McKinsey Global Institute

Authors
Mekala Krishnan
Olivia White
Sylvain Johansson
Sven Smit
Annabel Farr
Kanmani Chockalingam

Editor
Stephanie Strom

December 2025

Advancing adaptation

Mapping costs from cooling to coastal defenses

McKinsey Global Institute

The McKinsey Global Institute was established in 1990. Our mission is to provide a fact base to aid decision making on the economic and business issues most critical to the world's companies and policy leaders. We benefit from the full range of McKinsey's regional, sectoral, and functional knowledge, skills, and expertise, but editorial direction and decisions are solely the responsibility of MGI directors and partners.

Our research is currently grouped into five major themes:

— Productivity and prosperity: Creating and harnessing the world's assets most productively

— Resources of the world: Building, powering, and feeding the world sustainably

— Human potential: Maximizing and achieving the potential of human talent

— Global connections: Exploring how flows of goods, services, people, capital, and ideas shape economies

— Technologies and markets of the future: Discussing the next big arenas of value and competition

We aim for independent and fact-based research. None of our work is commissioned or funded by any business, government, or other institution; we share our results publicly free of charge; and we are entirely funded by the partners of McKinsey. While we engage multiple distinguished external advisers to contribute to our work, the analyses presented in our publications are MGI's alone, and any errors are our own.

You can find out more about MGI and our research at www.mckinsey.com/mgi.

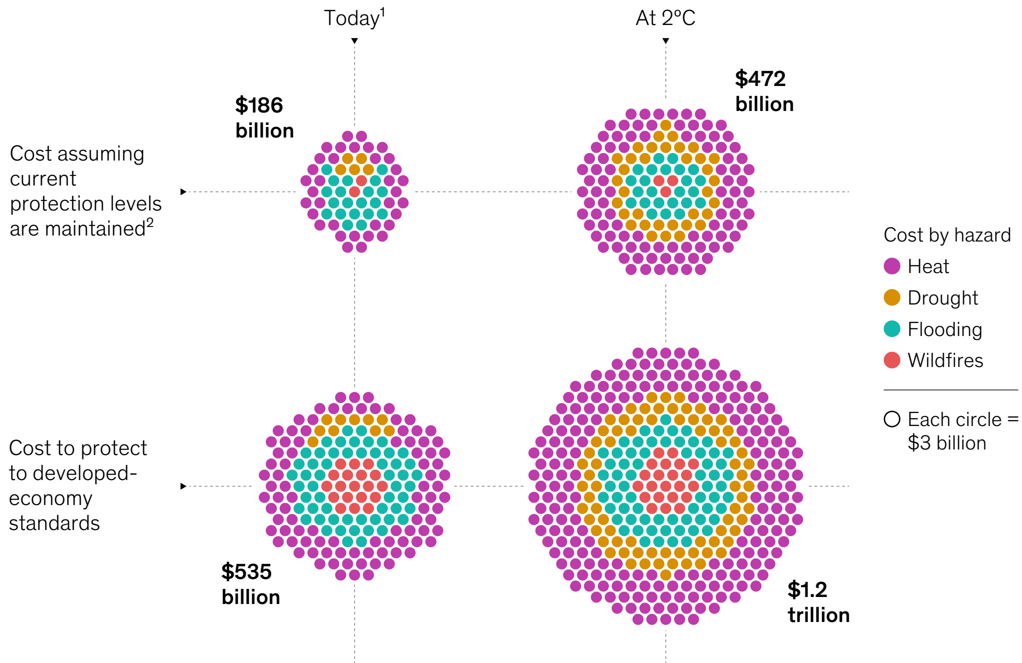
Contents

At a glance

- **Societies have adapted to their climates for millennia.** From the Mesopotamians to the Inuit, extreme weather has shaped how people live. Today, many proven, cost-effective measures to adapt already exist, and we examine 20 of them, ranging from air conditioners to irrigation and sea dikes.
- **The world currently spends $190 billion annually to defend against extreme weather.** This safeguards 1.2 billion people to protection standards in developed economies. Providing that level of protection for all 4.1 billion individuals living in places exposed to climate hazards, who today may face trade-offs and challenges in adapting, would cost $540 billion.
- **As the climate warms, exposure to heat and drought will increase the most.** On current emissions trajectories, the world is expected to warm by 2°C compared with preindustrial levels by about 2050. This could expose an additional 2.2 billion people to heat stress and 1.1 billion more to drought. By contrast, coastal flooding would threaten just 40 million more.
- **At 2°C, maintaining current protection levels would cost 2.5 times today's spending, while protection at developed-economy standards would require 6.2 times as much.** Of the estimated $1.2 trillion needed to achieve such standards globally, more than half would go to air conditioning and irrigation. Increasing spending in line with anticipated economic growth could cover 60 percent of total costs, but gaps would remain in lower-income places.
- **Adaptation is a good buy—but spending is not a given.** At 2°C, its benefits outweigh costs by seven to one, but factors like capacity to pay, competing spending priorities, collective action challenges, operational hurdles, and political will complicate implementation. Going forward, the ability to finance and scale adaptation—and mitigation—as well as the evolution of damages from extreme weather events and the limits of adaptation will determine the risks that societies bear.

At 2°C, maintaining current protection costs 2.5× today's spending, and protecting to developed-economy standards costs 6.2× as much.

Average annual operating and amortized capital costs to adapt to hazards, 2020–50 (2020 dollars)



Note: This analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to reach 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures). Costs are for 20 adaptation measures used to protect against 4 categories of hazards: heat, wildfires, drought, and flooding. See technical appendix for hazard definitions. This analysis relies on existing and established climate models and techniques, including from the sources below.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Assumes current level of adaptation spending relative to total spending to adapt to developed-economy standards at 1.1°C, by hazard and demographic group, stays the same at 2°C.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

Introduction

For millennia, economies and societies have adapted to their local climates. Mesopotamian civilizations developed extensive irrigation systems to combat drought and sustain agriculture starting about 8,000 years ago. In what is now the Netherlands, people began building artificial mounds known as *terpen* more than 2,000 years ago to defend against floods. A thousand years ago, the Thule people of the Arctic began building snow-block igloos, enabling survival in outdoor temperatures less than –45°C. In ancient Egypt, builders mastered passive cooling techniques like thick mud-brick walls and windcatchers to cope with blistering desert temperatures that could exceed 45°C.

Today, tried-and-true measures exist to protect against a range of hazards, from extreme heat to frigid cold and from crippling droughts to devastating floods. For instance, the Netherlands maintains the extensive and advanced Delta Works—a series of dams, sluices, locks, dikes, and storm surge barriers designed to protect against recurring flooding.[1] Lee Kuan Yew, the first prime minister of Singapore, credited air conditioning as the key to the country's success, saying in an interview, "Air conditioning was a most important invention for us, perhaps one of the signal inventions of history. It changed the nature of civilization by making development possible in the tropics."[2]

Yet the world has a resiliency gap. We are not all protected from today's extreme weather patterns, even before considering prospective climate change. About one billion people are protected by at least one of 20 commonly used adaptation measures, while three billion others remain unprotected.[3] Not surprisingly, gaps are wider in low-income places, although about 700 million people who lack protection do live in higher-income areas. As the global temperature climbs, the pattern and occurrence of hazards will shift, changing adaptation needs.

Advancing our understanding of adaptation both today and in the future is therefore essential. Ultimately, individuals, governments, and companies decide whether to adapt, based on multiple considerations ranging from capacity to spend and risk tolerance to political will and operational feasibility. Yet spending on adaptation isn't simply a matter of having available funds. Rather, it is how resources are prioritized to address competing demands including the energy transition, municipal services, and household expenses. Informed decisions about adaptation begin with identifying current resilience gaps, anticipating how they may evolve, and determining what is needed to protect against hazards now and as they shift.

To be sure, explicit adaptation planning has increased recently. As of October 2025, 141 countries had a formal adaptation plan, up from 84 countries five years ago.[4] But only a fraction map out clear priorities and include cost estimates.[5]

In this report, we undertake a first-of-its-kind comprehensive analysis of adaptation costs today and through 2050, using a granular, pixel-level, geospatial analysis.[6] The 20 adaptation measures we studied offer broad-based protection against four categories of hazards—heat, wildfires, drought, and flooding—and can be applied across diverse economies. Equipped with an understanding of how hazards could play out and the costs and benefits of adapting to them, leaders can make informed decisions about resilience today and for the long term.

As with all climate modeling, some caveats are in order. Climate modeling is an area of live refinement and debate and, like any modeling of complex phenomena, carries uncertainties. We aren't climate scientists, so we rely primarily on external climate models used in the sixth assessment report by the Intergovernmental Panel on Climate Change (IPCC).[7] We also do not examine all hazards, types of places, sectors, and categories of impact—such as impact on small island nations, biodiversity, and supply chains—that could require adaptation measures beyond our scope.[8] Instead, our findings aim to provide an order-of-magnitude analysis to help inform decision-making for different demographic groups and regions.


8
7

CHAPTER 1

The world today spends $190 billion annually to defend against extreme weather

About 40 percent of Earth's landmass periodically experiences severe heat, destructive wildfires, prolonged drought, and intense flooding rooted in current patterns of weather extremes.[9] This area is home to roughly four billion people, nearly half the global population.[10] These extreme weather events, which we call "climate hazards," can occur only rarely or can take place every year, and they are likely to span more of the planet and intensify in some places as the world warms. An additional 35 percent of the world's terrain experiences extreme cold, which could decline as the global temperature increases (see sidebar "The hazards we examine").

Individuals, governments, and companies currently spend about $190 billion on capital and operating expenses in total each year for protection against heat, wildfire weather (also referred to as "wildfires" in this report), drought in agricultural areas (referred to as "drought" in this report), and flooding (see sidebar "What about cold?").[11] This investment provides at least some protection to 1.2 billion people and their livelihoods around the world.[12]

Yet an additional three billion of the world's citizens are not protected from extreme weather, bearing the risk from these hazards.[13] These people face what we call a "resiliency gap," the difference between their current protection and the standards typically established in developed economies today. Not surprisingly, such standards are not always followed, and even wealthy urban areas have a small resiliency gap.

Even though the hazards in the four categories are considered meaningful enough to protect against, they are not all created equal, and their impact can be very different. Consider two forms of heat. What we call "heat stress" is defined as a period of more than a month of very hot and humid weather annually, reducing productivity and possibly harming health.[14] "Heat waves" are rarer and briefer—at least a week of locally high temperatures.[15] While such conditions can pose real risks, especially to vulnerable populations, they don't occur every year and are of relatively short duration when they do, often with lower overall impact than heat stress events.[16]

When resiliency gaps do exist, they may reflect an explicit choice to accept risk, such as when a person makes the choice to build a home in a wildfire or flood zone. In other cases, factors like imperfect information, political deadlock, and lack of finances dictate the level of risk taken. Whatever the reasons for gaps in protection, what would it cost to close them and protect the three billion people living with risk today?

Sidebar

The hazards we examine

We analyze eight types of hazards across four categories—heat, wildfires, drought, and flooding—to understand how people and places are exposed to them today and going forward, and analyze the costs to adapt. Separately, we also look at how cold might evolve.

While hazards are often described as "extreme weather events," in climate science the term refers to broadly both *chronic* and *acute* hazards. Two hazards we examine, heat stress and wildfire weather, are chronic and happen every year in the places that are exposed to them. The remaining six hazards we analyze—coastal flooding, riverine (fluvial) flooding, flooding caused by excessive rainfall (pluvial), heat waves, nonsurvivable heat, and drought in agricultural areas—are acute, meaning they are intense but rare events. For acute events, places may be exposed to them, but the actual event may not manifest every year.

These hazards can occur along a continuum of intensity, frequency, or duration, requiring a threshold for each in order to define the hazard. Thresholds can be established in various ways. Since our focus is on understanding and quantifying adaptation costs, we define them by drawing on protection standards commonly established in developed economies. Of course, even though the hazards we examine are considered meaningful enough to protect against, not all hazards are created equal, and their impacts could be very different. Heat stress, defined as more than a month of very hot and humid conditions each year, and heat waves, rare, multiday occurrences of local temperature extremes, can differ markedly in the nature and magnitude of their impacts, but both are considered important enough to warrant protection. Similarly, coastal flood protection standards in developed economies typically aim to withstand a one-in-100-year flood event, while pluvial flood protection standards often correspond to a one-in-20-year flood event.

Because protection standards are not always strictly defined, we exercised some judgment in our choice of thresholds and further validated them using literature from the Intergovernmental Panel on Climate Change (IPCC) on typical hazard definitions and their impacts (exhibit).[1] Continued efforts are needed to develop robust and comparable ways to quantify the impact of hazards and their link to adaptation metrics.

Naturally, impacts do not begin to appear only when a particular threshold is crossed. Rather, our thresholds are a way to dimensionalize exposure and protection levels and apply a consistent approach in line with typical design standards for protection.[2] We focus on a subset of climate hazards that meet three criteria: (1) they have a well established and direct link to climate change as the primary driver; (2) they are not slow-onset events, the impacts of which emerge over time; and (3) they have sufficient data to enable spatial analysis.[3]

For example, the link between water stress and climate change is not direct, since other factors, particularly population growth and rising demand for water, are at play.[4] While these and other hazards may be highly relevant for adaptation planning in any given location, they fall outside the scope of our global analysis. See the technical appendix for more details.

[1] We validated hazard thresholds with IPCC-referenced literature including, for heat stress, Camilo Mora et al., "Global risk of deadly heat," *Nature Climate Change*, July 2017, Volume 7; for heat waves, Alessandro Dosio et al., "Extreme heat waves under 1.5 °C and 2 °C global warming," *Environmental Research Letters*, May 2018, Volume 13, Number 5; and Cong Yin et al., "Changes in global heat waves and its socioeconomic exposure in a warmer future," *Climate Risk Management*, 2022, Volume 38; for nonsurvivable heat, Eun-Soon Im, Jeremy S. Pal, and Elfatih A. B. Eltahir, "Deadly heat waves projected in the densely populated agricultural regions of South Asia," *Science Advances*, August 2017, Volume 3, Number 8; for wildfires, John T. Abatzoglou, A. Park Williams, and Renaud Barbero, "Global emergence of anthropogenic climate change in fire weather indices," *Geophysical Research Letters*, January 2019, Volume 46, Number 1; for drought, Yadu Pokhrel et al., "Global terrestrial water storage and drought severity under climate change," *Nature Climate Change*, March 2021, Volume 11; for coastal flooding, Robert J. Nicholls et al., "A global analysis of subsidence, relative sea-level change and coastal flood exposure," *Nature Climate Change*, April 2021, Volume 11, Number 4; and for riverine and excessive rainfall flooding, Jun Rentschler, Melda Salhab, and Bramka Arga Jafino, "Flood exposure and poverty in 188 countries," *Nature Communications*, June 2022, Volume 13.

[2] In some cases, thresholds are based on local parameters, namely the intensity of locally extreme events. For example, we have defined exposure to drought in line with literature from the IPCC reflecting a local minimum in moisture in the soil, rather than an absolute measure of soil water content. This approach reflects the fact that agricultural activity depends on local climatic conditions and that changes relative to these conditions are most relevant for guiding adaptation responses. Exposure to heat stress, by contrast, is based on absolute physiological thresholds related to human productivity loss; this is because here, too, it is these thresholds that determine when an adaptation response becomes necessary.

[3] Because this work excludes slow-onset risks such as saline intrusion, we acknowledge that this excludes the coverage of key risks in some geographies, including risks for which there may be hard limits around 2°C, such as communities on small islands at risk of freshwater shortages. See "Key risks across sectors and regions," Table 16.3, in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022.

[4] See discussion in International Panel on Climate Change Sixth Assessment Report Working Group I Climatic Impact-Driver framework (see AR6 WGI chapter 12, §12.2) and Jacob Schewe et al., "Multimodel assessment of water scarcity under climate change," *Proceedings of the National Academy of Sciences*, March 2014, Volume 111, Number 9.

Sidebar (continued)

The hazards we examine

Exhibit

We examine chronic and acute hazards the world experiences today.

Hazard	Definition
HEAT • **Heat stress**	At least a month's worth of hot and humid or dry heat conditions, in an average year
• **Heat waves**	A 5% (1-in-20-year) likelihood of at least 7 consecutive days of locally defined high temperatures by today's standards
• **Nonsurvivable heat**	A 1% (1-in-100-year) likelihood of at least a day of extremely high, humid heat
FREEZING DAYS	At least a month's worth of below-freezing temperatures in an average year
WILDFIRES	At least 2 weeks' worth of hot, dry, windy weather that can fuel large wildfires in an average year
DROUGHT	A 5% (1-in-20-year) likelihood of at least half a year of unusually dry conditions by today's standards
FLOODING • **Excess rainfall**	A 5% (1-in-20-year) likelihood of a flood event causing at least 15cm of inundation
• **Riverine**	A 1% (1-in-100-year) likelihood of a flood event causing at least 50cm of inundation
• **Coastal**	A 1% (1-in-100-year) likelihood of a flood event causing at least 50cm of inundation

Note: See technical appendix for details.
Source: McKinsey Global Institute analysis

McKinsey & Company

Proven, cost-effective measures exist to protect against extreme weather

Humanity has the know-how to defend itself against extreme weather, at least in principle. Many approaches, or what we refer to as "adaptation measures," already protect against such patterns of weather. We examine 20 measures that are cost-effective, are broadly applicable in diverse economies, and protect widely against the four categories of hazards we analyzed (see end of this document for "Library of adaptation measures"). Examples range from large-scale measures that protect many people and require coordination and collective action, such as sea dikes to prevent coastal flooding and stormwater networks to divert heavy rainfall and surface water flooding, to measures that individuals and companies can adopt, such as air conditioning and fans that reduce heat impacts. (Other adaptation measures and approaches exist; see sidebar "What is adaptation, and what are its limits?")

These measures are at work today in myriad places around the world. Air conditioners, for example, are a commonly used cooling solution. In places affected by heat stress, an estimated 100 million air-conditioning units shield about 340 million people, primarily in high-income regions. Other heat protection measures are in use in some places. In Dubai, for example, centralized district cooling systems deliver cool air to residential and commercial buildings, while Spain has implemented a localized heat wave protection alert system.[17]

Sidebar

What about cold?

As global temperatures warm, the number of freezing days is expected to drop. In some cases, this could bring benefits. Cold increases the risk of illness and death, damages crops, and hobbles transportation systems. For example, some estimates suggest that almost 70 cold-related excess deaths per 100,000 people occur globally every year, a figure that will likely decrease as freezing days become less common.[1] Of course, fewer freezing days may also bring risks such as diminishing glacial freshwater supplies and thawing permafrost.[2]

Many regions encountering freezing days, at least one month a year with average temperatures below 0°C in our analysis, have adapted. For example, Montreal, Canada, has built heated tunnels and subways, snow-plowing systems, and a power grid designed to withstand prolonged cold.[3] Individual homes also have thick insulation and effective heating.

Our analysis finds that at 2°C by 2050, about 3 percent of land that currently experiences freezing days is expected not to have them. The population living in affected places is expected to fall by about 20 percent from 1.2 billion people today to roughly 1 billion—even accounting for anticipated population growth—as the number of very cold days falls. Moreover, those who continue to experience freezing days may face them for shorter durations, and we estimate that spending on heating could decline by 25 to 35 percent on average globally.

1 Qi Zhao et al., "Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: A three-stage modelling study," *Lancet*, July 2021.

2 *Climate Change 2021: The Physical Science Basis*, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, August 2021; and *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, Intergovernmental Panel on Climate Change, Cambridge University Press, 2019.

3 "After 1998: A more robust grid," Hydro-Québec, February 1998; "Montréal's Underground City: How to explore the network of corridors," Tourisme Montréal, October 2024; "Snow removal," Ville de Montréal, accessed November 21, 2025; and "About Énergir urban heating and cooling," Énergir Chaleur et Climatisation Urbaines, accessed November 21, 2025.

Sidebar

What is adaptation, and what are its limits?

In this research, "adaptation" refers to measures that protect against patterns of extreme weather, both those experienced today and those expected with climate change.[1] It differs from disaster response and recovery, which address the aftermath of extreme weather events, and from risk transfer such as insurance, which shifts financial loss. While adaptation is sometimes used interchangeably with "resilience" in research literature, resilience is also used more broadly to describe the capacity to absorb shocks, adjust, and recover.[2]

Adaptation reduces risk by limiting vulnerability or exposure.[3] This can be achieved through both targeted adaptation projects and embedding resilience considerations into broader investments, for example, infrastructure projects like constructing new buildings to be flood resilient.

Vulnerability is reduced through physical, behavioral, and operational actions, such as building seawalls, installing irrigation systems, and shifting work schedules. Exposure is reduced by keeping people and assets out of harm's way, for instance through planned relocation of homes and careful zoning of new development.[4] It could also involve diversifying economic activity like tourism away from at-risk regions, shifting agricultural activity to more suitable places, and taking advantage of new opportunities provided by a changing climate.

Adaptation measures can be sector specific, such as the use of cold-chain logistics in food supply chains and sediment control for floods in mining. Or they can cut across sectors, offering broad protection. Examples of such cross-cutting measures include levees, flood proofing, and air conditioners.

This research focuses on 20 such commonly used, cross-cutting adaptation measures that apply in diverse economies. Most of these measures primarily reduce vulnerability. They offer broad-based protection, but of course they don't safeguard against all potential impacts. Certain hazards, types of places, sectors, and categories of impact, such as impact on small island nations, biodiversity, and supply chains, may require adaptation measures beyond our scope.[5]

Adaptation is often assessed through a cost-benefit analysis. Benefits are typically measured as avoided damages, though many actions bring co-benefits such as higher yields and improved food security. In our analysis, we assess benefit-to-cost ratios based solely on avoided damages. However, other studies may account for additional types of benefits in their evaluations.[6]

Despite the cost-effectiveness of many adaptation measures in terms of benefits exceeding costs, some responses risk maladaptation, when efforts to improve protection inadvertently create new vulnerabilities or negative consequences.[7] Uncertainty in climate predictions can also cause maladaptation, such as overbuilding

---

1 The IPCC defines adaptation as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities." See "Glossary," in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022.

2 Sara Mehryar, "What is the difference between climate change adaptation and resilience?," Grantham Research Institute on Climate Change and the Environment, September 2022.

