy S. Simmonds et al., "Limiting the loss of terrestrial ecosystems to safeguard nature for biodiversity and humanity," February 2021; Chris Stone and Michael McGreevey, "Investing in nature: Innovations in conservation finance," Blue Nature Alliance, June 24, 2022.

[275] *Biodiversity credits: Unlocking financial markets for nature-positive outcomes*, World Economic Forum, September 2022.

[276] Ibid.

[277] Sophie Bertazzo, "What on Earth is 'REDD+'?," Conservation International, March 28, 2019.

[278] "Mapping co-benefits for carbon storage and biodiversity," January 2020.

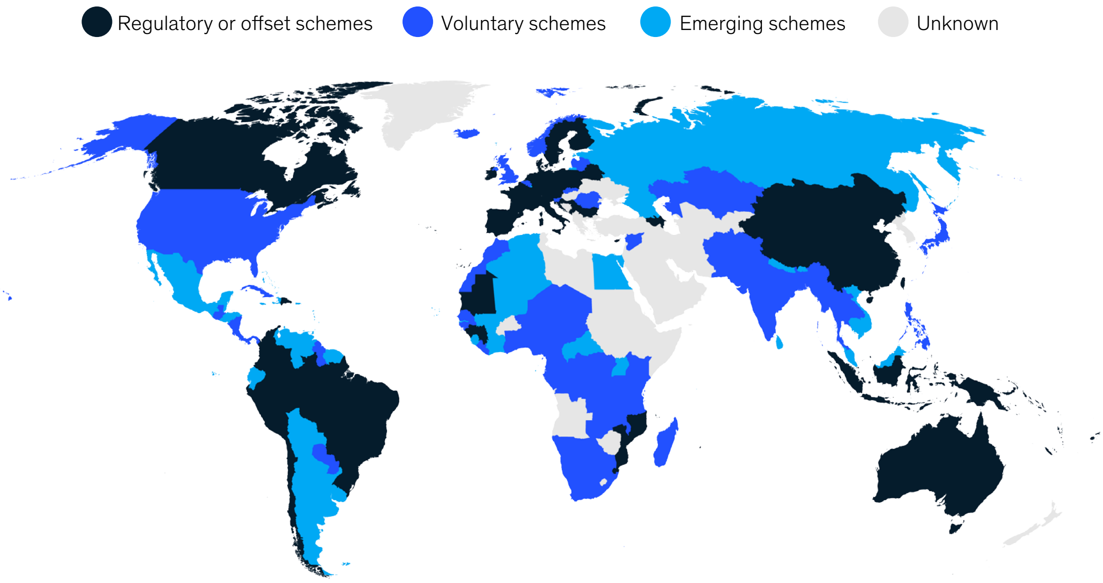
[279] Monica Noon, "Mapping the irrecoverable carbon in Earth's ecosystems," *Nature Sustainability*, November 18, 2021, Volume 5.

[280] *SD Vista – Nature Framework Advisory Group terms of reference*, Verra, August 10, 2022.

Exhibit 18

Credit schemes are gaining momentum around the world.

Select examples



Select examples include:

Eco-Markets Australia (Australia)

Funds Great Barrier Reef water quality improvement projects

LEAF Coalition (Brazil)

Raised $1 billion through Architecture for REDD+ Transactions (ART) credits to preserve biodiverse forests through REDD+ (Reducing Emissions From Deforestation and Forest Degradation in Developing Countries)

Operation Wallacea (United Kingdom)

Early development of a prototype biodiversity credit

South Pole (Australia)

Bundles carbon credits with Australian Biodiversity Units to sell EcoAustralia credits

Note: Voluntary schemes are shown above regulatory schemes where they co-occur. The boundaries and names shown on maps do not imply official endorsement or acceptance by McKinsey & Company.
Source: See bibliography

McKinsey & Company

While the overall trend in the development of credit projects is positive, companies still face barriers to investment due to differing standards and the variety of outcomes credits can generate.