3 Other prominent groups have developed frameworks to describe the mechanisms through which adaptation reduces risk. See, for example, the Emirates Framework for Global Climate Resilience (UAE Framework) for global climate resilience, adopted at the United Nations Climate Change Conference in December 2023; *Climate Change 2022: Impacts, Adaptation, and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022; "Climate bonds resilience taxonomy," Climate Bond Initiative, May 2025.

4 "Reducing exposure" aligns with the concept of transformational adaptation, which is defined as measures that reduce the root causes of vulnerability to climate change. See "Decision-making options for managing risk," in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022; and "Cities, settlements and key infrastructure," in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022.

5 Many studies show that impacts of hazards can cascade through supply chains and that practical adaptation measures exist. For example, firm-level evidence finds that extreme heat at supplier locations lowers suppliers' productivity; drought in producing states reduces interstate exports and downstream food manufacturing; and flooding, as in Thailand in 2011, can disrupt automotive and electronics networks. Supply chain resilience can be achieved through the 20 adaptation measures analyzed in our study, but other measures also exist. These include strategies such as multisourcing, maintaining inventory buffers and strategic reserves, securing capacity reservations, adopting flexible contracts, improving logistics planning, and relocating facilities to areas with lower exposure risks. See Nora M. C. Pankratz and Christoph M. Schiller, "Climate change and adaptation in global supply-chain networks," *The Review of Financial Studies*, 2024, Volume 37, Issue 6; Hyungsun Yim and Sandy Dall'erba, "Impact of extreme weather events on the U.S. domestic supply chain of food manufacturing," *Proceedings of the National Academy of Sciences*, October 2025, Volume 122, Issue 41; Masahiko Haraguchi and Upmanu Lall, "Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making," *International Journal of Disaster Risk Reduction*, 2015, Volume 14, Part 3; and Ying Guo et al., "Supply chain resilience: A review from the inventory management perspective," *Fundamental Research*, March 2025, Volume 5, Number 2.

6 Harald Heubaum et al., *The triple dividend of building climate resilience*, World Resources Institute, version 1.0, November 2022.

7 Examples of maladaptation include expanding irrigation without accounting for basin-level water availability and competing demands, which can exacerbate water scarcity, or building a seawall or flood defense in one area that inadvertently pushes flooding to another location. Another example is increasing reliance on air conditioning without addressing the emissions from energy use and refrigerants. Air conditioning contributes an estimated 1,950 million tons of CO_2-equivalent per year (3.94 percent of global greenhouse gas emissions). See Jason Woods et al., "Humidity's impact on greenhouse gas emissions from air conditioning," *Joule*, April 2022, Volume 6, Number 4.

Sidebar (continued)

What is adaptation, and what are its limits?

irrigation systems for projected droughts that do not materialize.[8] Trade-offs must therefore be carefully weighed when implementing adaptation measures, and risks effectively managed.

Adaptation also faces soft and hard limits. Soft limits arise from financial or logistical barriers that affect implementation, while hard limits occur when hazards exceed protective capacity. According to the Intergovernmental Panel on Climate Change (IPCC), at 1.5°C, small islands may face hard limits resulting in freshwater shortages, while at 2°C, coral reefs in East Africa could experience widespread bleaching.[9] Beyond 2°C, both types of limits increase, threatening biodiversity, water security, and coastal settlements worldwide.[10] The IPCC also highlights that risks of local biodiversity losses and species extinction are meaningfully lower at 1.5°C compared with a 2°C warmer world.[11]

8 Because climate projections involve significant uncertainty, adaptation strategies in areas of high uncertainty should prioritize flexibility, reversibility, and the ability to adjust over time rather than optimization for a single predicted outcome. Overcommitting to one climate scenario—such as building permanent infrastructure for an anticipated drought—can increase long-term vulnerability if conditions unfold differently. See Stéphane Hallegatte, "Strategies to adapt to an uncertain climate change," *Global Environmental Change*, May 2009, Volume 19, Number 2. For more details on how we address uncertainty in climate modeling, see the technical appendix.

9 See "Small islands," in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022; and "Key risks across sectors and regions," Table 16.3, in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022.

10 "Key risks across sectors and regions," Table 16.3, in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022.

11 Ove Hoegh-Guldberg, et. al., "Impacts of 1.5°C Global Warming on Natural and Human Systems," chapter 3 in *Global Warming of 1.5 °C*, Intergovernmental Panel on Climate Change, 2018.

Adaptation in action

Undergrounding power lines to reduce wildfire risk in Australia

In 2009, the "Black Saturday" bushfires swept through the Australian state of Victoria, killing 173 people and causing widespread damage. Investigations found that power lines sparked many of the worst fires. In response, the state launched the Powerline Bushfire Safety Program in 2011. Its goal was to stop power lines from sparking on hot, windy days.

Victoria prioritized undergrounding for sections that posed the highest risk. Crews dug trenches along roadsides and installed underground cables, replacing bare overhead wires that could hit branches or flap in the wind. In total, utilities moved more than 500 kilometers of power lines underground.

Undergrounding is highly effective but too costly to apply everywhere. For remaining overhead lines, the state added fast-acting shutoff devices and insulated high-risk sections to cut spark risk. Laying power lines underground, combined with insulating overhead lines, is estimated to have cut the chance of ignition in treated places by more than 98 percent.

Beyond the grid, Victoria conducts planned burns to manage vegetation and reduce fuel. Together, these steps can lessen the chance that power lines will ignite major fires and can reduce the strength and spread of those that do occur.[18]

Adaptation in action

Implementing a heat action plan to save lives in India

Ahmedabad, home to seven million people in western India, endured a deadly heat wave in May 2010 that caused more than 1,300 deaths. In 2013, the Ahmedabad Municipal Corporation launched South Asia's first city heat-health action plan. A color-coded early-warning system tied to national forecasts triggers clear public messages, opening of extra cooling and hydration rooms, hospital readiness measures, and priority electricity for key sites.

More recently, the city has been working to cut indoor heat with low-cost "cool roofs." A pilot project in 2017 and 2018 painted the roofs of about 3,000 low-income households, and in 2020, the city announced plans to paint the roofs of about 15,000 homes in informal settlements and 1,000 municipal buildings. Longer hot spells will keep testing the city, so Ahmedabad is adding upgrades such as cooled bus stops and reflective roofs on busy bus shelters.[19]

Adaptation in action

Restoring mangroves to reduce flooding in Brazil

Frequent flooding has caused coastal erosion in Rio de Janeiro's Guanabara Bay, threatening homes and infrastructure along the water's edge. To reverse this, local organizations including Guardiões do Mar and Instituto Mar Urbano began restoring the mangrove forest in 2021, rebuilding a living buffer to slow storm surge, stabilize the coast, and protect the people and assets there.

By 2024, crews had planted more than 30,000 mangrove seedlings on 12 hectares, the largest community-led effort in the bay in more than a decade. Monitoring shows that about 90 percent of the seedlings mature into trees, reaching as high as four meters and spreading along the once-eroded shoreline. While a major coastal flood hasn't yet tested the restored mangroves, studies of similar environments indicate that healthy and mature mangroves can reduce wave energy, stabilize sediment, and curb erosion, helping to protect coastal areas from flooding.[20]

The adaptation measures we studied confer benefits, measured as the value of avoided economic damages, that outweigh their costs by at least a factor of 1.5 on average globally.[21] Many measures may also yield benefits beyond avoided damages, such as irrigation that can both protect against damages from drought and boost agricultural yields, and urban tree planting that cools with shade and can also enhance the quality of city life.[22]

Measures vary in the protection they offer. Some adaptation measures offer significant protection against their target hazard. For example, when well designed and effectively implemented, levees and stormwater networks ensure that daily life and work continue, infrastructure and real estate are unharmed, and natural capital like crops and livestock is unaffected by the scale of events those measures protect against. Other measures address a meaningful portion of the impacts, but not all. For instance, natural defenses like mangroves can reduce the impact of storm surges but do not prevent all flooding.[23]

The resiliency gap is more than three times larger in low-income areas than in high-income ones

Each city, town, and rural area is unique in its built environment and topography, as well as in the details of its extreme weather patterns and in how it experiences and adapts to them. For instance, heat stress could make it difficult for rural smallholder farmers to work while the productivity of workers in air-conditioned offices in high-income cities is unaffected. Just as all politics is local, so, too, is all adaptation.

To capture the local dynamics of exposure and vulnerability to hazards globally, we divide the world into pixels of one square kilometer and then group them into nine demographic groups based on income levels and degree of urbanization (see sidebar "Our research methodology").[24] We then examine how pixels in each group are exposed to various extreme weather events similar in magnitude to those that developed economies often protect against today. We identify places currently protected against such events and where resiliency gaps remain for eight specific hazards spanning heat, wildfires, drought, and flooding.[25] Two hazards, heat stress and wildfire weather, are chronic and happen every year in the places that are exposed to them. The remaining six, coastal flooding, riverine (fluvial) flooding, pluvial flooding caused by excessive rainfall, heat waves, nonsurvivable heat, and drought in agricultural areas, are acute. They are intense but rare, and places exposed to them may not experience one every year.

Learn about adaptation measures
Library of adaptation measures examines 20 proven, cost-effective ways the world protects people and economic activity from hazards.

Sidebar

Our research methodology

This research estimates global protection needs and adaptation costs to manage impacts from extreme weather events today and at 1.5°C and 2°C. Various estimates suggest that by roughly 2030, the global, multidecadal mean surface temperature would rise to 1.5°C above preindustrial levels on a path to warm to 2°C by about 2050, with further warming anticipated beyond that time frame.[1] Since some adaptation measures take more than a decade to implement, anticipating needs at least for 2050 and a 2°C world now is prudent, even as the world works to reduce emissions.[2] Based on this analysis, when we refer to 1.5°C or 2°C, we consider a scenario where such temperatures are reached by 2030 and 2050, respectively.

We are not climate scientists and so use external climate models to examine how hazard patterns could evolve globally. Our approach uses models from the Coupled Model Intercomparison Project Phase 6 (CMIP6), which underpin much of the Intergovernmental Panel on Climate Change's Sixth Assessment Report (AR6), downscaled using NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP).[3] We also leverage resources from the Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP 2b) and Fathom.[4]

Climate modeling is an area of active refinement. Many uncertainties remain: the trajectory of future emissions, natural variability that can obscure long-term trends, and differences in how models represent complex physical processes. To manage this, we apply standard techniques such as using ensembles of models and multiyear averages, though of course such techniques do not fully address the underlying uncertainties and complexities.[5]

We map hazard "footprints" onto global population and GDP grids at roughly one-square-kilometer resolution, creating 130 million pixels worldwide.[6] These are sorted into nine demographic groups by income level and urbanization to capture the local dynamics of adaptation decisions. To align demographic and climate data, we link warming levels to approximate years: 1.1°C to 2020, 1.5°C to 2030, and 2°C to 2050, consistent with current emissions

1 We assessed 25 current-trajectory emissions scenarios, based on policies announced or implemented, from the IPCC, NGFS, and IEA to reflect the wide range of climate estimates. These scenarios suggest that 1.5°C of warming relative to preindustrial levels would be reached somewhere between 2025 and 2035, when warming is measured as a 20-year average centered on a given year and relative to a preindustrial average. In 2030, temperatures under the 25 scenarios range from 1.45°C to 1.55°C. In the IPCC scenarios, the median level of warming by 2050 is 2.0°C, and in the more recent NGFS and IEA scenarios, it is 2°C. By 2100, the temperature estimates from the same set of models are 3.0°C (average across IPCC scenarios, with a maximum of 3.7°C), 2.9°C (NGFS and IEA Current Policies), and 2.5°C (IEA Stated Policies). The IPCC and NGFS scenarios are based on the assumption that currently announced policies are preserved. For NGFS, this covers national climate policies that were legislated and supported by instruments as of March 2024. For IPCC scenarios, the specific policies reflected vary by model. The IEA Current Policies scenario (2025), by contrast, considers only policies already adopted in legislation and regulation, assuming no future changes, even where governments have indicated their intention to do so, and takes a cautious perspective on the pace at which new energy technologies are deployed and integrated into the energy system. The IEA Stated Policies scenario draws on a wider interpretation of the policy environment, incorporating not only enacted measures but also formally proposed ones and other official strategy documents that signal the intended policy direction. For details, see IEA, *World Energy Outlook 2025*, November 2025.

2 Moreover, some measures implemented today—for example, stormwater networks—can have multiple-decade lifetimes, making it prudent to consider how hazards could evolve a few decades out, to avoid costly retrofits down the road.

3 Models used are ACCESS-CM2, ACCESS-ESM1-5, CNRM-ESM2-1, EC-Earth3, GFDL-ESM4, IPSL-CM6A-LR, MIROC6, MPI-ESM1-2-HR, MRI-ESM2-0, and NorESM2-MM. For more details on climate model ensemble selection and downscaling, see the technical appendix. See Veronika Eyring et al., "Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization," *Geoscientific Model Development*, March 2018; NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6), NASA, February 2025; and NASA Earth Exchange, NASA Ames Research Center.

4 Global Flood Map, Fathom-Global 3.0, Fathom, June 2025; and ISIMIP2b, Inter-Sectoral Impact Model Intercomparison Project, June 2025.

5 For more on the uncertainties in climate models, see David Stainforth, *Predicting Our Climate Future: What We Know, What We Don't Know, and What We Can't Know*, Oxford University Press, 2023. Additionally, the Earth Virtualization Engines (EVE) initiative was established on the premise that existing climate model ensembles do not adequately represent future behavior. Its objective is to continually expand, quality-control, and update a data space with small ensembles of kilometer-scale multidecadal global climate projections, juxtaposed with larger ensembles at coarser granularity. See Bjorn Stevens et al., "Earth Virtualization Engines (EVE)," *Earth System Science Data*, April 2024.

6 Hazard modeling was undertaken at varying levels of resolution: heat and wildfires, 25 kilometers; drought, 50 kilometers; flooding, one kilometer. We built a database of population and GDP data at a resolution of one square kilometer to model exposure, using these sources: Matti Kummu, Maija Taka, and Joseph H.A. Guillaume, "Gridded global datasets for gross domestic product and Human Development Index over 1990–2015," *Scientific Data*, February 2018; Global Human Settlement Layer database, European Union, accessed June 1, 2024. We defined demographic groups using the current thresholds of income groups and urbanization levels from the World Bank. Low-income regions have GDP per capita less than $4,000, middle-income regions have GDP per capita ranging from $4,000 to $12,000, and high-income areas have GDP per capita exceeding $12,000. Population in cities exceeds 1,500 people per square kilometer and more than 50,000 people in total, while towns have a population density between 300 and 1,500 people per square kilometer and total population of more than 5,000. All other areas are rural. For population projections at the one-square-kilometer level, we relied on the medium-fertility variant from the UN *World Population Prospects* and differentiated population growth between rural and urban areas using country-level data on urban population shares from the UN *World Urbanization Prospects* (2018). For GDP projections, we used SSP2 projections from Tobias Geiger et al., "Continuous national gross domestic product (GDP) time series for 195 countries: Past observations (1850–2005) harmonized with future projections according to the Shared Socioeconomic Pathways (2006–2100)," *Earth Systems Science Data*, April 2018, Volume 10, Issue 2.

Since our analysis focuses on the primary impacts of drought on agricultural crop yields—occurring mainly in rural areas, though sometimes extending to nearby towns—we scale drought exposure according to the proportion of each grid cell classified as cropland in those areas. Cropland is identified using the European Space Agency (ESA) Climate Change Initiative (CCI) Plant Functional Type (PFT) data set at a 300-meter resolution in the year 2020. The cropland fraction (referred to "GRASS-MAN" in the original data set) is bilinearly interpolated to our one-square-kilometer grid, resulting in an estimated global cropland area of approximately 2.1 billion hectares. Similarly, wildfires can occur only in places with vegetation cover (trees or grassland). To determine vegetation cover, we use the same data set and methodology as for drought. For tree fraction, we sum the four tree plant functional types (PFTs) to obtain total tree fraction. Grass is taken from the GRASS-NAT PFT. We do not include shrub cover because global coverage is negligible.

Sidebar

Our research methodology

trends.[7] This research focuses on 20 such commonly used, cross-cutting adaptation measures that can be applied across diverse economies. Of course, specific hazards, types of places, sectors, and categories of impact may require adaptation measures beyond this scope. Our analysis of hazards, exposure, and adaptation costs extends only to 2050. Beyond that, higher levels of exposure and warming could result in higher costs for implementing the adaptation measures we examined.

To estimate current spending, we assess how widely these 20 measures that address heat, wildfires, drought, or flooding are already in place using data such as air-conditioning ownership by country and length of coastline protected.[8] We then multiply these coverage rates by standard unit costs, including capital and operating expenses such as the cost per kilometer and height of a seawall.[9] Unit costs are differentiated by region and across the nine demographic groups to reflect variations in context and affordability, and capital costs are annualized based on the expected lifetime of each measure.[10]

To estimate the adaptation cost to protect to developed-economy standards currently and at 1.5°C and 2°C warming, we identify protection standards in developed economies as a benchmark. We assess the adaptation measures that are most suitable to provide protection, incorporating considerations of physical feasibility and cost-effectiveness to identify measures most appropriate in each location.[11] If either of these considerations is not met, we identify the next-most-effective option for providing protection. These assessments have been conducted for ten regions and nine demographic groups within them. Of course, in reality, places may still choose to implement measures that are not cost-effective—that have low direct benefit-to-cost ratios—due to their ability to protect people and potential for broader benefits.

We then calculate costs at different warming levels using the same approach as above, multiplying the relevant number of people or areas of places exposed by unit costs to estimate the total adaptation cost.[12] The current cost of protection to standards established in developed economies less current spending is the cost to close the resiliency gap.

Finally, we estimate potential future adaptation spending for two possible trajectories. One assumes that current protection levels are maintained, and the other assumes that adaptation spending rises in line with anticipated economic growth. In both cases, the analysis is done at a demographic group level, hazard by hazard.

The findings we present in this research are not predictions; rather, they represent an order-of-magnitude analysis that can help inform decision-making for different demographic groups and regions. See the technical appendix for more details.

---

7 Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as “current” or “today’s” climate conditions. (The average of the most recent estimates for the 2015–2024 decade is 1.24°C of warming relative to the global temperature between 1850 and 1900.) All so-called current policy scenarios suggest that by roughly 2030, the global, multidecadal mean surface temperature will rise to 1.5°C above preindustrial levels, on a path to warm by 2°C by about 2050, when warming is measured as a 20-year average centered on a given year and relative to a preindustrial average.

8 We were able to gather data on the current penetration of measures that offer the most protection and those with the largest costs at a country or more granular level. For some solutions, penetration data is unavailable. For these, we assume their penetration matches that of other adaptation measures addressing the same hazard. Collectively, solutions where assumptions of this kind were made represent a small fraction, about 10 percent, of total current adaptation spending.

9 Drawing on a broad set of sources including engineering literature, academic studies, and private-sector projects.

10 Technological advances may lower capital costs, for example, making irrigation systems cheaper. Operating costs could change as well. Air conditioners may become more energy-efficient, but higher electricity prices during heat peaks could offset savings. Scarcity could cause water costs for irrigation to rise. Accounting for these shifts, we find that adapting to a 2°C warming scenario could cost roughly 10 percent less if only downward cost drivers are considered, and about 10 percent more if only upward cost drivers, including land costs where relevant, are counted, with the net effect remaining within approximately 5 percent of our central estimate.

11 We do not estimate costs for places currently exposed that will no longer be exposed under the 1.5°C or 2° scenarios or for places exposed today and at 1.5°C but no longer exposed under the 2°C scenario.

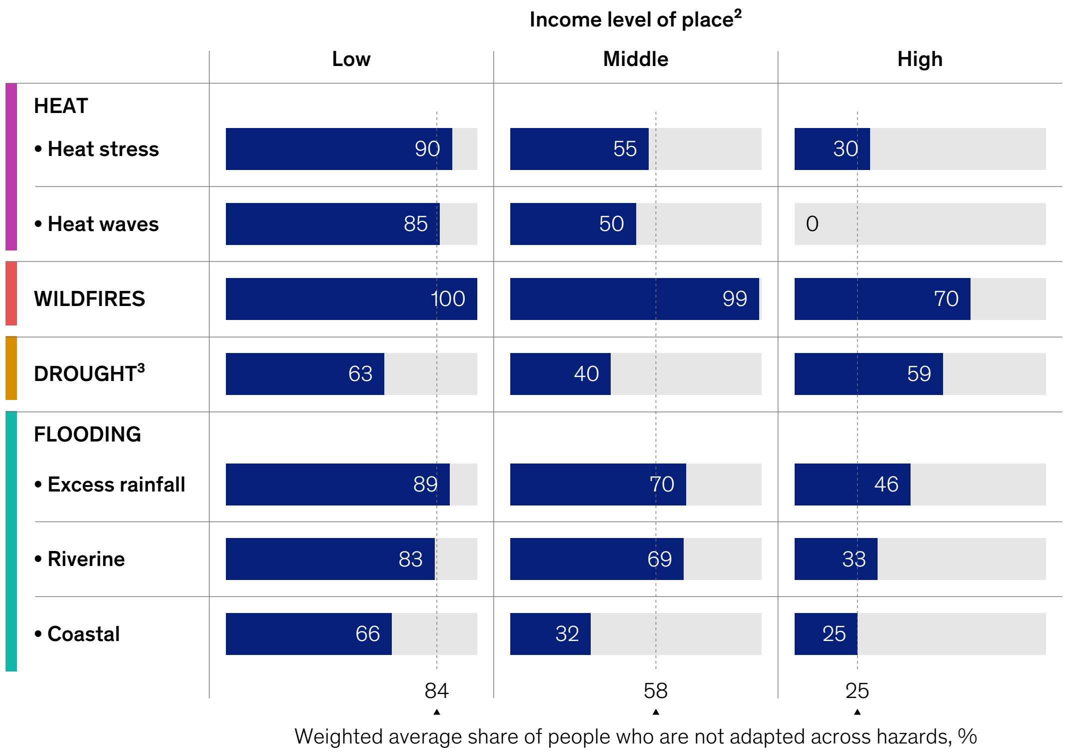
12 Technological advances may lower capital costs, for example, making irrigation systems cheaper. Operating costs could change as well. Air conditioners may become more energy-efficient, but higher electricity prices during heat peaks could offset savings. Scarcity could cause water costs for irrigation to rise. Accounting for these shifts, we find that adapting to a 2°C warming scenario could cost roughly 10 percent less if only downward cost drivers are considered, and about 10 percent more if only upward cost drivers, including land costs where relevant, are counted, with the net effect remaining within approximately 5 percent of our central estimate.

Those living in low-income places have the largest resiliency gap today.[26] Some 85 percent of people living in low-income places lack protection against the four categories of hazards we analyzed. By contrast, only a quarter of those living in high-income areas lack such protection (Exhibit 1). Around the world, many factors such as funding constraints, awareness of risk, risk tolerance, political will, and operational barriers can influence how much locales choose to invest in adaptation.[27]

Exhibit 1

The resiliency gap varies by income level and is largest in low-income areas.

Resiliency gap: Share of people who are not adapted to extreme weather events today,[1] %



Note: See technical appendix for detailed methodology. Assessment of resiliency gap is based on standards for protection established in developed economies. For this assessment, we consider the adaptation measure among the 20 examined in this research that offers the most protection against each hazard.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Resiliency gap by income level for heat, wildfires, and drought hazards is measured at the country level; for flooding hazards, at the 1-square-km level.
[3]Estimated only for places growing crops suitable for irrigation; high-income places have relatively low protection against drought from irrigation because they use other measures of protection like genetically modified drought-resistant strains of crops.
Source: Fathom Global Flood Map Fathom 3.0, 2021; McKinsey Global Institute analysis of a range of literature

McKinsey & Company

The disparity is greatest in protection from heat. For example, some 60 percent and 30 percent of the respective populations of India and Nigeria live in places that already experience heat stress each year. Yet air-conditioning coverage in these countries remains scant, at about 10 percent in India and 3 percent in Nigeria.[28] By contrast, in the United States, where just 4 percent of the population may experience heat stress today by our definition, air-conditioning coverage exceeds 90 percent. In general, advanced economies tend to have higher penetration of many adaptation measures (Exhibit 2).[29]

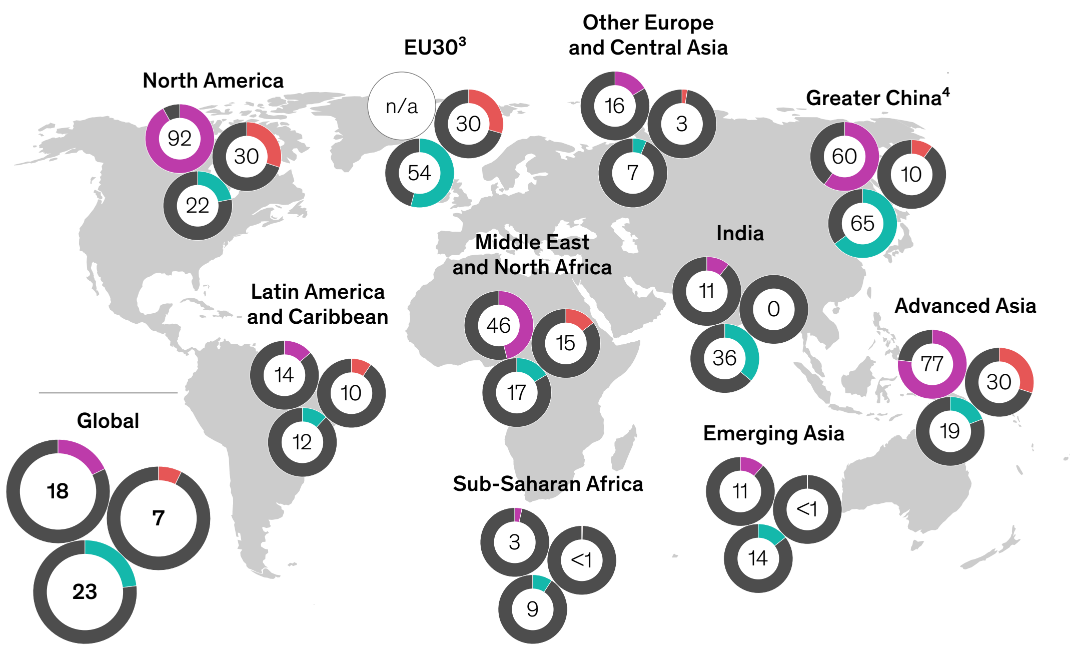
Lower-income people and places may struggle to meet basic, immediate needs like housing and food, let alone invest in adaptation measures, the benefits of which are primarily in avoiding a future cost that is uncertain and becomes evident only if and when a hazard occurs. A range of academic research has found that rich people are more likely to invest in insurance, which is one indicator of the willingness to spend on protection against an evolving climate.[30]

Exhibit 2

Adoption of adaptation measures varies across regions and is lowest in emerging economies.

Regions' adaptation to extreme weather events today, select adaptation measures,[1] %

- Air-conditioning coverage as share of people living in places exposed to heat stress
- Length of underground power lines as share of total in places exposed to wildfires
- Length of coastline protected as share of total length of coastline in places exposed to coastal flooding[2]



Note: This analysis draws on a range of literature. See technical appendix for hazard definitions.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Coastline is considered protected if coastal defenses can withstand a 1-in-100-year flood event with a height of at least 50 cm.
[3]EU30, which includes the 27 European Union economies plus Norway, Switzerland, and the United Kingdom, have had no population exposed to heat stress today by our definition.
[4]Our estimate for air-conditioning coverage uses data from 2018, the closest year to 2020 with available data. Air-conditioning penetration in Greater China has risen sharply and is expected to be higher in 2025.
Source: Fathom Global Flood Map Fathom 3.0, 2021; McKinsey Global Institute analysis

McKinsey & Company

In general, cities are best adapted regardless of their income level. For example, four-fifths of people living in high-income cities are protected against today's one-in-100-year riverine flood that exceeds 50 centimeters. Only 35 percent of residents in rural areas have such protection.[31] Since many adaptation solutions, such as seawalls, protect a specific area of land, the per-person cost of adaptation is lower for densely populated cities than for rural areas. Cities and their residents may also have a greater capacity to spend on adaptation than rural areas.

Protecting everyone today to developed-economy standards would cost $540 billion annually

Places around the world currently spend a total of $190 billion annually using one of the 20 adaptation measures we studied to protect themselves against hazards, collectively providing 1.2 billion people some form of protection.[32] Adapting to standards typically established in developed economies in all places exposed to extreme weather events today would cost almost three times more, or $540 billion annually, and protect all 4.1 billion individuals exposed today. Thus, the cost to close the resiliency gap, or the difference between what is spent today and spending to protect to standards established in developed economies, is $350 billion. The cost is highest in low-income places, about $200 billion, or 2.7 times the $75 billion each for middle- and high-income places (Exhibit 3).[33]

Across income groups, cities need to spend less than towns and rural areas to close today's resiliency gap as a share of affected GDP. For example, high-income cities that currently lack protection would need to spend about 0.3 percent of GDP to close their resiliency gap, compared with 0.8 percent in high-income rural areas. The disparity is even more pronounced in middle- and low-income places: closing rural resiliency gaps requires 1.0 to 1.5 percentage points more of GDP than closing urban gaps.

More than half of the $190 billion spent annually today is directed to protection against heat hazards, primarily heat stress. Yet the largest resiliency gaps remain in protecting low-income places from heat. Closing this gap would require about $125 billion. About $40 billion would be needed to close the gap to protect against excessive rainfall flooding in low- and middle-income regions, and $50 billion to close wildfire protection gaps across all income groups. Indeed, wildfire weather is the hazard that high-income cities are least protected against.

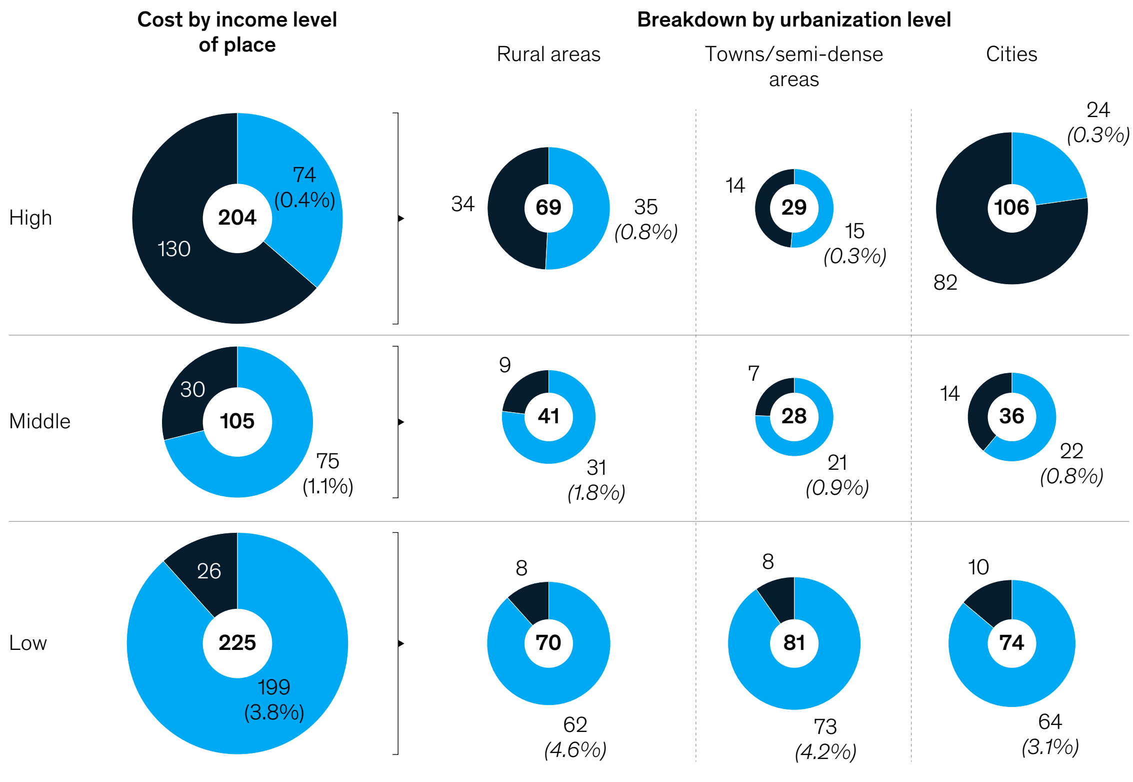
Of course, in applying developed-economy protection standards across the world, it is important to note that not all adaptation measures will be feasible everywhere. As individual stakeholders make spending decisions, they also weigh considerations of cost-effectiveness and physical feasibility of the adaptation measure. For example, the cost to implement a seawall in a low-income rural place may far exceed the magnitude of avoided damages. Measures like mangroves may often be far more cost-effective, even though they do not offer the same level of protection. Similarly, air conditioning is physically not feasible in places lacking access to electricity, making passive cooling a more practical alternative. Our estimates account for both cost-effectiveness and physical feasibility, assessed at a demographic group and region level.[34] And in reality, many other considerations may also be taken into account as stakeholders make decisions to adapt.

Exhibit 3

The cost to close the resiliency gap in low-income places is 2.7 times as much as for middle- or high-income places.

Average annual operating and amortized capital costs to adapt to extreme weather events today,[1] $ billion (2020 dollars)

Circle size = total cost, $ billion | Current spending | Cost to close resiliency gap[2] *(with cost as share of 2020 GDP in places exposed)*



Total annual cost
- **$349 billion** (cost to close resiliency gap)
- **$186 billion** (current spending)

Note: This is a geospatial analysis conducted by categorizing 1-square-km areas by income and level of urbanization; costs are for 20 measures used to adapt to 4 categories of hazards: heat, wildfires, drought, and flooding. Average annual costs are representative of costs from 2020 to 2050. This analysis relies on existing and established climate models and techniques, including from the sources below. Figures may not sum to 100%, because of rounding.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Assessment of resiliency gap is based on standards for protection established in developed economies.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

CHAPTER 2

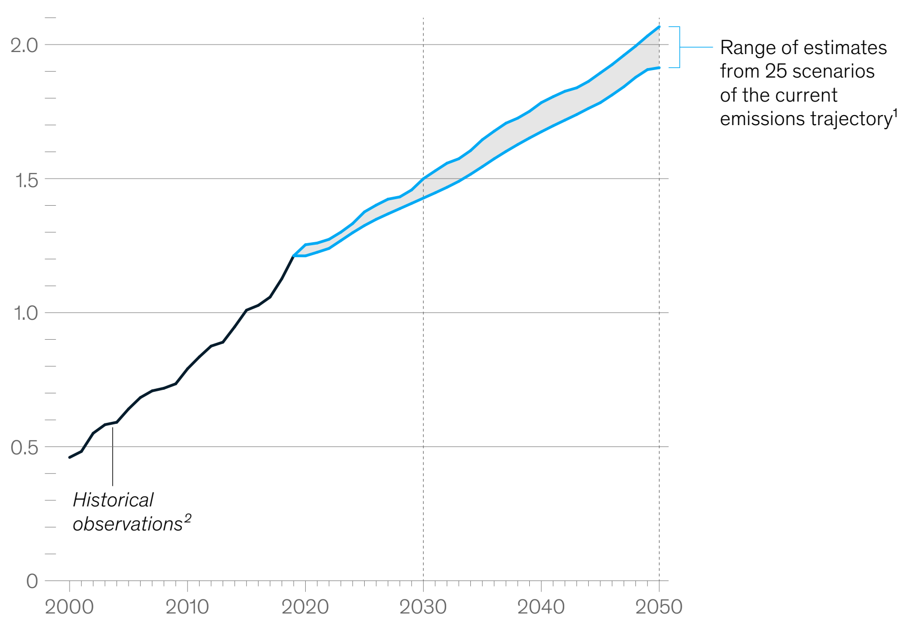
Adapting to developed-economy standards at 2°C could cost $1.2 trillion annually by 2050

On the current trajectory of emissions, global temperatures are expected to rise (Exhibit 4). Various estimates suggest that by roughly 2030, the global, multidecadal mean surface temperature would rise to 1.5°C above preindustrial levels on a path to warm to 2°C by about 2050, with further warming anticipated after that.[35]

Exhibit 4

Under the current trajectory of emissions, the world could warm to 1.5°C above preindustrial levels by roughly 2030 and 2°C by about 2050.

Global warming above preindustrial levels (1850–1900 average), °C



Note: Estimates of the current trajectory of emissions suggest that further warming, which is not shown, occurs beyond 2050. By 2100, these scenarios estimate warming between 2.3°C and 3.7°C above preindustrial levels.
[1]Range represents the modeled global mean surface temperature outcomes under current emissions trajectories based on policies announced or, in some cases, implemented to date. To form the range, the 50th percentile (median) outcome across model runs is used, with results presented as the long-term warming trend, excluding interannual variability. The 25 scenarios are:

- 19 from the IPCC AR6 database representing the C5, C6, and C7 pathways that correspond to current policy emissions trajectories using the 50th percentile GSAT MAGICCv7.5 variable
- 4 from the NGFS Phase V database, Current Policies Scenario (CPS), using the 50th percentile GSAT outcome from MAGICC7.5
- 2 from the IEA World Energy Outlook 2025 Stated Policies Scenario (STEPS) and Current Policies Scenario (CPS), derived by running the scenarios emissions trajectories through the MAGICC7 climate model

[2]Historical average annual global surface temperature anomaly relative to preindustrial levels is sourced from NOAA, and interannual variability/cyclicity is smoothed by taking rolling 11-year averages centered on the corresponding year (ie, average from 5 years before to 5 years after the year in question).
Source: US National Oceanic and Atmospheric Administration (NOAA Global Temp v6.0.0.202507); Network for Greening the Financial System (NGFS Phase V); International Institute for Applied Systems Analysis (IIASA hosted IPCC AR6 Scenario Explorer and Database); International Energy Agency World Energy Outlook 2025; McKinsey Global Institute analysis

McKinsey & Company

Since some adaptation measures take more than a decade to implement, anticipating needs at least for 2050 and a 2°C world now is prudent, even as the world works to reduce emissions.[36] So when we refer to 1.5°C or 2°C in this report, we mean a scenario where such temperatures are reached by 2030 and 2050, respectively.

Currently, about 40 percent of the Earth's landmass, including cities such as Ho Chi Minh City, which experiences coastal flooding and Phoenix, Arizona, which has periods of heat stress, is exposed to extreme weather events that occur at magnitudes typically protected against in developed economies.

More places could become exposed to such hazards at 1.5°C. For example, places in northern parts of Asia could newly experience heat waves, and wildfire weather could newly occur in parts of South America. Some places exposed to a hazard today could also experience more severe conditions as well as additional hazards.

On the current trajectory of emissions, as Earth further warms to 2°C, this trend of growing geographical expansion of hazards and, in some instances, rising severity could continue. For example, cities in Europe could become exposed to heat waves, while parts of Sub-Saharan Africa are likely to newly experience excess rainfall flooding.

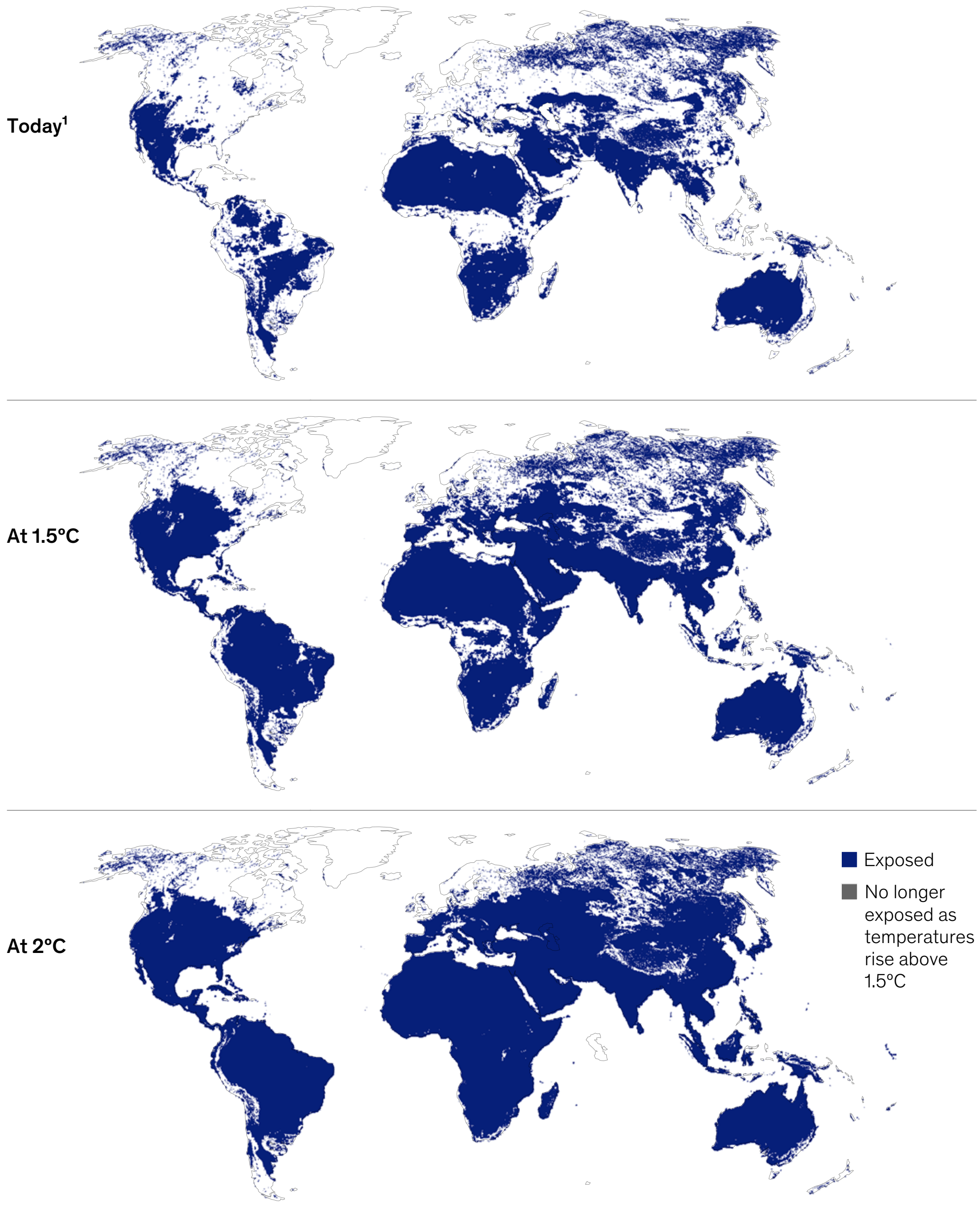
Hazards like excessive rainfall flooding and drought, while increasing in severity in many parts of the world, may diminish in some locales, though to a much lesser extent. Exposure to freezing days is expected to decline—and nowhere in the world will experience an increase. Thus, hazards will increase around the world, changing the adaptation landscape—but not everywhere, not in the same way, and not all at once.

Learn about climate hazards
Advancing adaptation: How evolving hazards could shape the adaptation agenda examines patterns of extreme weather events today and how they could shift going forward as the world warms, providing a foundation for understanding adaptation needs and costs.

Exhibit 5

As global temperatures rise, more places can become exposed to hazards.