Consider expanding financing and incentives

Financing the transition to a nature-positive future will require more resources than those provided by today's approaches to nature-related finance, many of which are concessionary. A key challenge for corporate action is that 55 percent of the abatement potential we identify in chapter 3 does not generate a positive, near-term return on investment under current assumptions. While companies have many incentives to act, a clear financial rationale is often the most immediate incentive. A range of new financial products, incentives, and ways of thinking would thus be needed to help provide that rationale. This section focuses on four broad enablers that could help drive action on finance for natural capital: reallocating subsidies, revaluing natural capital, redirecting funding flows, and rethinking traditional financial products. At the end of the section, we also include an example for nature-based solutions (see Box 13, "Scaling nature-based solutions").

A broader issue beyond the need for corporate financing options is that additional financing is largely beneficial in helping countries replace the near-term economic benefits generated by exploiting natural resources. For instance, developing countries are looking for financing and support as part of the CBD negotiations before committing to increase their nature-related efforts.[281] Corporate commitments on payment for ecosystem services and credit purchases (covered below) could help, as could financing mechanisms that help countries take advantage of alternative development opportunities (for instance, tourism).[282] The latter approach includes debt-for-nature swaps, in which countries receive debt relief in exchange for conservation commitments (as seen in at least 35 countries[283]), blue bonds to support marine development (as seen in the Seychelles and the Baltic Sea[284]), green bonds (as of 2021, the IFC had issued 178 such bonds in 20 currencies[285]), and project finance for permanence (as seen in Bhutan, Brazil, Canada, Colombia, Costa Rica, and Peru[286]), among many other examples.

Reallocate subsidies

Reallocating subsidies toward activities that benefit the environment would reduce harm, making the overall challenge smaller and helping close the funding gap.

The Paulson Institute estimates that nearly $270 billion in annual funding could be reallocated.[287] If such funds were targeted to support sectors that receive the bulk of such subsidies—agriculture, fisheries, and forestry—it could fundamentally change the calculus on action for those sectors, encouraging broader adoption of levers that may otherwise be ROI negative.

For example, since the 1990s, Switzerland has enacted a series of policy reforms to reduce overall levels of support to farmers. But between 2014 and 2017, direct payments to farmers remained constant. Transition payments to minimize the negative effect on farmers were decreased, while subsidies to promote biodiversity—including landscape quality, production

[281] The African Union and other developing countries are calling on developed countries to commit at least $100 billion annually initially, rising to $700 billion annually by 2030. See "African Union seeks billions in funding to conserve biodiversity," April 6, 2022.
[282] "Valuing nature conservation," September 22, 2020.
[283] Pervaze Sheikh, *Debt-for-nature initiatives and the Tropical Forest Conservation Act: Status and implementation*, Congressional Research Service, July 24, 2018.
[284] "Seychelles launches world's first sovereign blue bond," World Bank, October 29, 2018; "NIB issues first Nordic–Baltic blue bond," Nordic Investment Bank, January 24, 2019.
[285] "What you need to know about IFC's green bonds," World Bank, December 8, 2021.
[286] *Securing sustainable financing for conservation areas*, World Wildlife Fund, June 30, 2022.
[287] *Financing nature*, 2020.

systems, and resource efficiency—increased, resulting in better biodiversity outcomes.[288] Subsidy reforms have been implemented around the world with similar outcomes.[289]

Governments could take immediate action to implement subsidy reforms. For example, they could assess the effects of current subsidies, introduce graduated payments that encourage practices that have positive benefits for nature, and understand how subsidy reform will affect socioeconomic priorities.[290] Companies could play a role in identifying opportunities for reallocating subsidies and engaging with governments to identify pathways to subsidy reform.[291]

Revalue natural capital

Some literature suggests that the world's current economic system does not fully account for the benefits natural capital provides or the harm humanity's actions cause.[292] Companies and governments can potentially internalize the true cost of the depletion of natural capital to encourage positive action in several ways:

Payment for ecosystem services. Ecosystem services are the benefits the natural environment provide for humanity.[293] Payment for ecosystem services (PES) occurs when the beneficiaries or users of an ecosystem service compensate individuals or communities that "provision" or provide the ecosystem services.[294] Today, more than 550 PES programs are active worldwide with between $36 billion and $42 billion in annual transactions. They are primarily the result of government regulations requiring corporate payments or direct government payments.[295]

One of the most notable PES programs currently in place is Costa Rica's Payment for Environmental Services Program. Under this program, landowners receive direct payment for the environmental services that their lands produce—such as watershed services, carbon sequestration, and biodiversity conservation services—when adopting land-use and forest-management techniques.[296] Since its inception, the program in Costa Rica has enrolled more than 1.3 million hectares of land in PES contracts, increased forest cover from 42 percent to 51 percent,[297] channeled $524 million toward nature, and involved 19 Indigenous communities across 300 or more projects. The program has also been successful in driving changes in company behavior, such as encouraging logging and hydroelectric companies to shift operations to less environmentally sensitive areas.[298]

[288] *Reforming agricultural subsidies to support biodiversity in Switzerland*, OECD, 2017.
[289] A few more examples: In areas of Finland, forestry subsidies can only be granted for sustainable timber production, maintaining biological diversity of forests, and for forest ecosystem management activities. In 1986, New Zealand phased out agricultural and fisheries subsidies and assisted industries with transitioning by restructuring loans and generating social-welfare payments. Agricultural subsidy reform had a positive impact on biodiversity by reducing the use of fertilizer and pesticides, decreasing river pollution, and halting land clearance. See "Supported types of work, the Sustainable Forestry Financing Act," Metsakeskus Forest Centre, accessed November 14, 2022; *Subsidy reform and sustainable development: Political economy aspects*, OECD, 2007; *New Zealand: Removal of agricultural and fishery subsidies*, Secretariat of the Convention on Biological Diversity.
[290] *Financing nature*, 2020.
[291] "Businesses are calling for policy ambition," Business for Nature, accessed November 14, 2022.
[292] There are several interconnected market failures: the benefits of natural capital are often public goods that are non-excludable and non-rivalrous, the costs and benefits of nature are external to actors who conserve or destroy nature, and discount rates underestimate the value of long-term ecosystem stability compared with economic returns from short-term natural asset consumption. See *The economics of biodiversity: The Dasgupta review*, February 2021.
[293] There are four primary types of ecosystem services: provisioning, regulating, cultural, and supporting. See "Ecosystem services," National Wildlife Federation, accessed November 14, 2022.
[294] "Policy instrument: Payment for ecosystem services," Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, accessed November 14, 2022; B. Kelsey Jack, Carolyn Kousky, and Katharine R. E. Sims, "Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms," *PNAS*, July 15, 2008, Volume 105, Number 28.
[295] James Salzman et al., "The global status and trends of payments for ecosystem services," *Nature Sustainability*, 2018.
[296] "Payments for Environmental Services Program | Costa Rica," United Nations Climate Change, 2020; Karel Mayrand and Marc Paquin, *Payments for environmental services: A survey and assessment of current schemes*, Unisféra International Centre, September 2004.
[297] Impact may not be entirely due to PES.
[298] Blair Cameron, *Creating a green republic: Payments for environmental services in Costa Rica, 1994–2005*, Princeton University Innovations for Successful Societies, July 2015.

Use of internal costs of losing natural capital to guide decision making. PES programs provide incentives to change behavior and direct funds to actors whose projects and activities preserve natural capital. However, companies do not always have access to PES projects. Companies could instead set internal "costs of nature" to help guide economic decision making and, if implemented in internal accounting as a charge, fund company-led activities to address their environmental footprint.

Many companies already set an internal or "shadow" price for carbon (either per project or for the company as a whole) so that externalities caused by carbon emissions are factored into financial modeling.[299] According to a 2019 survey from the Carbon Disclosure Project, 23 percent of companies use an internal carbon charge and 22 percent plan to do so.[300] Internal carbon fees go one step further: they charge business units for their emissions and use the revenue to support investment in carbon-reduction projects.[301]