Places exposed to heat, wildfire, drought, or flooding, by developed-economy standards



Note: Exposure encompasses 4 categories of hazards: heat, wildfires, drought, and flooding. This analysis relies on existing and established climate models and techniques, including from the sources below. Hazards are defined based on protection standards established in developed economies. For details, see technical appendix.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; McKinsey Global Institute analysis

McKinsey & Company

At 2°C, protection at developed-economy standards would cost more than six times what is spent today

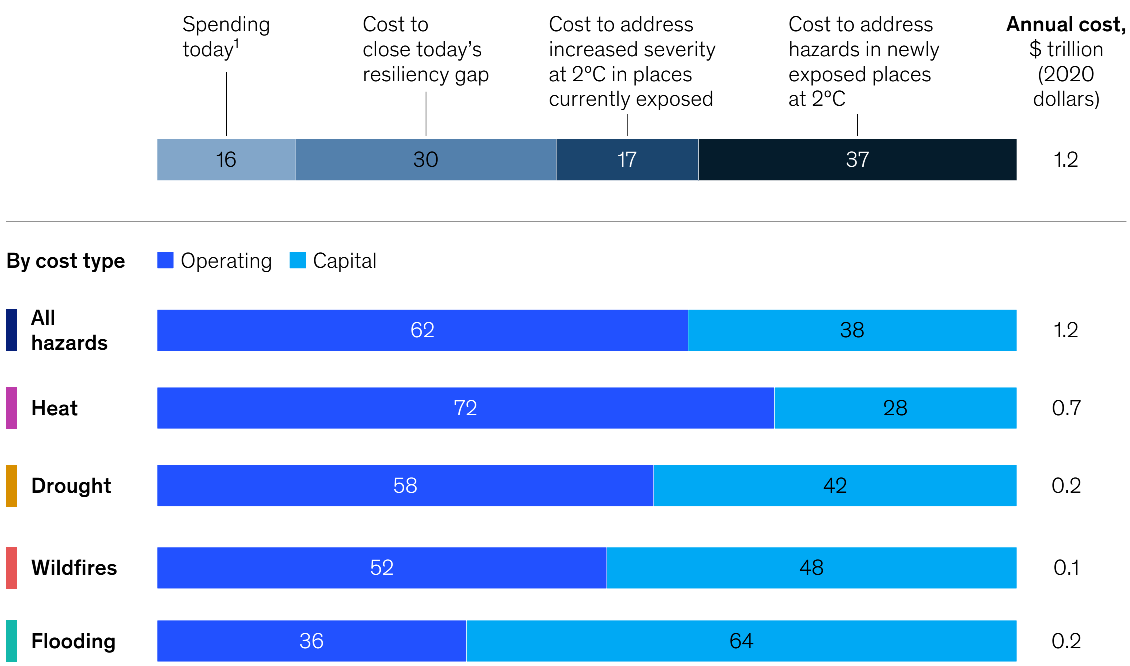
Climate hazards will affect more places and people, sometimes with greater severity, as the global temperature rises and populations increase. At 2°C by 2050, some 8.9 billion people will live in places that are exposed—in line with developed-economy protection standards—to climate hazards.

As a result, costs of protection to developed-economy standards would rise. If the 20 adaptation measures were implemented in a physically feasible and cost-effective way, annual adaptation costs to achieve developed-economy standards would be 6.2 times what is spent today. Overall costs would rise from $540 billion to protect against today's conditions to $800 billion at 1.5°C and would reach $1.2 trillion at 2°C through 2050 (Exhibit 6).[37] These costs are equivalent to about 0.8 percent of GDP in areas exposed to climate hazards by 2050.

Exhibit 6

Protecting against hazards at 2°C to developed-economy standards would require $1.2T in adaptation spending annually by 2050.

Distribution of average annual operating and amortized capital costs to adapt to hazards to developed-economy standards, 2020–50, %



Note: Costs are for 20 adaptation measures used to protect against 4 categories of hazards: heat, drought, wildfires, and flooding. Assessment of resiliency gap is based on standards for protection established in developed economies; our climate analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature could rise 2°C relative to preindustrial levels sometime in the next 3 decades as measured based on multidecadal average temperatures. This analysis relies on existing and established climate models and techniques, including from the sources below.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

This figure, however, is not a projection of actual spending. After all, the world spends only $190 billion of the $540 billion that protecting against today's hazards to developed-economy standards would require. Rather, this calculation provides a benchmark for decision-makers weighing future adaptation choices.

About 40 percent of the $1.2 trillion in annual adaptation costs would go toward capital expenditures, such as building infrastructure like levees and detention basins or purchasing durable goods like air conditioners and fans. The remaining 60 percent would be spent on operating costs, including infrastructure maintenance, electricity costs to run cooling technologies, and water costs for irrigation.

The composition of capital and operating costs varies by hazard. For instance, nearly two-thirds of flood protection costs are capital expenditures associated with building structures like sea dikes, which require significant up-front investment. By contrast, about three-fourths of heat protection costs are ongoing operating expenses, for example, to run air conditioners.

These costs are only for protection at 2°C through 2050. Further warming would likely entail higher adaptation costs and additional adaptation measures beyond those considered here.

Heat and drought account for more than three-quarters of the costs to adapt to developed-economy standards at 2°C

At 2°C, more than half of the $1.2 trillion in adaptation spending would go into protection against heat, with active cooling solutions like air conditioning accounting for the largest share.[38] Drought would account for one-fifth, the largest share of which, about 15 percent, is related to installing irrigation systems. Building levees and detention basins to mitigate riverine flooding and flooding from excessive rainfall would also require sizable investments (Exhibit 7).[39] The composition of adaptation spending is broadly similar at 1.5°C.

That heat stress–related measures would eat up most of the costs while coastal flooding linked to sea level rise accounts for only a small sliver may seem surprising.[40] However, at 2°C by 2050, more than 40 percent of people would live in places exposed to heat stress, while less than 1 percent would live in areas exposed to coastal flooding. That share could rise over time, however, even if global temperatures stabilize, as sea levels continue to climb.[41]

From an implementation perspective, more than half of the costs would be directed toward private actions typically undertaken by individuals and companies, such as air conditioning, flood proofing of individual assets, and crop shading; about 30 percent would fund public goods like sea dikes, levees, mangroves, and early-warning systems; and the remaining 20 percent would be allocated to measures such as irrigation, which can be implemented through private initiatives or public programs.

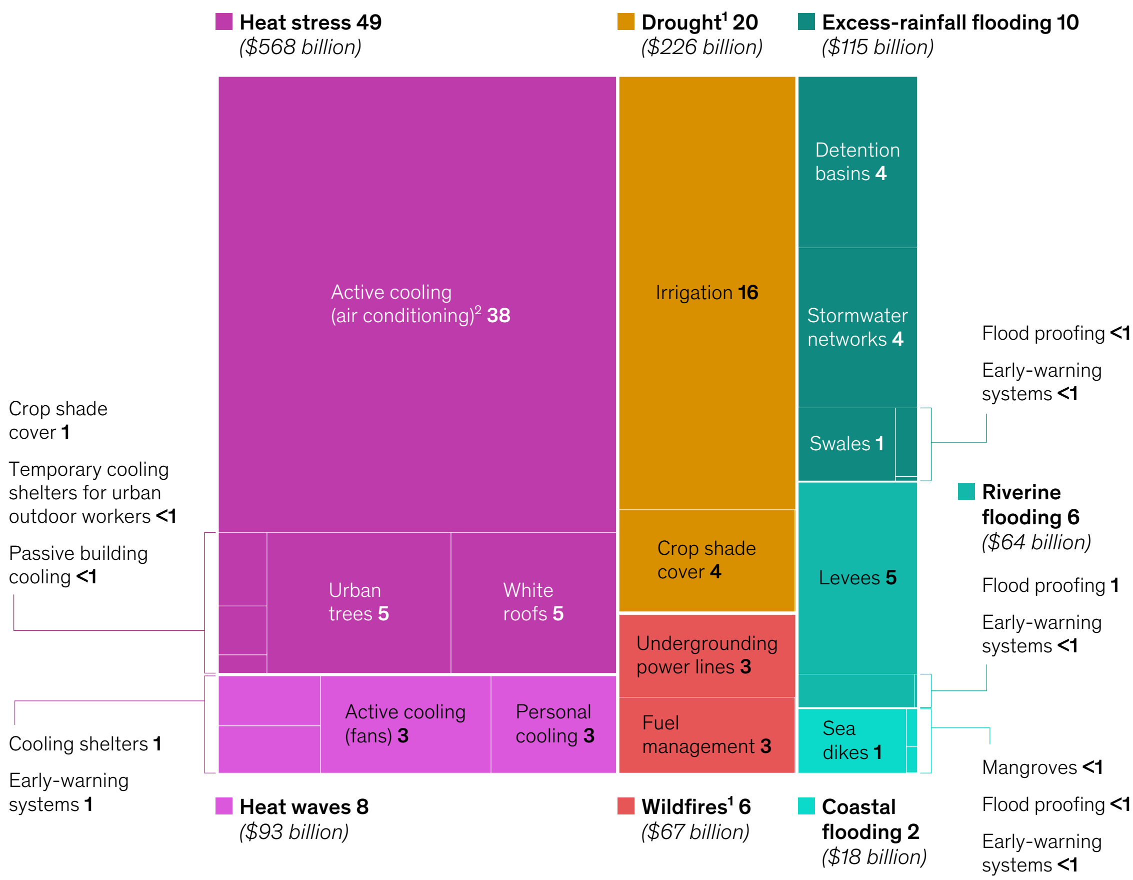
Careful planning is needed to avoid maladaptation when implementing measures. For example, building a seawall or flood defense in one area may inadvertently push flooding to another location, scaling irrigation must take into account basin-level water availability and competing uses for water, and implementing air conditioning requires consideration of emissions related to energy use and refrigerants, which can be material.[42]

Coordinating flood management across administrative boundaries, jointly assessing upstream and downstream impacts, and aligning defenses with natural hydrology and land use can help manage the maladaptation risks related to flooding.[43] Employing efficient irrigation systems and drought-tolerant crop varieties can reduce maladaptation risks of irrigation.[44] Similarly, adopting high-efficiency cooling equipment, refrigerants that contribute less to global warming, and effective cooling demand management, as well as combining active and passive cooling measures, can help reduce energy use and emissions from air conditioning. Continued innovation to lower the cost and improve the effectiveness of energy-efficient alternative cooling technologies like heat pumps and evaporative coolers can also help.[45]

Exhibit 7

Air conditioning and irrigation systems account for more than half of the adaptation spending to protect at 2°C to developed-economy standards.

Distribution of annual average operating and amortized capital costs to adapt to 2°C hazards to developed-economy standards, 2020–50, %



Note: This analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to rise 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures). It includes nonsurvivable heat, the costs of which are incorporated into the other heat-related hazards. This analysis relies on existing and established climate models and techniques, including from the sources below. See technical appendix for detailed methodology and sources. Currency figures are in 2020 US dollars. Figures may not sum to 100%, because of rounding.
[1]Drought and wildfire figures each include segments for early-warning systems at <1% of the total cost.
[2]Active cooling costs assessed using air conditioners, which are currently among the most effective measures for protecting against heat. Other measures like heat pumps, evaporative coolers, and fans also exist but have not yet widely scaled or are less effective.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

At 2°C, adaptation measures could deliver benefits about seven times their costs

As with hazards, not all adaptation measures are created equal. The 20 measures vary in costs, benefits, and level of protection, offering a spectrum of investment choices (Exhibit 8).[46]

Approaches to address heat illustrate this diversity. Air conditioning, for instance, eliminates almost all heat-related damages when it can be used, such as in places with access to electricity and to protect indoor workers. It has benefit-to-cost ratios (BCRs) of between roughly three and five. Though offering less protection, fans deliver higher BCRs because they are much cheaper. Similarly, white roofs have higher BCRs than air conditioning. While they provide less than half the protection, they also cost much less.

For wildfire adaptation, no one adaptation measure can fully prevent fires. Laying power lines underground limits ignition risk from power-line sparks but requires high capital investment, while fuel management limits fire spread and requires continuous maintenance expenditures, both yielding similar BCRs.

When effectively implemented, structural measures such as sea dikes and detention basins for flooding and irrigation systems for drought can protect up to the intensity of the hazard and the associated impacts that they are designed to target. Their relative costs for construction and maintenance primarily dictate their BCRs.

These BCRs are global averages across measures in places exposed to hazards and can vary significantly at a local level, a necessary consideration in adaptation planning in specific locations. For example, sea dikes in urban areas yield BCRs of more than ten due to the concentration of economic activity they protect, while sea dikes protecting rural areas have BCRs lower than 1.5, reflecting less economic activity there.

Looking across measures, more than 80 percent of the adaptation costs would be directed toward measures that deliver benefits exceeding three times their costs on average. And in aggregate, the average BCRs of these adaptation measures could reach seven at 2°C, up from four at 1.5°C and about three in today's climate. As hazards become more severe, the cost of adaptation measures goes up, but often more slowly than the damages that are avoided. For example, air conditioners need to cool more and run for more days with rising heat stress, as well as to protect a growing population over time—but cost would rise more slowly than the benefits they deliver, at least up to 2°C (see sidebar "What is adaptation and what are its limits?").[47]

Of course, these 20 measures don't protect against all hazards or all impacts, or in all places. For example, while temporary cooling shelters may benefit urban outdoor workers in areas exposed to heat waves, those in sectors such as agriculture may be harder to protect due to the geographically distributed nature of their work and the challenges in reaching them. For outdoor workers in areas exposed to both heat stress and heat waves, other measures beyond those described here may need to be considered—for example, behavioral adaptations such as modifying work hours, taking regular breaks, and maintaining proper hydration, and using other measures like air-conditioned equipment in, say, agriculture or mining, where feasible.[48] Additionally, some places such as small island developing states, may also begin to encounter the limits of adaptation at 2°C and beyond, as rising risks outpace the effectiveness of measures, particularly those designed to reduce vulnerability (for a discussion on the limits of adaptation, see sidebar "What is adaptation, and what are its limits?").

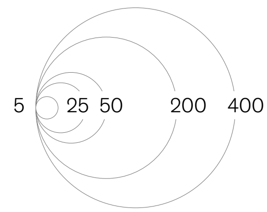
Exhibit 8

Adaptation measures vary in their cost-effectiveness and level of protection.

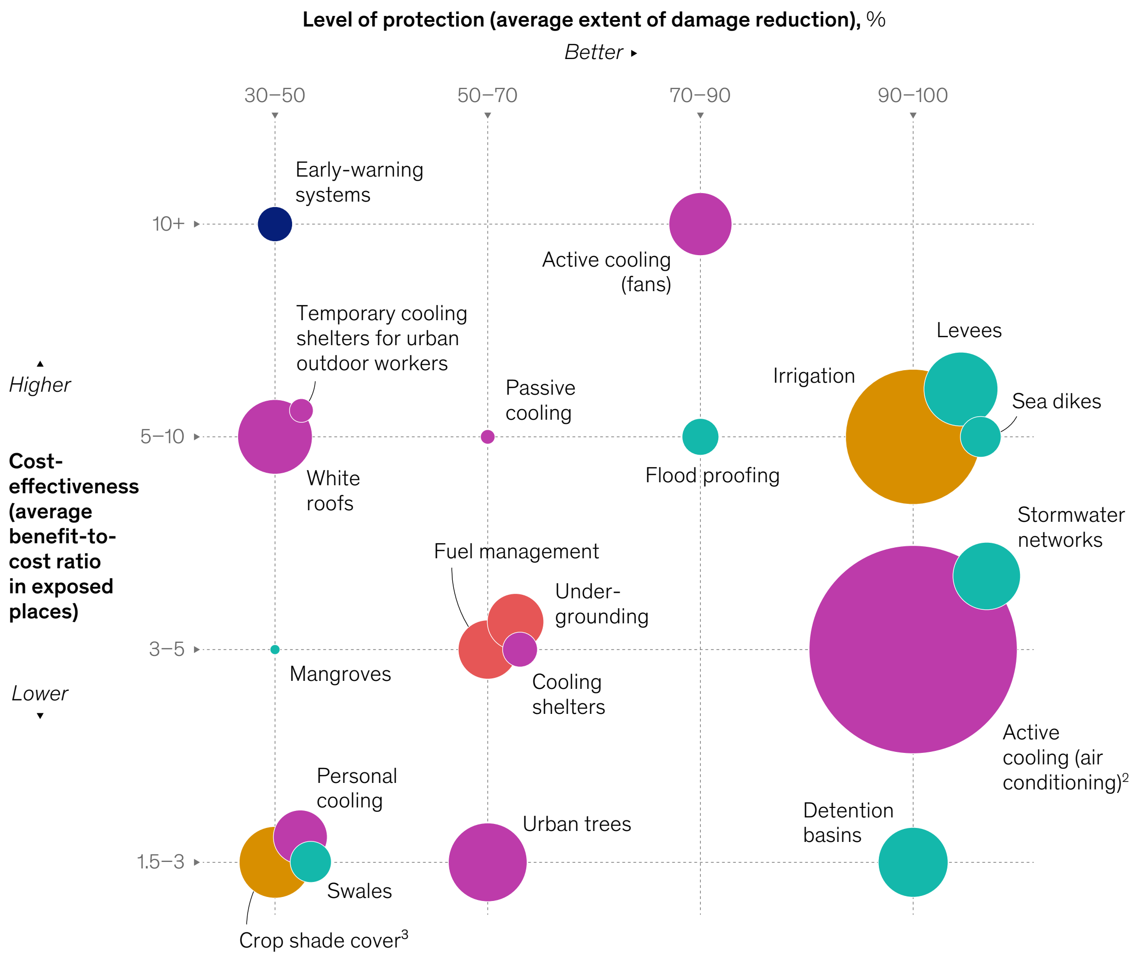
Cost-effectiveness and level of protection at 2°C for 20 adaptation measures examined[1]

Hazard addressed by adaptation measure:

● All hazards ● Heat ● Wildfires ● Drought ● Flooding



Circle size = annual operating and amortized capital costs to adapt to 2°C hazards to developed-economy standards, 2020–50, $ billion (2020 dollars)



Note: This analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to rise 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures).
[1]Extent of damage reduction percentages indicate how effectively an adaptation measure reduces damages from hazards in its most suitable use case up to the design limit of the solution. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure; and costs measured as annual capital and operating expenses.
[2]Active cooling costs assessed using air conditioners, which are currently among the most effective measures for protecting against heat. Other measures like heat pumps, evaporative coolers, and fans also exist but have not yet widely scaled or are less effective.
[3]We estimate >80% of crop shade cover costs address drought; the remaining costs address heat stress.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

Adaptation costs rise as hazards become more widespread and sometimes more severe

Places like Toronto, Warsaw, and Kyoto are not currently exposed to the four categories of hazards by our definition but are likely to be by 2°C.[49] At the same time, some places would experience more severe hazards compared with today. For example, the average duration of heat stress could grow from less than 12 weeks currently to about 16 weeks at 2°C, increasing demands on electrical grids and operating costs as air conditioners run longer.

Together, these factors explain why the annual costs of protecting to standards established in developed economies increase from $540 billion today to $1.2 trillion at 2°C. About two-thirds of this increase would go to protecting people in areas exposed to new hazards, while the remainder would go toward addressing costs from rising severity (for more information, see sidebar “Evolving hazard patterns”).

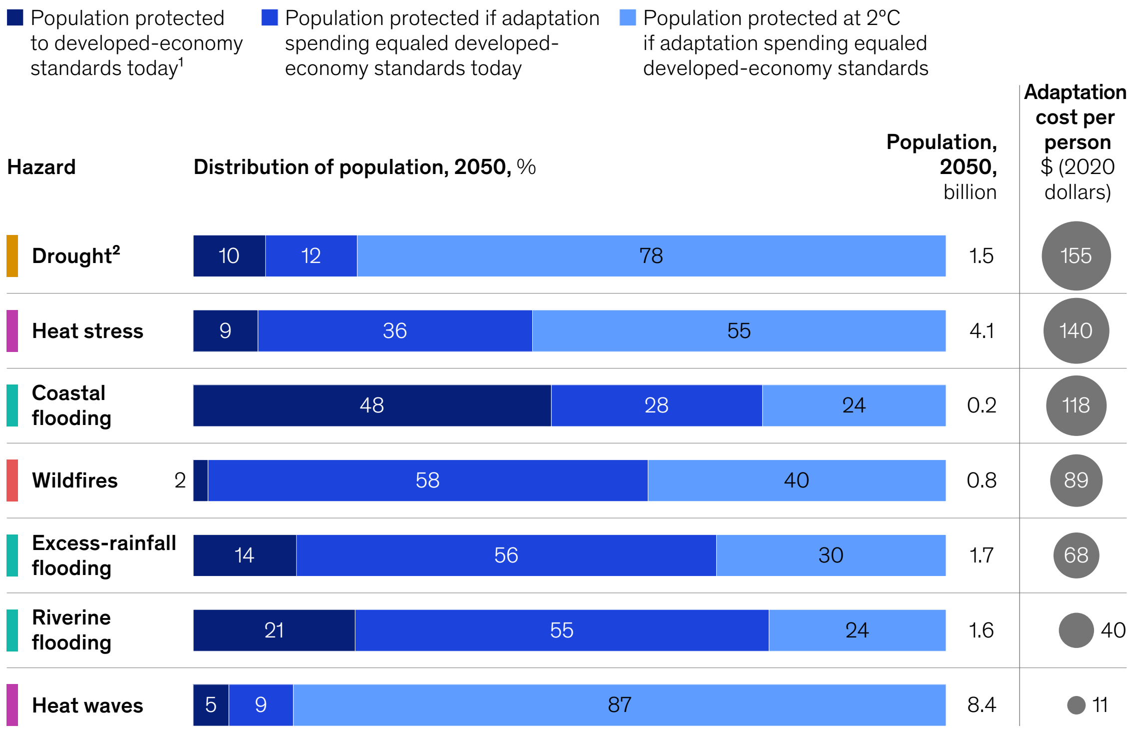
At the level of individual hazards, the adaptation cost per person is highest for heat stress, drought, and coastal flooding. At 2°C, providing protection in line with developed-economy standards would mean safeguarding roughly 4.1 billion people against heat stress, 1.5 billion against drought, and 200 million against coastal flooding through measures such as air conditioning and white roofs, irrigation and crop shading, and sea dikes and flood proofing (Exhibit 9). The largest increases in people needing protection compared with today are expected for heat stress and drought—an additional 2.2 billion and 1.1 billion, respectively. On the other hand, just 40 million more people may live in places that could become exposed to a one-in-100-year coastal flood at least 50 centimeters high, though everyone exposed would experience such an event eight times more frequently on average.

Protection against heat waves falls at the other end of the cost spectrum, at only about $10 per person to adapt to developed-economy standards. Defined as rare periods of at least seven consecutive days exceeding local temperature extremes, heat waves are place specific, for example, occurring when daily maximum temperatures rise above 35°C in Nice, France, or above 45°C in New Delhi. More places may have a chance of experiencing such heat waves at 2°C.[50] Although generally less debilitating than long periods of heat stress, these events could still particularly affect vulnerable populations. Protecting to standards established in developed economies means that places around the world would be prepared should such a heat wave occur, even if only every ten or 20 years. With protection to developed-economy standards, many people would be covered by inexpensive measures such as early-warning systems and cooling shelters, ready to activate as needed.

Exhibit 9

People protected and cost to protect to developed-economy standards vary widely across hazards.

Population and adaptation cost per person in places that could adapt to hazards at 2°C to developed-economy standards, 2020–50



Note: Costs are for implementing 20 adaptation measures. Our climate analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature could rise 2°C relative to preindustrial levels sometime in the next 3 decades as measured based on multidecadal average temperatures. This analysis relies on existing and established climate models and techniques, including from the sources below. Not all hazards have comparable impacts. For example, heat stress as we define it may persist for more than a month each year, while heat waves are brief and occur once in a generation. See technical appendix for hazard definitions.

[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."

[2]Per-person costs for drought are based on the population of people who live in places suitable for agriculture.

Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

Relative to GDP, cost to adapt would be higher for low-income places

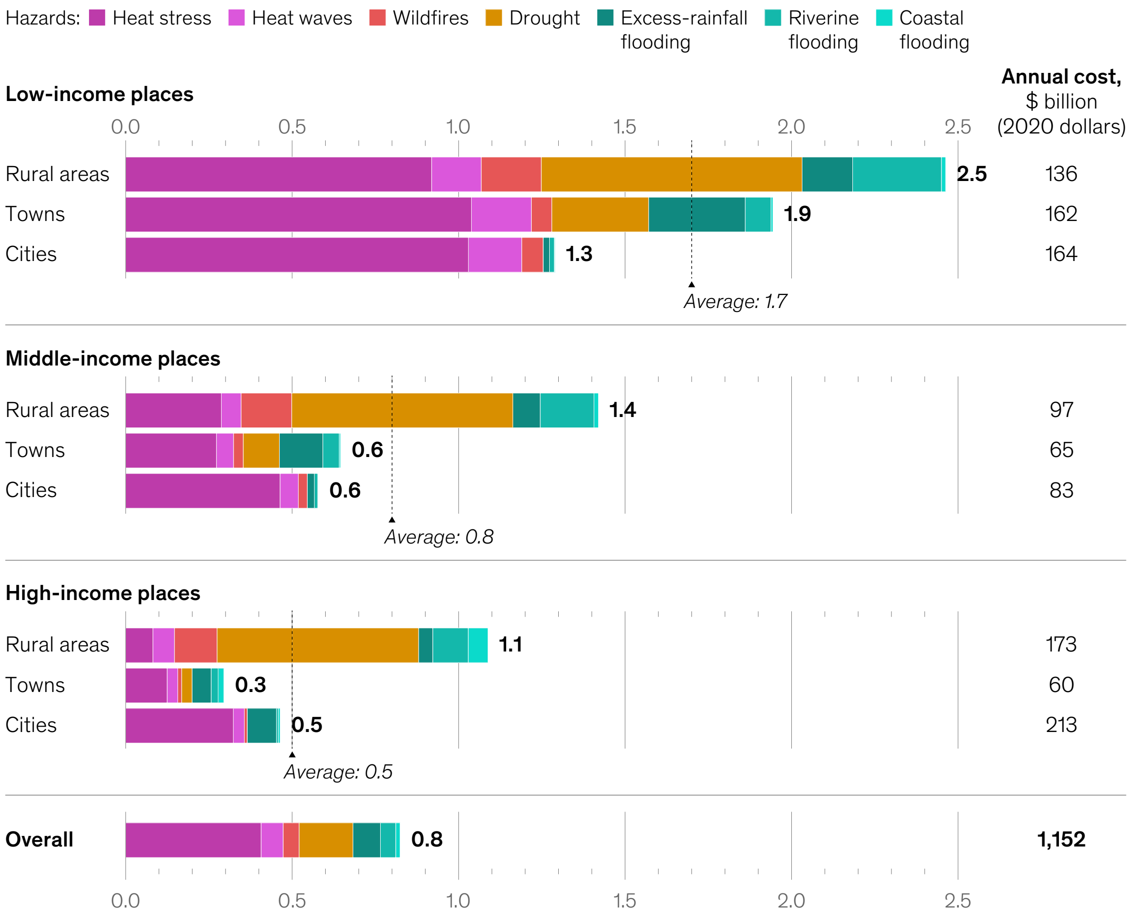
At 2°C, the costs of adaptation would fall unevenly across demographic groups. Protecting low-income places exposed to hazards at developed-economy standards would cost an average of 1.7 percent of GDP in those regions (Exhibit 10). Protecting low-income rural areas against hazards would require even more, 2.5 percent of GDP. By contrast, adaptation would require a significantly smaller share of GDP in wealthier places, just 0.5 percent in high-income areas and 0.8 percent in middle-income places on average. This disparity is driven by more people living in places exposed to hazards as well as lower GDP in low-income places.

Across income groups, 60 to 80 percent of the total adaptation costs we estimate in cities would protect people from heat stress. In rural areas, by contrast, estimated adaptation costs could fall more evenly across multiple hazards, reflecting lower population density (and therefore overall lower cooling costs, which typically scale per person) and a greater prevalence of drought.

Exhibit 10

Adaptation costs represent a larger share of GDP in low-income locales.

Average annual operating and amortized capital costs, as share of exposed 2050 GDP, to adapt to 2°C hazards to developed-economy standards, by income group, 2020–50, %



Note: Costs are for implementing 20 adaptation measures. This is a geospatial analysis conducted by categorizing 1-square-km areas by income and level of urbanization; this analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to rise 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures). The scope also encompasses nonsurvivable heat, the costs of which are incorporated into the other heat-related hazards. This analysis relies on existing and established climate models and techniques, including from the sources below. See technical appendix for detailed methodology and sources.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

Sidebar

Evolving hazard patterns

At 1.5°C or 2°C relative to preindustrial levels, many places are expected to experience more severe hazards relative to today and, in some cases, face more hazards than they currently encounter. Understanding these shifts is important in estimating how adaptation costs are likely to evolve. It is also important in considering how the nature of adaptation planning may need to change.

Consider severity. Some climate hazards are projected to intensify, become more frequent, or last longer at 2°C. For example, the average duration of debilitating heat stress in places currently exposed to the hazard could increase from less than 12 weeks to about 16 weeks at 2°C, in turn increasing demand for electricity for cooling and raising operating costs (exhibit).[1]

Similarly, a coastal flood that currently occurs once every 100 years could happen as often as once every 13 years at 2°C—which can result in increased average annual damages.[2] It could also become more intense and have a greater flood depth, requiring higher sea dikes for protection. However, the increase in capital costs related to higher sea dikes is likely to be modest globally, because flooding heights for future one-in-100-year events may be only 10 percent higher than today, on average. Given these limited increases, adaptation costs may not rise sharply. Perhaps more important than the spending level are understanding how flood heights may evolve and ensuring that adaptation measures are designed to remain effective even as hazards intensify.

Not all hazards are expected to become more severe, however. Globally, compared with the changes in severity projected for other hazards, inland floods due to rising rivers and excessive rainfall in places already exposed today are unlikely to occur much more frequently, and the duration of wildfire weather is expected to increase only slightly (though specific locales may see greater severity increases).

People may also need to increasingly consider protection against multiple hazards. Currently, about 60 percent of land areas exposed to climate hazards face more than one type of hazard, and that share could rise to roughly 80 percent at 2°C. For example, people facing heat stress today primarily experience only one other hazard, but going forward, they may also need to consider protection against heat waves, drought, and wildfires.

Beyond increasing adaptation costs, these shifts could influence how adaptation planning is approached. Some places may need to account for the evolving nature of hazards—those that are becoming more intense, longer, or more frequent—when designing adaptation measures. This includes ensuring that assets with long lifespans, such as stormwater networks, are built to withstand changes in the future climate and that electrical grids are designed to accommodate higher cooling loads. Some may need to develop new capabilities to address emerging hazards, and places facing multiple hazards may need to adopt integrated planning and synergistic adaptation measures, such as flood proofing infrastructure that protects against multiple types of flooding and early-warning systems that can help manage multiple hazards.

1 Increases in hazard severity are measured as an increase in intensity, frequency, or duration. The numbers in this analysis represent land-area averages, although similar trends will occur in individual locations as well. These changes in intensity, frequency, and duration are consistent with the literature. See, for example, Simone Russo et al., "Half a degree and rapid socioeconomic development matter for heatwave risk," *Nature Communications*, January 2019; G. Naumann et al., "Global changes in drought conditions under different levels of warming," *Geophysical Research Letters*, March 2018; and Michael Wehner et al., "Changes in extremely hot days under stabilized 1.5 and 2.0°C global warming scenarios as simulated by the HAPPI multi-model ensemble," *Earth System Dynamics*, March 2018, Volume 9, Issue 1.

2 Stéphane Hallegatte et al., "Future flood losses in major coastal cities," *Nature Climate Change*, August 2013.

Sidebar (continued)

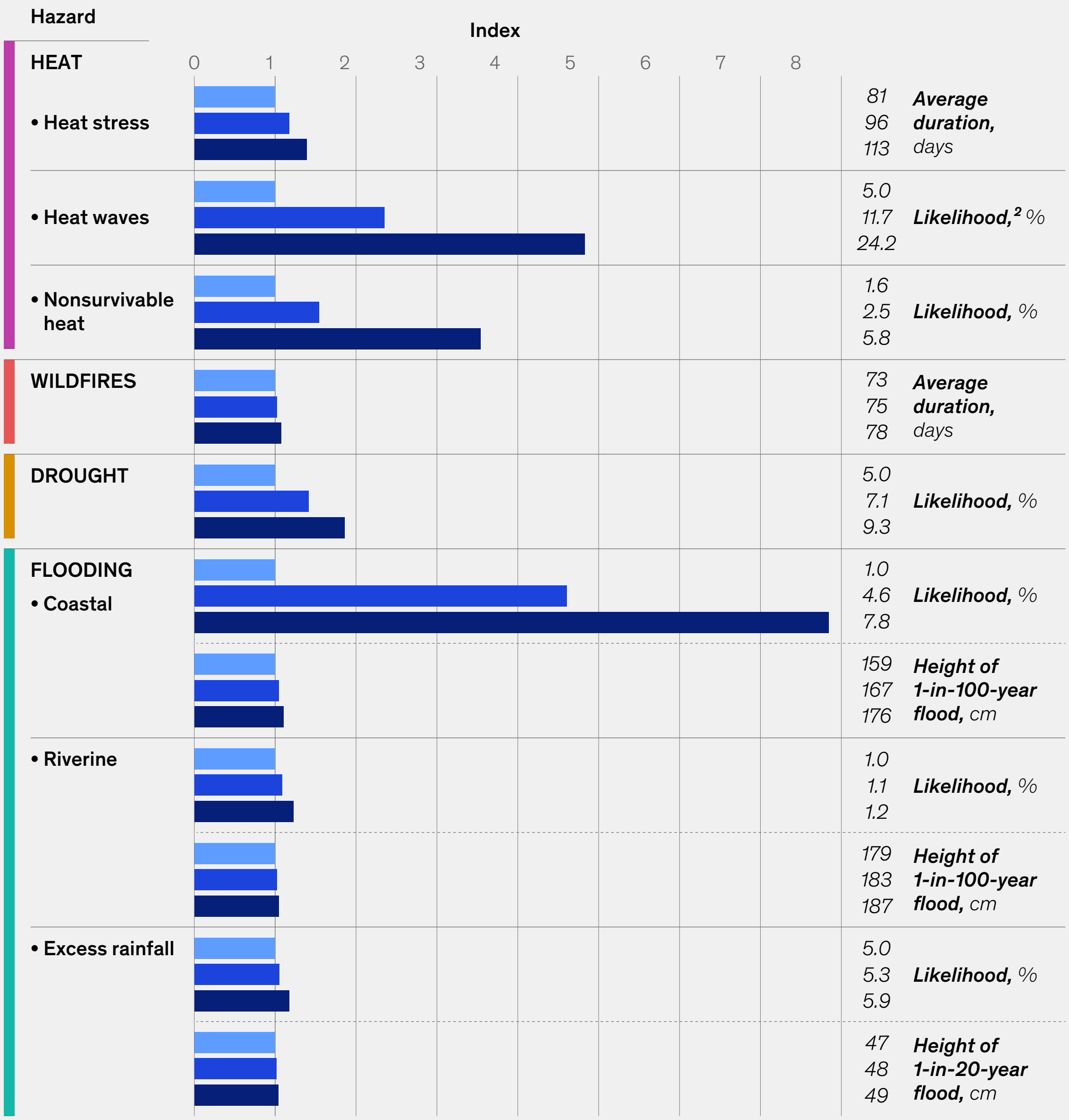
Evolving hazard patterns

Exhibit

As Earth warms, hazards could become more frequent or last longer.

Examples of increasing hazard severity in places exposed at 1.1°C,[1] index (1.1°C levels = 1)

Hazard severity at: 1.1°C 1.5°C 2°C



Note: This analysis relies on existing and established climate models and techniques, including from the sources below.
[1]Intensity, duration, and probability weighted averages by land area. Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Likelihood reflects probability of hazard occurrence in any given year.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom-Global 3.0; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

CHAPTER 3

How much will be spent on adaptation?

If adaptation spending decisions were based only on cost-benefit economics, there would be no resiliency gap today. As discussed, the combined benefits of the 20 adaptation measures we analyzed total about three times adaptation costs today, and the benefit-to-cost ratios will increase to about seven at 2°C.[51] Clearly, multiple factors beyond cost-benefit economics determine how much households, governments, and companies spend to defend against extreme weather today, and a similar set of considerations may influence their adaptation choices at 2°C. We have no crystal ball, and so we outline several trajectories to "bookend" how much stakeholders might spend to adapt to 2°C by 2050.

Why stakeholders might not pay the costs of protecting to developed-economy standards at 2°C

Stating the obvious, governments, companies, and individuals have multiple demands on their pocketbooks, from national priorities like economic development and energy security to local considerations like civic priorities and individual needs. These competing demands in an often resource-constrained world, together with each stakeholder's risk tolerance and level of risk awareness, shape the prioritization of adaptation spending.

Today, providing protection to match developed-economy standards would cost roughly $130 per person on average, yet current spending averages only about $45 per person.[52] Per-person adaptation costs at 2°C would be roughly the same as today.[53] In some places, this may be a manageable cost. For example, $130 is equivalent to less than four hours of average wages in the United States, or about one-sixth of the average minimum premium to insure a car.[54] However, in Bangladesh, that amount is equivalent to about half the monthly average household income, more than 40 percent of which currently goes toward buying food.[55]

The situation is further complicated by the fact that the upside of adaptation takes the form of avoided damages. This can seem intangible and be difficult to appreciate, and upsides are also realized, as we have noted, only if and when hazards materialize. Evidence suggests that people are more likely to invest immediately after extreme weather events, when the benefits of adaptation are readily apparent.[56] For example, government agencies and businesses in California accelerated investment in fire protection following the 2025 Los Angeles wildfires.[57] As such events recede into the past, their influence on adaptation behavior can diminish.[58] Furthermore, risk awareness may be calibrated to today's climate, yet as the world warms to 2°C, adaptation needs could look quite different, as discussed earlier.

Additionally, incentives to invest in adaptation are not always aligned; those who pay are not always the ones who benefit, reducing the motivation to spend. For example, under traditional funding models, all taxpayers may finance projects such as sea dikes, while the direct benefits accrue to specific coastal communities.

Beyond financial considerations, adaptation projects can be challenging to execute, slowing down or even stopping their deployment. Supply chain issues may impede progress on large projects, as may technical challenges, coordination hurdles, and political will. For instance, the Netherlands' "Room for the River" program, designed to increase safety for four million people living in the Dutch river delta, involved a decade of multilevel coordination and consultation among stakeholders.[59]

Maintaining current levels of protection would cost $470 billion annually at 2°C, 2.5 times current spending

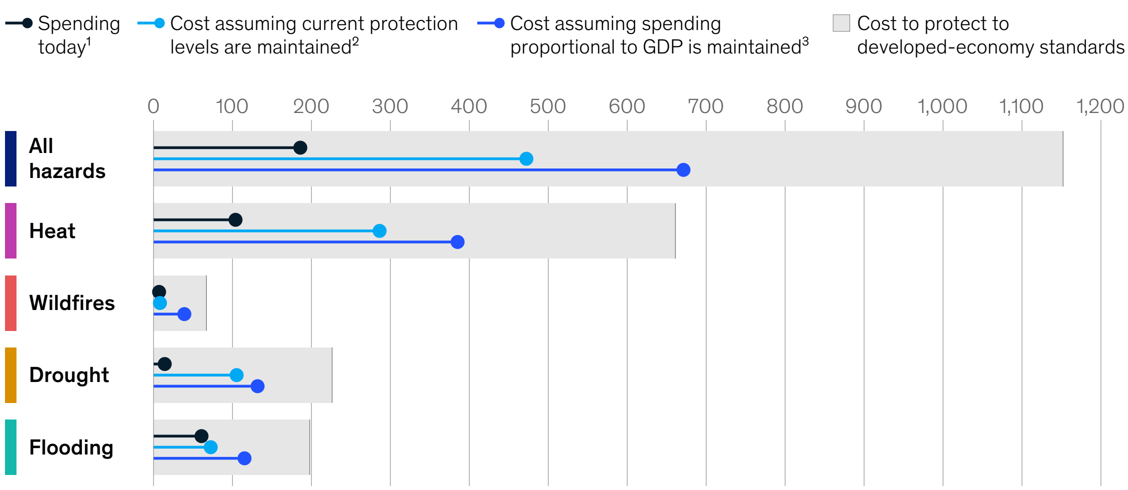
In a warmer world, places facing new or more intense hazards may make spending decisions and trade-offs similar to those of places with similar climatic conditions and demographic characteristics that face hazards today. In other words, the factors that influence how places make adaptation spending decisions today, as evident in current levels of protection, could remain the same. For instance, if 70 percent of high-income urban households are currently protected against heat stress, a similar share might seek protection in the future.

In this case, adaptation spending to protect against 2°C could reach approximately $470 billion annually through 2050, or about 40 percent of the total $1.2 trillion price tag for protecting to standards established in developed economies (Exhibit 11).[60] This would be about 2.5 times current spending. The largest relative gap by hazard on this trajectory is for protection against wildfires, which isn't surprising given that only about 10 percent of land area exposed to wildfires is protected today.

Exhibit 11

Maintaining today's protection levels would represent 40 percent of adaptation costs to protect to developed-economy standards.

Estimated spending on average annual operating and amortized capital costs to adapt to 2°C hazards, 2020–50, $ billion (2020 dollars)



Note: This analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to rise 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures). Costs are for 20 adaptation measures used to adapt to 4 categories of hazards: heat, wildfires, drought, and flooding. The scope also encompasses nonsurvivable heat, the costs of which are incorporated into the other heat-related hazards. This analysis relies on existing and established climate models and techniques, including from the sources below.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Assumes current levels of adaptation spending relative to total adaptation costs continue from 2020 to 2050.
[3]Assumes current levels of adaptation spending relative to GDP continue from 2020 to 2050.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; Kummu, Taka, and Guillaume, 2018; European Union Global Human Settlement Layer; McKinsey Global Institute analysis

McKinsey & Company

Maintaining spending proportional to GDP would cost $670 billion annually at 2°C

As global economic growth continues, the capacity to spend on adaptation could increase. More people can better afford air conditioning as they become wealthier, and richer cities can build more robust flood protection.

Beyond having a bit more to spend, other reasons could motivate people, governments, and companies to spend more in the future; for example, if extreme weather becomes increasingly common. And as we have noted, the cost-benefit economics of adaptation improves with warming.

Should adaptation spending increase in line with anticipated income growth across demographic groups going forward, total annual spending would increase to about $670 billion.[61] This would be 3.5 times today's spending and roughly 60 percent of the estimated costs to adapt to standards established in developed economies in a 2°C world.

The degree to which economic growth helps meet adaptation costs by 2050 is likely to be uneven across the world. If adaptation spending scaled in tandem with economic growth, that growth could offset almost all additional costs of adapting to 2°C in high-income places. In low-income places, however, growth could offset some but not all of the costs.

Adaptation costs and current spending at a regional level illustrate these differences. Take North America. Exposed places there currently spend 0.4 percent of their GDP on average on adaptation measures, or more than enough to cover the costs of protecting to developed-economy standards at 2°C by 2050, assuming spending as a share of GDP stays constant with anticipated economic growth. But emerging economies have a different calculus. For example, current adaptation spending in emerging Asia equals about 0.6 percent of GDP on average in places exposed to climate hazards, yet costs for protecting to developed-economy standards at 2°C could rise to 1.4 percent of exposed GDP by 2050.[62]

Of course, spending may not scale in lockstep with GDP. There is no evidence that spending on adaptation stays constant as a share of GDP as countries grow wealthier.[63] The Netherlands has invested in flood protection for centuries, yet even as total spending has risen over time, the share of spending relative to GDP has declined.[64] And spending patterns are different even among relatively similar places with similar GDP levels. For example, Texas and Missouri have relatively high GDP per capita, yet Missouri has developed comprehensive early-warning systems for riverine flooding while coverage in Texas is uneven across local jurisdictions.[65]

And economic development trajectories themselves are not a given. Importantly, the presence or absence of adaptation measures is itself likely to influence the pace of economic development.[66] Researchers have found that labor productivity among outdoor workers could fall by 25 percent if heat conditions persist at a wet-bulb globe temperature averaging 29.4°C or higher daily.[67] Similarly, drought or flooding can slow income growth for smallholder farmers by reducing agricultural productivity, which in turn could dampen economic growth in countries heavily reliant on agriculture.[68]

CHAPTER 4

A view of adaptation across the world

Hazards vary significantly across the world. So, too, will the costs of adapting to them. As a general rule, a smaller share of places in advanced economies will be exposed at 2°C and will face relatively lower adaptation costs, both on an absolute basis and relative to their GDP. Emerging economies will have greater exposure, and protection to standards established in developed economies could cost more. Nearly everywhere in the world, heat and drought will become more common and contribute most to overall costs.

Advanced economies are more likely to cover a larger share of their adaptation costs

In absolute terms, Greater China and India would incur the highest adaptation costs to provide protection in line with standards established in developed economies—more than $200 billion each annually at 2°C in 2050 (Exhibit 12). Much of this relatively high total compared with other regions is due to each place's large population in places exposed to hazards. Yet in India, even the per capita number of $125 per person is more than a third of the amount budgeted to spend per person in its 2025 central government budget.[69]

Relative to GDP, the costs of protecting to developed-economy standards would be highest by far in Sub-Saharan Africa, with 3 percent of the region's projected GDP in exposed places. That is about 50 percent more than governments in the region paid to service their external debt as a share of GDP in 2024.[70] The costs of such protection in the Middle East and North Africa and in India are a somewhat distant second and third, respectively.