A similar process could potentially be extended to include other dimensions of natural capital. Companies can price internal nature-related charges based on the cost of restoring an affected area, the cost of mitigating impacts, the value of ecosystem services lost, or other methods. Some companies have already implemented internal charges on multiple dimensions of natural capital. For example, Colgate-Palmolive has developed an internal True Cost of Water Toolkit to help the company's sites quantify the full cost associated with water usage, including pretreatment and wastewater treatment, and encourage reduced freshwater consumption.[302]

Environmental taxes and fees. Taxes or environmental fees are another well-recognized tool[303] to factor in environmental costs and provide ongoing incentives to act while also allowing consumers and businesses to choose the most cost-effective way to reduce environmental harms and encourage innovation.[304] Funds raised can also be used for environmental activities if they are earmarked for such purposes.[305] Taxes can take many forms, including special taxes, fees, and levies. Together, they could raise $103 billion to $155 billion per year for nature-related efforts, according to one estimate.[306]

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[299] "Carbon pricing: Setting an internal price on carbon," October 14, 2022.
[300] "The state of internal carbon pricing," February 10, 2021.
[301] "Internal carbon pricing," Center for Climate and Energy Solutions, accessed November 14, 2022.
[302] *Colgate Palmolive Company – water security 2021.*
[303] A study of seven emerging economies between 1994 and 2015 showed that an increase in environmental taxes can directly reduce CO_2 emissions. Eyod Mulat-Weldemeskel and Yemame Wolde-Rufael, "Do environmental taxes and environmental stringency policies reduce CO_2 emissions? Evidence from 7 emerging economics," *Environmental Science and Pollution Research*, 2021, Volume 28.
[304] *Environmental taxation: A guide for policymakers*, OECD, 2011.
[305] For example, Trinidad and Tobago has imposed a 0.1 percent tax on all goods sold, raising $400 million from 2001 to 2011 for conservation, remediation, and restoration activities. Chile's 2014 tax reform bill introduced taxes on new-car sales, local contaminants, and CO_2 emitters, raising $190 million in 2017 for biodiversity recovery and climate mitigation and adaptation. See Maurice Rawlins, "The Green Fund of Trinidad and Tobago: Innovative financing," Cropper Foundation, October 2011; "Funds from the National Green Tax to support ecological restoration and nature-based solutions in Chile," WWF, July 2021.
[306] *Financing nature*, 2020.

Redirect funding flows

Public and private financial institutions could also support efforts to tackle nature-related crises by implementing risk management practices to channel funding toward nature-positive activities.[307] The Finance for Biodiversity Pledge shows that there is already momentum toward such efforts,[308] as does the TNFD's efforts to promote nature-related disclosures, which has the backing of 40 institutions with more than $20 trillion in assets.[309]

Financial regulators and central banks could play a role in encouraging financial institutions to act. For example, regulators can require financial institutions to publish reports on the impacts of their lending portfolios on natural capital, regulatory time horizons could be lengthened to better account for anticipated losses and instability of natural capital, and stricter requirements could be implemented on investments that are potentially harmful to nature.[310]

On the international stage, multilateral development banks and international financial institutions may have a particular responsibility. The Ten Point Plan for Financing Biodiversity, recently released by the UK government along with the governments of Ecuador, Gabon, and the Maldives (along with subsequent signatories), calls on these institutions to align their efforts to the CBD, similar to how they have with the Paris Agreement, and to increase funding for nature to developing countries.[311]

Rethink traditional financial products

Finally, new, nature-oriented financial products could be required. While climate finance has expanded significantly, more finance could be needed specifically for natural capital,[312] as well as a potential expansion in the use of green debt products—such as impact bonds, green bonds, low-interest green loans, and sustainability-linked loans[313]—and green-credit facilities, including thematic equity funds and diversified sustainability funds.[314] The Paulson Institute estimates that such green financial products could direct between $31 billion and $93 billion in funds toward companies and projects each year, which could have a positive impact on biodiversity.[315]