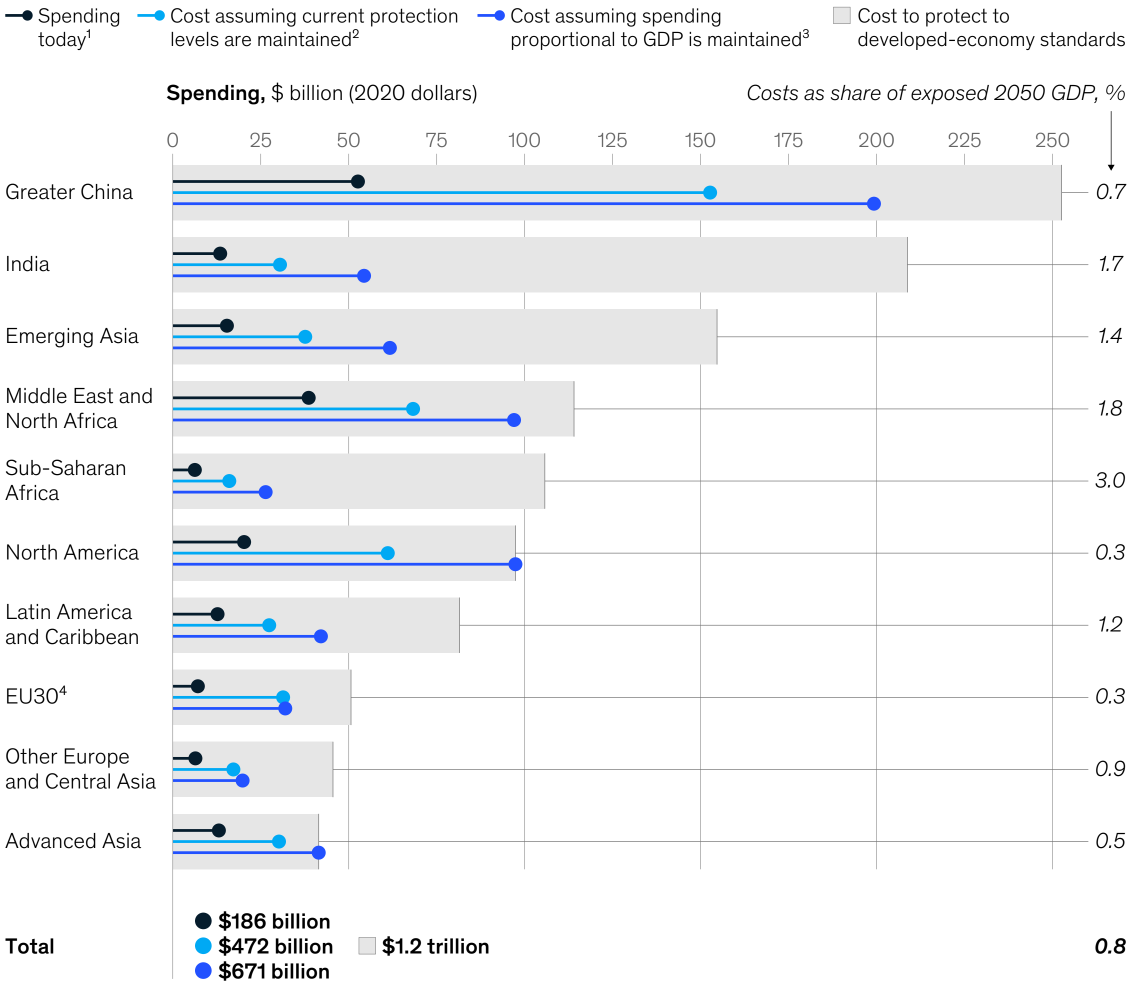
If lower-income regions, including Sub-Saharan Africa and India, maintain their current protection levels at 2°C, they would cover only about 15 percent of the costs to protect to developed-economy standards. Even if adaptation spending in these regions grows in line with anticipated economic growth, it would cover just 25 percent of that cost.

By contrast, advanced economies benefit from higher protection levels today, as noted earlier. If these levels are maintained at 2°C in Advanced Asia and North America, for example, two-thirds of those regions' protection costs may be covered, and increasing spending in line with anticipated income growth could even lead to full coverage of adaptation costs at 2°C.[71]

Exhibit 12

Potential spending estimates suggest many regions could face an adaptation spending gap in a 2°C warming scenario.

Estimated spending on average annual operating and amortized capital costs to adapt to 2°C hazards, 2020–50



Note: This analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to rise 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures). Costs are for 20 adaptation measures used to adapt to 4 categories of hazards: heat, wildfires, drought, and flooding. The scope also encompasses nonsurvivable heat, the costs of which are incorporated into the other heat-related hazards. This analysis relies on existing and established climate models and techniques, including from the sources below.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Assumes current levels of adaptation spending relative to total adaptation costs continue from 2020 to 2050.
[3]Assumes current levels of adaptation spending relative to GDP continue from 2020 to 2050.
[4]Includes the European Union's 27 economies plus Norway, Switzerland, and the United Kingdom.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; McKinsey Global Institute analysis

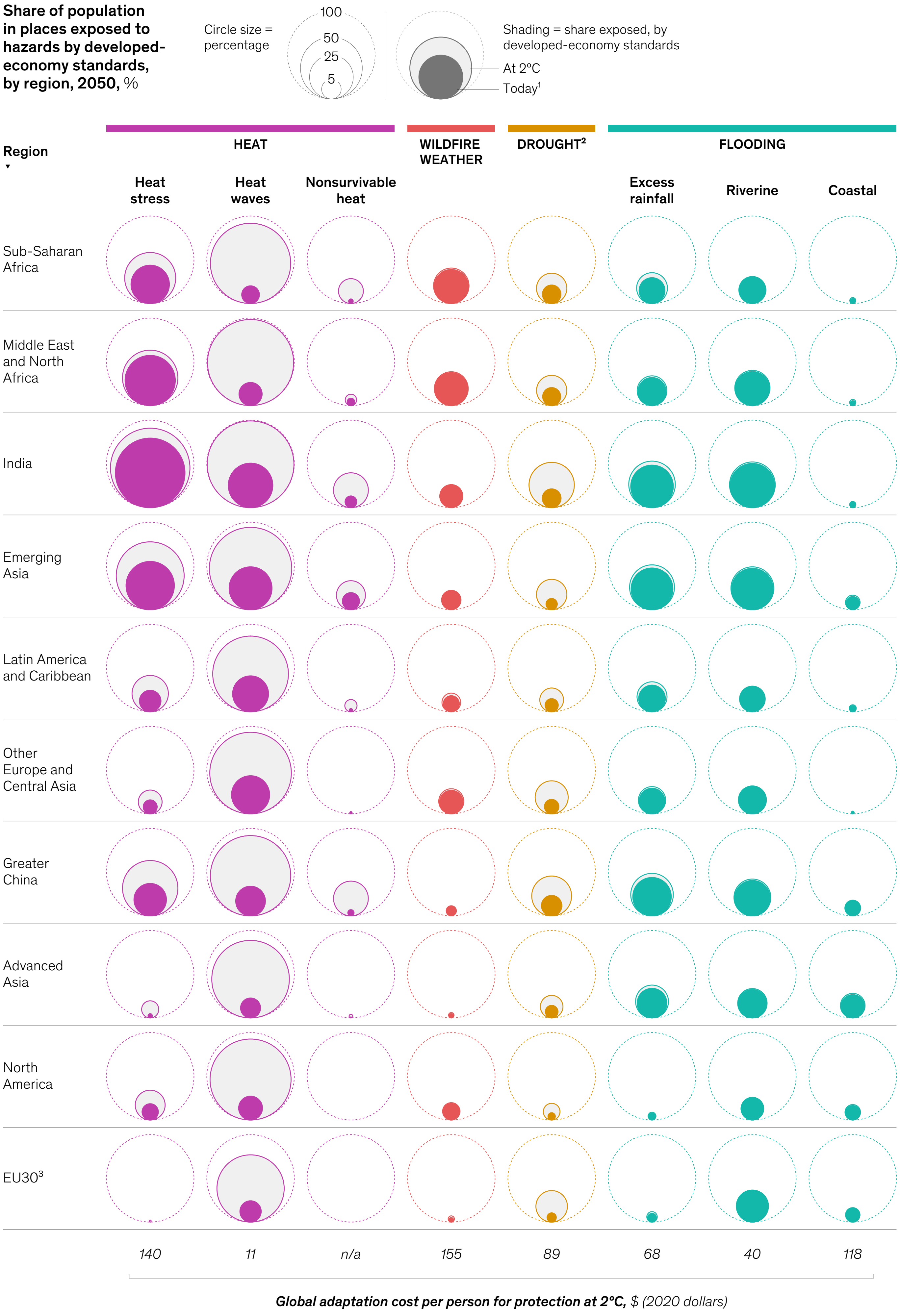
McKinsey & Company

Heat stress and drought contribute most to increase in costs to protect to developed-economy standards at 2°C

As the climate warms to 2°C, heat and drought could see the largest increases in places exposed across regions (Exhibit 13). Floods and wildfires present a different picture. In both cases, a meaningful number of people live in places already exposed today. However, geographic expansion of exposures is likely to be minimal, though some currently exposed places may experience these events more severely.[72] Across the board, adopting standards of protection in developed economies would shield people living in places exposed to hazards at 2°C.

Exhibit 13

Exposure to heat and drought would increase most, as measured by standards in developed economies.



Note: This analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to rise 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures). We refer to places as being "exposed" if they experience events of a magnitude linked to adaptation triggers in developed economies. They could either experience such events every year (for chronic hazards) or have some likelihood of experiencing the event in any given year (for acute events). Not all hazards have comparable impacts. For example, heat stress as we define it may persist for more than a month each year, while heat waves are brief and occur once in a generation. See technical appendix for hazard definitions. The scope also encompasses nonsurvivable heat, the costs of which are incorporated into the other heat-related hazards. This analysis relies on existing and established climate models and techniques, including from the sources below.
[1]Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "today."
[2]Per-person costs for drought are based on the population of people who live in places suitable for agriculture.
[3]Includes the European Union's 27 economies plus Norway, Switzerland, and the United Kingdom.
Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; McKinsey Global Institute analysis

McKinsey & Company

The land area and people living in places exposed to heat will increase most, a pattern that requires an understanding of various heat hazards to interpret properly. Heat stress can have large impacts every year in affected places and is among the most expensive hazards to protect against. Exposed places endure at least a month of very hot and humid weather every year, compromising productivity and potentially affecting the health of residents unable to stay cool. Many regions are expected to see an increase in heat stress exposure at 2°C, and lower-income regions are expected to see the largest exposures at that level of warming. Across China, emerging Asia, India, and Sub-Saharan Africa collectively, more than half of the population could live in locations exposed to heat stress. With protection, people living in these places would be safeguarded by measures such as air conditioning and urban greening.

At protection standards established in developed economies, even more places across all regions would be exposed to heat waves at 2°C compared with today. While heat waves can hit vulnerable people particularly hard, they are relatively rare and short events and affect the average person less, as previously discussed.[73] The adaptation measures to address heat waves are also relatively inexpensive, accounting for only a minimal portion of overall adaptation costs. Protecting to developed-economy standards would mean putting in place measures like early-warning systems ready to deploy should an event occur.

Exposure to nonsurvivable heat, a near-theoretical concern today, may increase in some emerging economies as the global temperature rises to 2°C. Nonsurvivable heat occurs when temperatures and humidity are so high that the body can no longer cool itself by sweating, a condition that can lead to fatal overheating. Exposure is defined as having a greater than 1 percent probability of such extreme heat and humidity occurring. Places exposed to nonsurvivable heat generally are also exposed to heat stress and heat waves, and adaptation measures for those hazards also offer protection against nonsurvivable heat.

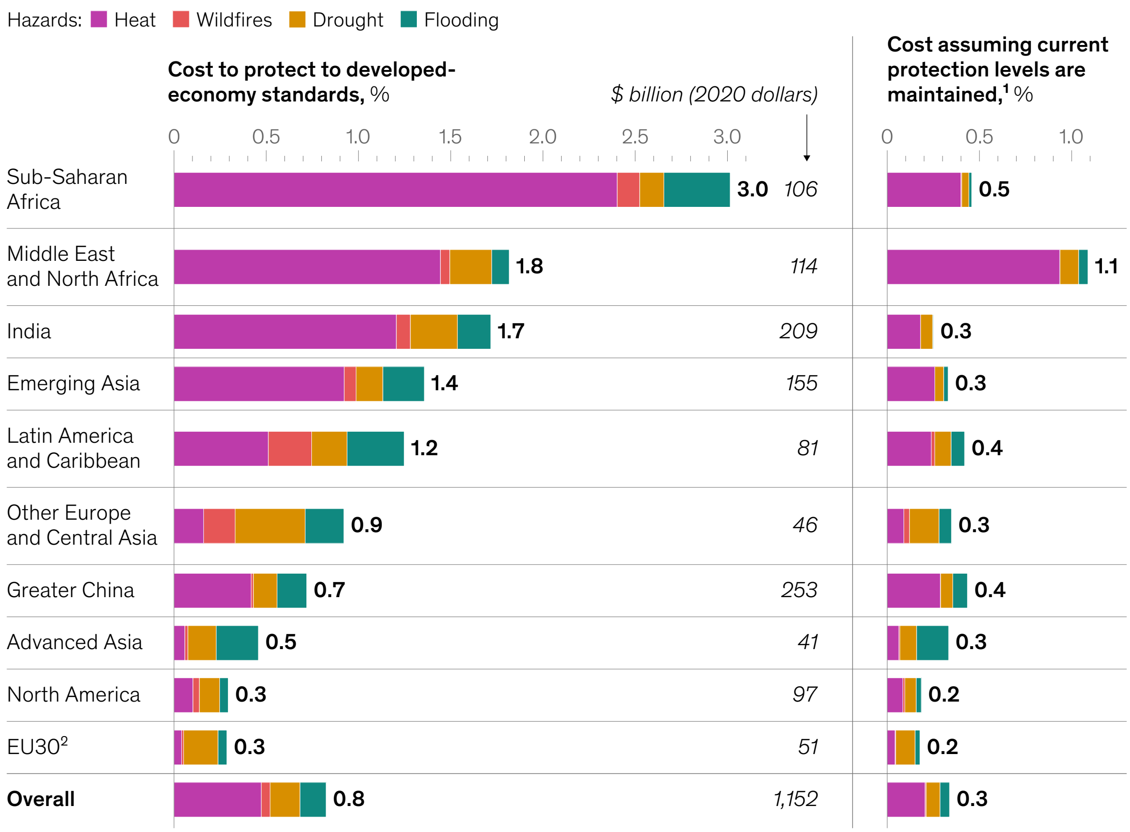
The costs of providing protection in line with standards established in developed economies at 2°C would increase across regions corresponding to these shifts. In Emerging Asia, Greater China, India, the Middle East and North Africa, and Sub-Saharan Africa, about 70 percent of the adaptation costs at 2°C would go toward combating heat hazards, primarily air-conditioning costs to cool people during protracted periods of heat stress (Exhibit 14). Even if protection remains at current levels, these regions would devote almost three-fourths of their adaptation spending to addressing heat.

By contrast, less than 10 percent of the population of the EU30, North America, and Other Europe and Central Asia would live in places exposed to heat stress.[74] The largest share of spending at 2°C in these regions would go toward managing drought. If current levels of protection were maintained at 2°C, more than 40 percent of their spending would be allocated to addressing drought, and slightly more than a third toward managing heat stress.

Exhibit 14

More than 70 percent of adaptation costs in Sub-Saharan Africa, the Middle East and North Africa, and India would go toward heat hazards.

Average annual operating and amortized capital costs to adapt to 2°C hazards, as share of 2050 exposed GDP, %



Note: Costs are for 20 adaptation measures. This analysis is based on warming levels likely under current emissions trajectories, which project that the global temperature is likely to rise 2°C relative to preindustrial levels sometime in the next 3 decades (measured based on multidecadal average temperatures). The scope also encompasses nonsurvivable heat, the costs of which are incorporated into the other heat-related hazards. This analysis relies on existing and established climate models and techniques, including from the sources below.

[1]Assumes current level of adaptation spending relative to total adaptation spending to adapt to 1.1°C, by hazard and demographic group, stays the same at 2°C.

[2]Includes the 27 European Union economies plus Norway, Switzerland, and the United Kingdom.

Source: Coupled Model Intercomparison Project (CMIP6), 2021; NASA NEX-GDDP, 2021; Fathom Global Flood Map Fathom 3.0, 2021; Inter-Sectoral Impact Model Intercomparison Project Phase 2b (ISIMIP2b), 2017; McKinsey Global Institute analysis

McKinsey & Company


HYUNDAI

CHAPTER 5

Who pays?

Ultimately, households, governments, and companies decide what to spend on. As noted, numerous factors beyond cost-benefit economics, ranging from capacity to pay to risk tolerance to operational challenges, could shape adaptation decisions. Importantly, spending on adaptation isn't just a matter of availability of funds, but also of how resources are prioritized to address competing demands (see also sidebar "Adaptation in the context of other spending priorities"). Going forward, the ability to finance and scale adaptation—and mitigation—as well as the evolution of damages from extreme weather events and the limits of adaptation will determine the risks societies bear.

How might different actors make adaptation decisions? And who bears the cost ultimately? Crucially, these decisions are not made in isolation. Each actor's decisions are shaped by and, in turn, shape the choices of others.

Individuals and households are on the front lines of heat adaptation

About half of the estimated $1.2 trillion of the costs needed to adapt to 2°C is tied to protection against heat, about three-quarters of which are operating costs. Many of the measures that address heat, such as air conditioning, passive cooling, and reflective roofs, can be implemented by individuals, provided they can afford them.

Economic development linked to rising incomes for individuals can help, as we've noted. Yet household-level adaptation is more than a question of personal finances. Governments can shape how individuals approach decision-making by improving awareness of climate risks and enhancing affordability through rebates, tax incentives, and procurement plans that lower costs and strengthen supply chains. Government flood-resilience grants that support retrofitting in Queensland, Australia, and the Eco-Roof Incentive Program in Toronto, Canada, illustrate how targeted policies can support adoption.[75] New York City helps vulnerable residents purchase and install air conditioners.[76] Insurers, too, can encourage adaptation, as we discuss later. In practice, the balance between private capacity and public support could shape how widely and quickly households adapt.

Governments can build and enable large-scale infrastructural defenses, especially for floods and wildfires

For hazards requiring large-scale, infrastructure-related defenses such as flood barriers and wildfire prevention, measures for which capital expenditures amount to about $160 billion annually, governments may play a more central role. In such cases, the collective risk tolerance of communities and their degree of exposure influence decisions on whether to adapt or accept the risk.

Moreover, these projects require significant financing, raising questions of capital availability and how to best spread costs across taxpayers and beneficiaries of these investments. Some projects, like London's £16 billion Thames Estuary 2100 program, have pursued "beneficiary pays" models with contributions from businesses, developers, and protected landowners using tools like planning obligations and community levies.[77]

Sidebar

Adaptation in the context of other spending priorities

As stakeholders decide how to allocate funds for adaptation, they will likely weigh this spending against other competing priorities. It is essential, therefore, to understand how to situate adaptation within the broader context of other spending.

One natural comparison that may be tempting to make is between the adaptation costs identified in this work and the costs of mitigation. Adaptation and mitigation can both reduce the impact of climate hazards, but each in its own way. Adaptation is about protecting people from hazards today and in the future as Earth warms. Mitigation, on the other hand, aims to slow or halt that warming by reducing emissions, thereby influencing the level of adaptation needed.

In earlier work, MGI estimated that an emissions trajectory consistent with limiting warming to 1.5°C would require high- and low-emissions capital spending for energy and land-use systems (like solar or gas power assets) of about $9.2 trillion annually through 2050 with continued investments beyond that.[1] However, interpreting this to suggest that adaptation is less expensive than mitigation is misleading, as this number and the adaptation cost estimates in this research are not directly comparable.

Instead, a meaningful comparison of the relative role of adaptation and mitigation in reducing climate risks would require a systematic assessment of their respective costs at different warming levels. After all, even 2°C or 3°C of warming would entail some capital spending for energy and land use. Such an assessment also would need to account for a host of other factors, such as the evolution of climate damages with warming; the increasing costs and potential limits of adaptation at higher warming levels; the knock-on effects—both the economic costs and benefits—of adaptation and mitigation investments; and any residual risks that remain and associated costs to bear and recover from those risks, as well as differing views on the appropriate discount rates to apply.[2] More broadly, beyond the relative costs, factors such as equity, outcomes for the most vulnerable, and impacts on nature can shape how stakeholders view the relative role of each.

Additionally, in a world constrained by limited funding, another tempting comparison is between adaptation costs and the costs of economic development, such as investments in infrastructure, education, healthcare, and other drivers of productivity. Spending needs for development are high, with large gaps. For example, the annual UN Sustainable Development Goals investment gap in developing countries is estimated at about $4 trillion.[3] Yet here, too, adaptation must be weighed with care against economic development. As this research highlights, development enhances the capacity to adapt. Thoughtful development activity, for example through urban planning that incorporates climate risks, can also support resilience. At the same time, insufficient adaptation could hinder development.[4] And, in fact, many adaptation measures can even promote development. For example, irrigation systems can limit the impact of drought and also boost agricultural output, creating mutually reinforcing benefits rather than competing priorities.

1 *The net-zero transition: What it would cost, what it could bring*, McKinsey Global Institute, January 2022.
2 Some academic studies have attempted a systematic comparison of all climate costs. See, for example, Simon Dietz et al., "The economics of 1.5°C climate change," *Annual Review of Environment and Resources*, 2018, Volume 43; Martin C. Hänsel et al., "Climate economics support for the UN climate targets," *Nature Climate Change*, March 2021; and Peter H. Howard and Thomas Sterner, "Few and not so far between: A meta-analysis of climate damage estimates," *Environmental and Resource Economics*, June 2017.
3 *SDG Investment Trends Monitor*, Issue 4, UNCTAD, September 2023.
4 *Rising to the challenge: Success stories and strategies for achieving climate adaptation and resilience*, World Bank, 2024.

Given the scale of funding required and the typically long lifetimes of these projects, such measures need to be designed carefully, taking into account not just the climate conditions of today but future climate changes as well. This can be done through flexibility or modularity that allows upgrades as risks evolve, for example. An illustration of this is the Thames Barrier, a major component of the Thames Estuary program, designed to accommodate additional gates and increase defenses over time as sea levels rise.[78] Keeping warming beyond 2°C in mind can also be important for specific places, where taking a long-term view could result in a different suite of measures than a short-term view alone might. For example, zoning could limit the construction of assets in hazard-prone areas, rather than merely building defenses. Furthermore, when governments undertake broader public infrastructure investments such as urban planning projects or building infrastructure related to the energy transition, they could ensure that these investments are designed to be climate resilient.

Another consideration is how to manage the uncertainties associated with climate modeling, especially at the more granular levels relevant to local decision-making. This could influence design parameters such as the carrying capacity of stormwater networks and the height of coastal flood defenses.[79] Adaptation planning could account for these uncertainties through a range of approaches, from implementing "no regrets" measures that deliver benefits under any future scenario to applying more conservative or stringent design standards and adopting flexible strategies, as described above, that include trigger points for future interventions as conditions evolve.

In addition to playing a central role in large public adaptation projects, governments also play an enabling role in supporting adaptation. They can provide social protection, supporting the most vulnerable with direct subsidies or community-level investments, approaches that vary widely across contexts and political philosophies. Cities like Seoul and Phoenix, Arizona, for example, provide subsidies to low-income households for cooling measures like air-conditioning installation and repair.[80] In India, public programs invest in drought-resilient crops and irrigation systems to support the adaptation efforts of smallholder farmers.[81] Another approach is to offset the up-front costs of adaptation measures, such as home flood retrofits, and allow repayment over time via property tax assessments.[82]

Planning and setting standards are other tools that governments use to support adaptation. Land-use rules can prevent new development in high-risk areas, and updated building codes can encourage more resilient real estate development. Such standards can be put in place proactively to address potential climate shifts down the road. For example, New York City restricts new construction in flood-prone areas, while France requires new public buildings to incorporate shading and ventilation.[83] Another approach is to establish recognized standards that enable private stakeholders, such as insurers, to encourage adaptation. For example, the FORTIFIED Home program in the United States certifies storm-resistant properties, which can then qualify for lower insurance premiums.[84]

Companies could navigate resilience across hazards and consider opportunities

Ultimately companies from the largest to the smallest need to decide where and how to invest in resilience and where to bear some level of risk. Of course, larger companies may have greater resources, so their calculus will differ, whereas small businesses may be more financially constrained.

No matter the landscape in which companies make these decisions, the broader context of public infrastructure and household income levels will shape them. A business operating behind a government-built levee will have a different calculus from one directly exposed to flooding. Similarly, a company operating in a region with extensive, government-supported irrigation systems, such as India's Indira Gandhi Canal, will approach drought risk differently from one operating where drought is not managed by any public entity.[85]

For companies that choose to invest in managing direct or indirect exposures in their operations, supply chains, or distribution channels, many options exist. Even today, many firms in sectors ranging from utilities to food and beverage are actively considering how to manage climate risks. Measures being put in place include site-level defenses like flood proofing and firebreaks around buildings, microgrids, and cooling systems, to name a few.

Embedding adaptation decisions into forward-looking capital planning is another important consideration. For instance, some agricultural businesses may consider moving cultivation zones, as specialty crops like coffee and wine may thrive in new regions. New assets could be built in locations that have lower exposure to risks.[86]

Additionally, companies may also extend support to their employees, customers, and even surrounding communities, as many already do. Some businesses are investing directly in local resilience efforts by funding community infrastructure such as cooling hubs, supporting rural livelihoods through ecosystem restoration and water-access initiatives, and even creating biodiversity corridors that help buffer surrounding landscapes against droughts and floods.

Shifting climate conditions can also create new opportunities to meet demand for adaptation products and services. Revenue pools may emerge as private actors—individuals and companies—seek to manage their exposure to risk and as governments invest to protect their populations. For example, companies that provide roofing, insulation, and waterproofing systems that increase the resilience of buildings against heat and water damage can find revenue opportunities. One vital ingredient for adaptation is companies' participation in providing solutions, including the innovation they can bring to reducing the costs of adaptation measures and enhancing the efficiency and effectiveness of technologies such as undergrounding, irrigation, and air conditioning.

Unlocking capital: Financing and scaling adaptation

Adaptation cannot happen without financing. Some 40 percent of the overall adaptation costs for the 20 measures we analyzed are capital expenditures, a share that's still higher for hazards requiring major infrastructure such as flood defenses. Consumer-led measures such as air conditioning may have relatively lower up-front capital costs, but the investments required could nonetheless be material for an individual or household.

Yet financing for adaptation measures is challenging, and many structural barriers exist. Incentives to invest can be misaligned, as those who pay and those who benefit are not always the same. Benefits often come in the form of forgone damages rather than direct cash flows, and underlying climate risks can be hard to evaluate, resulting in uncertainty about the value and timing of benefits.

Maintaining today's protection levels at 2°C by implementing the 20 adaptation measures we examine would require a total of $6 trillion in capital investment by 2050.[87] While some of this could come from individuals, governments, and companies funding the adaptation measures themselves, much would likely require external financing. Financial institutions can play a pivotal role in mobilizing this capital, starting with scaling existing financial products. Banks, for instance, could extend targeted loans for household retrofits such as flood proofing, particularly where mortgage relationships already exist. Similarly, up-front resilience investments could be included in project finance for large infrastructure projects.

If protection were raised to developed-economy standards everywhere at 2°C, a total of roughly $15 trillion in capital investment would be needed, further increasing financing demands. Meeting these needs would likely require scaling traditional financial products and innovating new, adaptation-focused financing solutions.

Blended finance models that combine concessional and market-rate capital as well as instruments like municipal bonds are already supporting adaptation and could be scaled further.[88] For instance, Miami's $400 million Miami Forever Bond financed climate resilience as well as other municipal priorities such as infrastructure and public safety initiatives.[89]

Emerging mechanisms such as resilience bonds go further by channeling capital exclusively toward adaptation and, in some cases, linking payouts directly to measurable resilience outcomes. Tokyo's certified Resilience Bond directs funds to projects like flood defenses and undergrounding utility poles.[90] In parallel, institutional investors are beginning to show interest in funding resilience and investing in companies that supply adaptation products and services, supported by emerging taxonomies that identify such businesses and enable the development of focused investment strategies.[91]

To serve this expanding adaptation finance market, financial institutions will need to build new capabilities, such as climate-risk modeling, techniques for quantifying returns from adaptation, and embedding resilience metrics into underwriting and investment frameworks.

Finally, while overall adaptation financing is of course contingent on demand from individuals, governments, and companies looking to manage their risks, in some instances financial institutions are proactively undertaking measures aimed at spurring demand and driving scale. In California, insurers have begun offering discounts on property insurance for homeowners who adopt wildfire adaptation measures, though it is too early to determine the uptake.[92]

Picking up the pieces: Who pays when adaptation is absent or insufficient

As with any form of risk, people and organizations hoping to manage climate-related risks can invest to adapt to various degrees or to bear the risk. As we have discussed, various factors ranging from risk tolerance to spending priorities and the decisions of other actors can influence how households, governments, and companies make this decision.

Those who choose to bear some or all of the risk may use insurance to help them manage and shift its financial burden. Under typical property insurance plans, policyholders pay annual premiums that they cash in on, say, in the event of flood-related damages. Parametric insurance is a variation on this, paying out a fixed amount to the policyholder when a specific, measurable trigger event occurs, like a heat wave above a certain temperature and over a certain number of days. Unlike traditional property insurance, parametric insurance doesn't require an assessment of actual physical damage, although establishing and monitoring trigger parameters must be done carefully. Recently, such insurance plans were launched for women farmers in India and construction workers in Hong Kong to protect them from income loss during extreme heat waves.[93]

Of course, stakeholders may instead opt to absorb the risk and not rely on insurance, which may not always be available or affordable, especially as risks intensify.[94] And even in cases where an adaptation measure or insurance is in place, hazards can still generate residual losses that must be absorbed somewhere in the system. To absorb losses, households may need to draw down savings or go into debt, businesses may need to write off assets, insurers and reinsurers may pay claims, and governments often need to step in with disaster relief. In many high-income settings, the expectation that public authorities will act as insurers of last resort may also dampen incentives for private adaptation and risk reduction.[95] Ultimately, someone will have to pay for risks.

Humans have long adapted to extreme weather, using often ingenious methods to survive droughts, wildfires, heat stress, and flooding. The world has developed many cost-effective adaptation measures that are in use today. Yet resiliency gaps persist and will increase and evolve as our climate shifts. Ultimately, households, governments, and companies will decide if and how to spend more on adaptation. Understanding today's gaps and future needs will help inform those choices—and support increased well-being and prosperity for all.

Library of adaptation measures

Active cooling—air conditioning

How it works: Active cooling (air conditioning) uses mechanical cooling systems, like standard AC units or heat pumps, to regulate indoor temperatures.

Hazards protected against: Heat stress, heat waves, nonsurvivable heat

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	50–70%	70–90%	**90–100%**

- Protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments
- Offers complete indoor protection from heat exposure, but limited outdoor benefits
- Protects only electrified areas

Benefit-to-cost ratio[1]

1.5–3	**3–5**	5–10	10+

Challenges and risks

- May increase energy consumption and emissions in regions reliant on fossil-based power
- Can exacerbate the urban heat island effect through waste heat discharge

Examples of deployment

- New York City offers a program that assists vulnerable populations with the purchase and installation of air conditioners.
- In Dubai, UAE, centralized plants have district cooling systems that provide AC to residential and commercial buildings, saving up to 35% in energy through efficiencies.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Active cooling—fans

How it works: Electrically- or manually-operated fans circulate air, increasing convective and evaporative cooling in ways that help people feel cooler during heat events.

Hazards protected against: Heat stress, heat waves

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	50–70%	**70–90%**	90–100%

- Protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments, cooling the body rather than the environment
- Offers limited protection in extreme heat or high humidity, when cooling without lowering ambient air temperature may be insufficient to prevent heat-related risks

Benefit-to-cost ratio[1]

1.5–3	3–5	5–10	**10+**

Co-benefits

- Uses much less electricity than air conditioning, lowering utility costs and emissions

Examples of deployment

- Singapore's Ministry of Manpower has a heat stress framework which guides employers to provide fans for workers at specified Wet Bulb Globe Temperature thresholds.
- In Dallas, Texas, TXU Energy and The Senior Source partnered to provide over 200 box fans to seniors who lack access to air conditioning.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Passive building cooling

How it works: Passive building cooling uses passive physical strategies, such as shading, insulation, and natural ventilation, to reduce indoor temperatures.

Hazards protected against: Heat stress, heat waves, nonsurvivable heat

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50% | **50–70%** | 70–90% | 90–100%

- Moderately protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments
- Does not protect against damages related to outdoor heat
- Can decrease temperatures by 2°C or more but may not fully protect against heat-related risks at higher temperatures

Benefit-to-cost ratio[1]

1.5–3 | 3–5 | **5–10** | 10+

Co-benefits

- Decreases energy consumption, lowering utility costs and emissions

Examples of deployment

- Barcelona conducted a pilot project to passively cool 11 public schools, and students attending those schools reported reduced fatigue, increased concentration, and less stress.
- Oman relies on traditional wind catchers, rectangular towers designed to passively direct breezes into buildings and allow warm air to escape to reduce heat stress.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

White roofs

How it works: White roofs use reflective materials such as white coatings or membranes to reduce solar heat absorption and lower indoor temperatures. Green roofs are similar solutions, using vegetation to provide similar cooling benefits through enhanced evapotranspiration.

Hazards protected against: Heat stress, heat waves, nonsurvivable heat

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	50–70%	70–90%	90–100%

- Protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments
- Can decrease temperatures by 1°C or more, although may not fully protect against heat-related risks at higher temperatures
- Protects only covered structures and does not extend to outdoor environments or all building types, such as stadiums

Benefit-to-cost ratio[1]

1.5–3	3–5	**5–10**	10+

Co-benefits

- Decreases energy consumption, lowering utility costs and emissions

Challenges and risks

- Must be repainted roughly every decade in addition to regular cleaning for maintenance, which may add operational costs

Examples of deployment

- Telangana, India, has a cool roof policy that mandates cool roofing in government and nonresidential buildings.
- New York City's CoolRoofs program aims to install one million square feet of white rooftops annually.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Urban trees

How it works: Expansion of tree canopy and vegetative cover in cities lowers ambient and surface temperatures through shading and enhanced evapotranspiration.

Hazards protected against: Heat stress, heat waves, nonsurvivable heat

Places this adaptation measure is most relevant: Towns, cities

Extent of damage reduction

30–50% | **50–70%** | 70–90% | 90–100%

- Protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments
- Reduces broader urban heat intensity when implemented at scale, although may not fully protect during extreme heat events
- Offers direct protection for outdoor spaces, and shade may also reduce indoor heat exposure in buildings

Benefit-to-cost ratio[1]

1.5–3 | 3–5 | 5–10 | 10+

Co-benefits

- Decreases stormwater runoff by enhancing soil infiltration and improves urban air quality by filtering pollutants
- Improves access to nature and outdoor spaces

Examples of deployment

- Melbourne's Urban Forest Strategy aims to increase canopy cover from 22 percent to 40 percent by 2040 to reduce urban heat.
- Medellín, Colombia, reduced average temperatures by 2°C by implementing "green corridors" with trees and plants at a cost of $6.50 per person.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Cooling shelters for vulnerable populations

How it works: Cooling shelters, sometimes called cooling centers, are air-conditioned public spaces that provide safe refuge, hydration, and basic services for vulnerable populations such as older adults during extreme heat events.

Hazards protected against: Heat waves, nonsurvivable heat

Places this adaptation measure is most relevant: Towns, cities

Extent of damage reduction

30–50%	**50–70%**	70–90%	90–100%

- Protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments
- Protects only people who can spend time in a shelter during a heat event

Benefit-to-cost ratio[1]

1.5–3	**3–5**	5–10	10+

Co-benefits

- Can serve as emergency shelters during natural disasters

Challenges and risks

- Transportation barriers may limit use among vulnerable populations

Examples of deployment

- During the 2021 Pacific Northwest heat dome, Portland, Oregon, activated three cooling shelters that were open all day to provide relief for vulnerable residents.
- Valencia, Spain, has a network of public cooling shelters to provide safety during heat waves.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Temporary cooling shelters for urban outdoor workers

How it works: Temporary urban cooling shelters for outdoor workers provide shaded, ventilated, or air-conditioned spaces where outdoor workers can take breaks to lower their core body temperatures when encountering heat stress.

Hazards protected against: Heat stress, heat waves

Places this adaptation measure is most relevant: Towns, cities

Extent of damage reduction

30–50% | 50–70% | 70–90% | 90–100%

- Protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments
- Offers limited protection to outdoor workers, constrained by the time spent inside shelters

Benefit-to-cost ratio[1]

1.5–3 | 3–5 | **5–10** | 10+

Co-benefits

- Reduces absenteeism during extreme heat events

Examples of deployment

- South Korea requires outdoor workers to take 20-minute breaks every two hours, with employers expected to provide rest areas with shading and hydration.
- The United Arab Emirates provides more than 10,000 air-conditioned rest stations for delivery workers to use during afternoon breaks in the hottest months.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Personal cooling

How it works: Personal cooling is the distribution of heat management solutions, such as water bottles, electrolyte packets, portable fans, and cooling towels, to vulnerable populations, outdoor workers, and other individuals who lack reliable access to other cooling measures. Cooling kits are modular and can be tailored to individual needs.

Hazards protected against: Heat waves, nonsurvivable heat

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	50–70%	70–90%	90–100%

- Moderately protects against heat-related health risks such as heat stroke and sleep disruption, and reduces productivity losses from poor work performance in overheated environments
- Targets individuals without access to other cooling measures
- Offers only short-term relief, with limited capacity to reduce core body temperature during prolonged heat exposure

Benefit-to-cost ratio[1]

1.5–3	3–5	5–10	10+

Examples of deployment

- Budapest, Hungary, has public drinking-water fountains to protect residents during heat waves, a part of its Cooling Programme.
- In Sacramento, California, local community groups operate dozens of pop-up cooling stations, simple coolers filled with ice and bottled water set out across neighborhoods during heat waves to provide relief to passersby.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Crop shade cover

How it works: Crop shade cover creates partial shading over crops using physical structures, like nets or canopies, as well as natural elements like tall trees, to reduce direct solar radiation.

Hazards protected against: Heat stress, drought

Places this adaptation measure is most relevant: Rural areas, towns

Extent of damage reduction

30–50%	50–70%	70–90%	90–100%

- Protects against crop yield loss, slightly lowering crop temperatures and evapotranspiration rates.

Benefit-to-cost ratio[1]

1.5–3	3–5	5–10	10+

Co-benefits

- Shields plants from harmful UV radiation and, if insect-proof netting is used, pests
- Can reduce irrigation needs, decreasing the operational costs of water management

Challenges and risks

- Needs adjustment for local conditions and crop needs, as excessive shade may restrict sunlight

Examples of deployment

- Western Australia recently allocated $2.6 million for permanent horticultural netting, which is expected to make crops more resilient to extreme weather and increase water use efficiency.
- Netting has been used in the apple-producing region of southern Tyrol, Italy, and has been found to reduce the temperature and evaporation rate in apple orchards.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Underground power lines

How it works: Undergrounding powerlines involves moving electrical transmission or distribution lines below ground to reduce wildfire ignition risk.

Hazards protected against: Wildfires

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	**50–70%**	70–90%	90–100%

- Significantly reduces ignition risk from overhead powerline, which are linked to two thirds of wildfire damages.

Benefit-to-cost ratio[1]

1.5–3	**3–5**	5–10	10+

Co-benefits

- Improves reliable access to power by preventing damage to powerlines from wildfire, flooding, and a range of other natural disasters
- Lowers maintenance costs by reducing inspections and vegetation trimming
- Enhances property values in nearby areas by reducing risk and improving aesthetics

Examples of deployment

- Powercor, an Australian electricity distributor, undergrounded 334 kilometers of lines as part of a government program to reduce the risk of wildfires.
- In Greece, the Hellenic Electricity Distribution Network Operator has undergrounded roughly 30 thousand kilometers of lines, partly by removing overhead lines that passed through a protected forest area.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Fuel management

How it works: Fuel management strategically removes flammable vegetation such as forests, grassland, and urban interfaces to reduce the severity of wildfires.

Hazards protected against: Wildfires

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	**50–70%**	70–90%	90–100%

- Protects against wildfire damages to homes and infrastructure
- Does not reduce the probability of ignition
- Offers limited protection during extreme wildfires as conditions can overwhelm its protective effects

Benefit-to-cost ratio[1]

1.5–3	**3–5**	5–10	10+

Co-benefits

- Helps manage ecosystems by promoting native plant growth and decreasing exotic plant cover
- Reduces firefighting costs by making wildfires easier and safer to control

Challenges and risks:

- Can create costly wildfire damages if prescribed burns escape containment, although the likelihood is less than 1 percent

Examples of deployment

- In California's Sierra Nevada foothills, local associations conduct prescribed burns, a fuel management technique, across private lands as part of a state-supported initiative to reduce wildfire fuel loads on 400,000 acres annually.
- The Government of South Australia runs a Prescribed Burn Program that dynamically schedules burns on short notice when weather conditions favor effective and low-risk burning.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Irrigation

How it works: Irrigation systems, including hand pump, drip, sprinkler, gravity-fed, and other methods, optimize water delivery to crops.

Hazards protected against: Drought

Places this adaptation measure is most relevant: Rural areas, towns

Extent of damage reduction

30–50%	50–70%	70–90%	**90–100%**

- With adequate water supply, protects against crop yield loss and maintains soil moisture during drought

Benefit-to-cost ratio[1]

1.5–3	3–5	**5–10**	10+

Co-benefits

- Enhances food security by stabilizing crop yields during dry spells or irregular rainfall
- Increases reliability of harvests, which supports rural livelihoods by improving farmer income and reducing vulnerability to climate shocks.

Challenges and risks

- May deplete scarce water resources in drought-prone regions if water demand is high
- May not be feasible in regions with limited or unreliable water availability, where existing resources are already stressed

Examples of deployment

- Almost all California cropland is irrigated, where water-efficient drip irrigation techniques have increased in response to drought.
- The Gezira plan in Sudan leverages 4,300 kilometers of canals and ditches to irrigate cash crop fields with water from the Nile river.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Detention basins

How it works: Detention basins are engineered landforms that temporarily hold stormwater runoff, releasing it gradually through soil infiltration or drainage infrastructure. By buffering excess flows until existing systems can accommodate them, they reduce the severity of excess-rainfall flooding.

Hazards protected against: Excess-rainfall flooding

Places this adaptation measure is most relevant: Towns

Extent of damage reduction

30–50%	50–70%	70–90%	**90–100%**

- With sufficient capacity, protects against most flood-related damages such as property destruction, infrastructure impacts, and economic disruptions

Benefit-to-cost ratio[1]

1.5–3	3–5	5–10	10+

Co-benefits:

- Can enhance water quality, as vegetation and soil filter out pollutants in runoff

Challenges and risks

- Requires substantial land area, limiting feasibility of deployment in densely developed urban environments

Examples of deployment

- Champaign, Illinois, spent $38 million to construct Boneyard Creek, a large detention basin, to prevent 100-year flood events in its downtown areas.
- Christchurch, New Zealand, employs multiple detention basins, including the Winters Road basin, which can hold 50 thousand cubic meters of floodwater.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Stormwater networks

How it works: Stormwater drainage systems are networks of underground pipes and storage systems that store and convey stormwater.

Hazards protected against: Excess-rainfall flooding, riverine flooding

Places this adaptation measure is most relevant: Towns, cities

Extent of damage reduction

30–50%	50–70%	70–90%	**90–100%**

- With sufficient capacity, provides benefits by protecting against most flood-related damages such as property destruction, infrastructure impacts, and economic disruptions

Benefit-to-cost ratio[1]

1.5–3	**3–5**	5–10	10+

Co-benefits

- Can improve water quality by incorporating elements to filter sediments and pollutants before discharge

Challenges and risks

- Requires careful upfront design to ensure effectiveness under future climate conditions and urban growth, given its long lifespan

Examples of deployment

- Howard County, Maryland, has broken ground on a mile-long tunnel that will transport up to 26,000 gallons of water per second from Ellicott City to the nearby Patapsco river.
- Ahmedabad, India, is linking 50 lakes through an interconnected stormwater pipeline network that can serve as overflow sink during monsoons.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Swales

How it works: Swales are shallow channels cut into the ground to capture and direct stormwater, conveying it away from buildings or agricultural areas.