[307] There are many avenues to integrate risk assessments into financing decisions, including (1) positive screening; (2) negative screening; (3) environmental, social, and governance (ESG) engagement, activism, and divestment; (4) ESG integration into business as usual risk management processes; and (5) the adoption of norms and standards that address impacts to biodiversity. See *Financing nature*, 2020.
[308] A total of 111 financial institutions managing more than €16.3 trillion in assets have committed to set targets on their impacts on nature. See "Financial institutions launched Finance for Biodiversity Pledge during UN event," Finance for Biodiversity Pledge, September 25, 2020.
[309] TNFD has also adapted its LEAP framework, LEAP-FI, to address actions for financial institutions, including banks, insurance companies, asset managers, asset owners, and development finance institutions. See "The LEAP nature risk assessment approach," Taskforce on Nature-related Financial Disclosures, accessed November 17, 2022.
[310] *Call to action to ensure transition to a net zero and nature positive economy,* World Wildlife Fund, September 2022.
[311] MBDs and IFIs also have a responsibility to allocate funding to less developed countries. See *The 10 Point Plan for financing biodiversity,* UK Department for Environment, Food & Rural Affairs, September 22, 2022.
[312] In 2019, although $271 billion in green bonds were issued, only 1 percent of the total went toward biodiversity conservation. The majority of investment was in projects aimed at GHG emissions reduction. See *Financing nature,* 2020.
[313] Sustainability-linked loans increased in volume by 168 percent in 2019 to a total volume of $122 billion. See *Mobilizing private finance for nature*, September 2020.
[314] Overall, securitized products represented 24 percent of the total green bond market. See *Green bonds: The state of the market 2018*, March 6, 2019.
[315] *Financing nature*, 2020.

Box 13

Scaling nature-based solutions

Scaling up nature-based solutions (NBS) could cut across the financial enablers outlined above. NBS are “actions to protect, sustainably manage, or restore natural ecosystems, that address societal challenges such as climate change, human health, food and water security, and disaster risk reduction” and balance human needs with protecting nature.[1] Payment for ecosystem services (PES) and natural climate solutions are types of NBS. In 2020, funding for NBS reached $133 billion, with public funds accounting for 86 percent of that total and private financing making up the other 14 percent. Projections show that NBS could reach $536 billion per year by 2050.[2]

Scaling NBS, including revaluing nature, mainstreaming new financial products, and redirecting existing flows, could require more work. Barriers to scaling NBS include the need for governments to institutionalize NBS in policy, legislation, and regulations; a lack of standard measures of impact; a still-nascent set of financial products and mechanisms for NBS; limited capabilities; and a limited project pipeline, all of which lead to a reliance on public-sector financing instead of larger-scale private-sector investment. A consistent recognition of NBS by governments across jurisdictions could reduce uncertainty for both investors and developers, clearing the way for greater scale.[3]

[1] *What you need to know about nature-based solutions to climate change*, World Bank, May 19, 2022.
[2] Ivo Mulder et al., *State of finance for nature*, United Nations Environment Programme, 2021.
[3] Barriers collated from multiple reports: *Accelerating financing for nature-based solutions to support action across the Rio Conventions*, Commonwealth Secretariat, October 2021; Erik van Eekelen et al., *Paving the way for scaling up investment in nature-based solutions along coasts and rivers*, EcoShape, May 2021; Graham Watkins et al., *Nature-based solutions: Scaling private sector uptake for climate resilient infrastructure in Latin America and the Caribbean*, Inter-American Development Bank, December 2019.

In the current economic environment, companies face a multitude of challenges, from talent retention to macroeconomic pressures, geopolitical instability, and supply chain challenges, just to name a few. But taking action on nature is not another burden. It could bring tangible benefits to both natural capital and company revenue. Companies could start their journey by understanding their footprint and implementing ROI-positive actions that address both climate and nature capital. Over time, companies could increase the ambition of their targets for nature and potentially build new businesses around the technologies and approaches that can help return the economy to a safe operating space for humanity.

Building a nature-positive economy is not the responsibility of corporate actors alone. It would also require investing in science to better understand the problem and its potential solutions, collaborating to define standards and the right level of ambition as knowledge accumulates, and overcoming a range of technical and financial barriers. It will be a journey, but one that leads to a destination of much greater prosperity and an economy operating within safe limits.

Taking action on nature is not another burden. It could bring tangible benefits to both natural capital and company revenue.

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