Hazards protected against: Excess-rainfall flooding, riverine flooding

Places this adaptation measure is most relevant: Rural areas

Extent of damage reduction

30–50%	50–70%	70–90%	90–100%

- Modestly protects against damages to crops and land by reducing soil erosion, runoff, and standing water
- Offers limited protection as intense flooding can overwhelm storage capacity

Benefit-to-cost ratio[1]

1.5–3	3–5	5–10	10+

Co-benefits

- Increases groundwater recharge through reduced runoff, collecting water that can be used for irrigation

Examples of deployment

- In New Mexico, ranchers used swales in combination with rip-lines, which are shallow furrows above the swales, to slow and spread rainwater across pastures by increasing infiltration in the soil.
- Farmers in Tanzania employ traditional techniques similar to swales, called fanya chini and fanya juu, preventing soil erosion while capturing stormwater.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Levees

How it works: Levees are barriers along riverbanks that reduce flooding into protected portions of a floodplain.

Hazards protected against: Riverine flooding

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	50–70%	70–90%	**90–100%**

- With sufficient capacity, protects against damages such as property destruction, infrastructure impacts, and economic disruptions

Benefit-to-cost ratio[1]

1.5–3	3–5	**5–10**	10+

Co-benefits

- Can be used as roads, trails, or bike paths for transport and recreation

Challenges and risks

- Can elevate long-term flood risk by spurring development in protected areas, increasing the number of people exposed when extreme floods overtop or breach levees
- Disrupts ecosystems and constrains land use due to extensive land required parallel to rivers
- Requires careful upfront design to ensure effectiveness under future climate conditions, given its long lifespan

Examples of deployment

- Hundreds of miles of levees line the Rio Grande River, protecting communities in Texas and Mexico from flooding.
- In Japan, levees protect communities and cropland within the floodplain of the Kiso, Nagara, and Ibi rivers.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Sea dikes

How it works: Sea dikes are engineered barriers typically constructed from earth, rock, or concrete that serve as fixed defenses against coastal flooding, blocking or redirecting seawater to reduce exposure.

Hazards protected against: Coastal flooding

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	50–70%	70–90%	**90–100%**

- With sufficient capacity, protects against damages such as property destruction, infrastructure impacts, and economic disruptions

Benefit-to-cost ratio[1]

1.5–3	3–5	**5–10**	10+

Co-benefits

- Can be used as roads, trails, or bike paths for transport and recreation

Challenges and risks

- Can elevate long-term flood risk by spurring development in protected areas, increasing the number of people exposed when extreme floods overtop or breach sea dikes
- Can shift storm surge, driving higher flood levels in adjacent or less-protected areas
- Disrupts ecosystems and constrains land use due to extensive land required along coastline
- Requires careful upfront design to ensure effectiveness under future climate conditions, given its long lifespan

Examples of deployment

- The Netherlands' Delta Works project, a network of dams, sluices and dikes completed in 1997, defends the Rhine-Meuse-Scheldt delta from sea floods.
- South Korea's Saemangeum Seawall is the world's longest sea dike, spanning 33 km and built to reclaim land and protect the coast from flooding.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Mangroves

How it works: Mangroves are forests of trees and shrubs growing along coastlines in tropical areas, creating natural buffers that dissipate wave energy and reduce peak height of coastal flooding.

Hazards protected against: Coastal flooding

Places this adaptation measure is most relevant: Rural areas

Extent of damage reduction

30–50%	50–70%	70–90%	90–100%

- Moderately protects against damages such as property destruction, infrastructure impacts, and disruptions to economic activity by providing a buffer against coastal floods

Benefit-to-cost ratio[1]

1.5–3	**3–5**	5–10	10+

Co-benefits

- Supports coastal biodiversity and ecosystem resilience
- Provides long-term carbon sequestration benefits by accumulating biomass and sediments

Challenges and risks

- Depends on precise tidal, salinity, and sediment conditions to prevent die-off
- May require multiple decades for restoration projects to mature and deliver full protective benefits

Examples of deployment

- An Indonesian initiative to regenerate natural mangroves along a 20 kilometer coastline aims to reduce damages to over 70,000 people and triple the yields of local shrimp farmers.
- In Brazil's Guanabara Bay, Instituto Mar Urbano planted 30,000 mangroves over four years to help mitigate flooding.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Flood proofing

How it works: Flood proofing adapts structures to withstand flooding through specific construction and design strategies, such as elevation, dry flood proofing with sealants and protective shields like flood doors, and wet flood proofing that controls water with drainage openings, elevated utilities, and flood-resistant materials like tile and concrete.

Hazards protected against: Excess-rainfall flooding, riverine flooding, coastal flooding

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50% | 50–70% | **70–90%** | 90–100%

- When properly designed, protects against most flood-related damages from structural losses and recovery needs
- Offers limited protection against high-velocity or deep floods, when height or force can overwhelm dry or wet flood proofing designs
- Is less suitable for critical infrastructure such as power stations and transport corridors because approaches like elevation are likely infeasible

Benefit-to-cost ratio[1]

1.5–3 | 3–5 | **5–10** | 10+

Co-benefits

- Can increase property values by lowering flood risk
- Provides eligibility for certain flood insurance products or programs

Examples of deployment

- Many historic buildings in the United States are being retrofitted with elevated foundations or break-away walls to survive coastal flooding.
- In Vietnam, a United Nations Development Programme-led project constructed around 4,000 flood-resilient homes across seven coastal provinces, protecting over 20,000 people.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Early-warning systems

How it works: Early warning systems monitor and forecast weather to anticipate extreme events and share guidance with exposed populations, including information about protective measures such as evacuation or sheltering. Protection can be activated at the community level, for example, evacuation orders, and individual level, for example, through mobile alerts.

Hazards protected against: Heatwaves, nonsurvivable heat, wildfires, drought, flooding

Places this adaptation measure is most relevant: All

Extent of damage reduction

30–50%	50–70%	70–90%	90–100%

- While not standalone protective measures, protects against damages to health, productivity, and assets by giving communities advance notice of climate hazards and enabling protective actions
- Provides limited protection when communities lack the preparedness or capacity to respond to early warnings

Benefit-to-cost ratio[1]

1.5–3	3–5	5–10	10+

Co-benefits

- Reduces disaster response costs by limiting damages and lowering recovery and insurance expenses

Challenges and risks

- Depends on reliable infrastructure, limiting effectiveness in some remote or marginalized communities
- Loses effectiveness when forecast errors or false alarms erode public confidence

Examples of deployment

- The Heat Health Alert system in the United Kingdom combines Met Office forecasts and National Health Service advisories to issue tiered alerts during anticipated heatwave conditions from June through September.
- An Early-warning system in Indian Himalayan regions uses flood sensors and mobile alerts to notify 45 vulnerable communities of impending flooding. This provided lead time to protect assets, like cattle and pigs.

[1] Values apply to use cases where the measure is feasible. Benefits measured as the expected annual value of damages avoided by implementation of this adaptation measure, and costs measured as annual capital and operating expenses.
Source: This analysis draws from a range of academic literature; McKinsey Global Institute analysis. See Technical Appendix for detailed methodology and sources

Acknowledgments

This report builds on a larger body of work from the McKinsey Global Institute (MGI) that explores responses to a shifting climate, including an assessment of the costs of mitigation and the tools needed to achieve it. The research was led by **Mekala Krishnan,** an MGI partner; **Olivia White** and **Sylvain Johansson,** MGI directors; **Sven Smit,** MGI's former chair; and **Annabel Farr** and **Kanmani Chockalingam,** MGI senior fellows.

Many McKinsey colleagues and alumni also participated in this research. During the early stages of this work, Gillian Pais co-led the research. At that stage, Gualtiero Jaeger led the working team, which included Riley Brady, Enrico Calvanese, Clark Doman, Jamie Dunn, Meredith Fish, Marie Houdou, Caroline Jupe, Sonya Kalara, Francois Klein, Dhiraj Kumar, Jake Lieberfarb, Sophia Lien, Trevor Liu, Shilpita Mathews, Reid McLaughlin, Adam Nowakowski, Brandon Nguyen, Shreyangi Prasad, Khalyani Sankar, Aidan Sarazen, and Emily Spittle. Expert members of the team included Jean-François Lamarque and Jan Lenaerts.

We are grateful to the academic advisers who provided guidance, challenged our thinking, and sharpened our insights: Simon Dietz, professor of environmental policy in the Department of Geography and Environment at the London School of Economics; Sam Fankhauser, professor of climate change economics and policy at the Smith School and the School of Geography and the Environment at Oxford University; David Stainforth, fellow of the Royal Meteorological Society and professorial research fellow at the London School of Economics; Wim Thiery, associate professor at Vrije Universiteit Brussels, who additionally reviewed the methodological design and the results on the evolution of climate hazards; and John Ward, visiting senior fellow at the Grantham Research Institute on Climate Change and the Environment at the London School of Economics.

This research benefited greatly from the expertise of academics who shared their insights and helped shape analysis: Sara Boettiger, senior fellow at Harvard University, Matthew Huber, professor in the Department of Earth, Atmospheric, and Planetary Sciences at Purdue University; Karen Aline McKinnon, associate professor at the Institute of the Environment and Sustainability in the Department of Statistics at the University of California, Los Angeles; Robert Nicholls, professor of climate adaptation at the University of East Anglia; Lorenzo Rosa, principal investigator at Carnegie Science and assistant professor in the Doerr School of Sustainability at Stanford University; and Xianli Wang, research scientist at the Canadian Forest Service of Natural Resources Canada. We also thank our external data partners at Fathom.

Many McKinsey colleagues and alumni contributed their analysis and perspectives, including Antara Banerjee, Chris Bradley, Zach Bruick, Dave Eickholt, Kandice Harper, Nick Kingsmill, Adam Rubin, Alexis Trittipo, Sean Turner, and Lola Woetzel.

This report was edited and produced by executive editor Stephanie Strom, together with senior data visualization editor Chuck Burke, data visualization editor Laura M. Mandujano, assistant managing editor Rishabh Chaturvedi, editor Mary Gayen, and lead designer Nathan R. Wilson. We also thank Suzanne Albert, Ankush Arora, David Batcheck, Nienke Beuwer, Ashley Grant, Cathy Gui, Stephen Landau, Janet Michaud, Marie Morris, Rebeca Robboy, Rachel Robinson, and Julie Schwade for their contributions and support.

This research contributes to our mission to help business and policy leaders understand the forces transforming the global economy. As with all MGI research, it is independent and has not been commissioned or sponsored in any way by any business, government, or other institution. While we benefited greatly from the variety of perspectives we gathered, we have independently formed and articulated our views in this report. Any errors are our own.

Endnotes

1 "Delta works," Institution of Civil Engineers, accessed October 7, 2025; and Yannick Rack, "How the Netherlands became the global leader in flood defense," *Our Industrial Life*, February 2025.

2 Lee Kuan Yew, "The East Asian way—with air conditioning," *New Perspectives Quarterly*, September 2009, Volume 26, Number 4.

3 We estimate protection against four categories of climate hazards we examine: heat, wildfires, drought, and flooding. See sidebar "The hazards we examine" for details on the definitions of these hazards.

4 Estimated for 198 countries in December 2020 and October 2025. National adaptation plans were counted if they were formally submitted to the United Nations Framework Convention on Climate Change (UNFCCC), the European Union, or independently adopted. Seventy-eight countries submitted adaptation plans specifically to the UNFCCC. See "Submitted NAPs from developing country parties," UNFCCC, November 18, 2025, and "NAPs shared by developed country parties," UNFCCC, November 5, 2025. For a similar analysis, see "Paving the way to resilience: Strengthening public-sector adaptation planning and execution," McKinsey, November 2023.

5 Of the 141 countries with a formal adaptation plan, we analyzed the 50 most populous in greater detail to assess whether they identify priorities and include cost estimates. We find that as of October 2025, only 14 outline a criteria-based or stepwise approach to prioritizing actions, and a similar number include quantified investment estimates.

6 Our geospatial analysis of hazards and exposure uses climate models and scientific assessments also used by the Intergovernmental Panel on Climate Change (IPCC). We refer to places as being "exposed" to climate hazards if they experience the hazard every year (for chronic hazards) or have some likelihood of experiencing it in any given year (for acute events). Exposure does not refer to actual damages from the impact of a climate hazard. For example, both places exposed to a one-in-100-year flood of 50 centimeters and more than a month of heat stress conditions are considered "exposed," even though the nature and magnitude of damages they may experience from such events could be very different. For hazard definitions, see sidebar "The hazards we examine" and the technical appendix.

7 *Climate Change 2023: Synthesis Report*, Contribution of Working Groups I, II, and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Intergovernmental Panel on Climate Change, 2023.

8 Many studies show that impacts of hazards can cascade through supply chains and that practical adaptation measures exist. For example, firm-level evidence finds that extreme heat at supplier locations lowers productivity of suppliers; drought in producing states reduces interstate exports and downstream food manufacturing; and flooding, as in Thailand in 2011, can disrupt automotive and electronics networks. Supply chain resilience can be achieved through the 20 adaptation measures analyzed in our study, but other measures also exist. These include strategies such as multisourcing, maintaining inventory buffers and strategic reserves, securing capacity reservations, adopting flexible contracts, improving logistics planning, and relocating facilities to areas with lower exposure risks. See Nora M. C. Pankratz and Christoph M. Schiller, "Climate change and adaptation in global supply-chain networks," *The Review of Financial Studies*, 2024, Volume 37, Number 6; Hyungsun Yim and Sandy Dall'erba, "Impact of extreme weather events on the U.S. domestic supply chain of food manufacturing," *Proceedings of the National Academy of Sciences*, October 2025, Volume 122, Number 41; Masahiko Haraguchi and Upmanu Lall, "Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making," *International Journal of Disaster Risk Reduction*, 2015, Volume 14, Part 3; and Ying Guo et al., "Supply chain resilience: A review from the inventory management perspective," *Fundamental Research*, March 2025, Volume 5, Number 2.

9 Observations of global temperatures indicate that Earth warmed by 1.1°C relative to preindustrial levels in the decade prior to 2020, which is when our analysis starts and what we refer to as "current" or "today's" climate conditions. (The average of the most recent estimates for the 2015–24 decade is 1.24°C of warming relative to the global temperature between 1850 and 1900.) We aligned the assessment of climate hazards at 1.1°C of warming with baseline population and GDP values for 2020 to apply the observed average climate from 2011 to 2020 to socioeconomic conditions in 2020. In this report, warming levels refer to long-run average temperatures rather than temperatures in any given year, in line with typical climate analysis. See "Summary for policymakers," 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, Cambridge University Press, 2021, and "Indicators of Global Climate Change 2024: Annual update of key indicators of the state of the climate system and human influence," in *Earth System Science Data*, Copernicus Publications, 2025. Our analysis excludes Antarctica because it is not populated.

10 Our estimate of 4.1 billion people living in places exposed to climate hazards at 1.1°C in 2020, under our definitions of adaptation standards in developed economies, aligns closely with the World Bank's estimate of 4.5 billion, though the hazard sets differ. The World Bank includes cyclones, which our analysis does not. Our analysis additionally considers heat stress, nonsurvivable heat, and wildfire weather. Moreover, even for similar hazards, definitions vary. As a result, there is some variation in our overall exposure numbers. See Miki Khanh Doan et al., *Counting people exposed to, vulnerable to, or at high risk from climate shocks*, Policy Research Working Paper number 10619, World Bank, November 2023.

11 We analyze eight hazards in the four categories. Two hazards, heat stress and wildfire weather (also referred to as "wildfires" in this report), are *chronic* and happen every year in the places exposed to them. The remaining six hazards we analyze—coastal flooding, riverine (fluvial) flooding, flooding caused by excessive rainfall (pluvial), heat waves, nonsurvivable heat, and drought in agricultural areas (referred to as "drought" in this report)—are *acute*, meaning they are intense but rare events. For acute events, places may be exposed to them, but the actual event may not manifest every year.

12 This investment protects 1.2 billion people with some adaptation measures against at least one climate hazard. Some individuals may need protection from multiple climate hazards but could be protected against only one. We assessed how many people were protected on a hazard-by-hazard basis by analyzing a range of hazard-specific data sets and assessing the penetration levels of the most commonly implemented adaptation measures for each hazard.

13 Various researchers have estimated the damages associated with climate hazards. According to Bloomberg, global multi-hazard damages in critical impact channels such as

property damages, business disruptions, labor productivity, and crop yield losses amounted to approximately $1 trillion in 2020. See Bloomberg NEF, *Ranking resilience: Assessing country climate adaptation*, October 2025. Swiss Re finds $177 billion in expected annual losses to property from flooding and $106 billion in losses to property from wildfires over 2014 to 2023. See Swiss Re, *Changing climates: The heat is (still) on*, February 2024, and Swiss Re, *Focus on natural catastrophes: Wildfires*, January 2025. Research has also documented that damages have been increasing over time. Damages reflect a lack of sufficient protection from climate hazards as they would have occurred in a preindustrial climate and the fact that several hazards have already intensified in today's warmer world. Research estimates that much of the increase in damages over time stems from development patterns: Populations have expanded into hazard-prone areas without adequate protection. Munich Re's NatCatSERVICE (1980–2021) shows that the rise in disaster losses is largely explained by increasing concentrations of people, assets, and economic activity in exposed regions. Pielke (2019) finds that historically, rising exposure and socioeconomic development—rather than climate change alone—have been the dominant drivers of growing disaster damages. Yet there is also emerging evidence that the climate itself has measurably changed and that this is contributing at least in part to the rise in damages. The IPCC finds with high confidence that human-induced warming has increased the frequency and intensity of heat extremes and, in some regions, heavy precipitation, drought, and fire weather. Attribution studies, such as Stott et al. (2016), similarly show that many recent heat waves and floods have become significantly more likely due to climate change. See Munich Reinsurance Company, *NatCatSERVICE: Loss events worldwide 1980–2021*, 2022; Roger Pielke, "Tracking progress on the economic costs of disasters under the indicators of the sustainable development goals," *Environmental Hazards*, 2019, Volume 18, Number 1; *Climate Change 2021: The Physical Science Basis*, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2021; and Peter A. Stott et al., "Attribution of extreme weather and climate-related events," *Wiley Interdisciplinary Review of Climate Change*, January/February 2016, Volume 7, Number 1.

14 We define a place as being exposed to heat stress if it experiences at least 28 days in an average year of either humid heat, when the daily average wet-bulb globe temperature (WBGT, a measure that combines heat and humidity) exceeds 29.4°C (corresponding to roughly 25 percent of labor productivity loss), or dry heat, when the daily maximum air temperature exceeds 40°C.

15 We define a place as being exposed to heat waves if it experiences at least seven consecutive days of locally defined high temperatures, by today's standards with a 5 percent (1-in-20-year) likelihood. Locally defined high temperature is defined as the current local 99th percentile daily maximum temperature in that place, provided it is at or above 32°C.

16 Estimates from multiple literature sources suggest damage functions for heat stress, encompassing health, labor productivity, business disruptions, agricultural output, and asset damage, that are seven times more than heat waves at 1.1°C, on average, in places that could be exposed to the hazard. See, for example, Yida Sun et al., "Global supply chains amplify economic costs of future extreme heat risk," *Nature*, March 2024; and Ludovic Subran et al., *Global boiling: Heatwave may have cost 0.6pp of GDP*, Allianz SE, August 2023.

17 Emicool, accessed October 6, 2025; and Science Media Center (SMC) Spain, *How the Ministry of Health's extreme temperature alerts work*, June 2024.

18 *Powerline bushfire safety program: Benefits realisation report*, Aurecon and the Victoria Department of Environment, Land, Water and Planning, June 2021; *Rapid Earth Fault Current Limiter (REFCL) report*s, December 2024; *Victoria's bushfire risk management report 2023–2024*, Victoria Department of Energy, Environment and Climate Action, December 2024.

19 Sibi Arasu, "In one Indian city, reflective paint and bus stop sprinklers offer relief from killer heat," Associated Press, May 13, 2025; Ahmedabad heat action plan, Ahmedabad Municipal Corporation, 2019; Jeremy J. Hess et al., "Building resilience to climate change: Pilot evaluation of the impact of India's heat action plan on all-cause mortality," *Journal of Environmental and Public Health*, November 2018, Volume 2018; Amit Dave, Gloria Dickle, and Shilpa Jamkhandikar, "Indian slums get 'cool roofs' to combat extreme heat," Reuters, March 10, 2025; and "Preparedness & response through passive infrastructure: Cool roofs in heat action plans," NRDC-WHO Capacity Building Workshop on Health, sector action plan for preparedness and response to heat wave, July 15, 2021.

20 Peyalo Menendez et al., "The Global Flood Protection Benefits of Mangroves," *Scientific Reports*, March 2020, Number 10; and Diarlei Rodrigues and Maurício Savarese, "Rio de Janeiro Bay reforestation shows mangroves' power to mitigate climate disasters," Associated Press, May 14, 2025.

21 "Benefits" are the annual average losses avoided by implementation of adaptation measures, estimated as the expected annual value of damages. Average annual damages are drawn from research literature and represent the impact of climate hazards on human capital, physical capital, and natural capital, typically including both direct and second-order impacts. They could differ widely across regions, depending on hazard severity and the economic activity in places exposed to those hazards. These damages are aggregate losses borne by an economy rather than by any single group of stakeholders. Costs are measured as annual capital and operating expenses.

22 See also Harald Heubaum et al., *The triple dividend of building climate resilience*, World Resources Institute, version 1.0, November 2022.

23 In addition, some adaptation measures for wildfire weather work by reducing but not eliminating the likelihood of the hazard itself taking place. For example, burying power lines underground works by lowering ignition risk, though of course it does not eliminate the risk of wildfires.

24 We built a database of population and GDP data at a level of one square kilometer "pixel" leveraging these sources: Matti Kummu, Maija Taka, and Joseph H. A. Guillaume, "Gridded global datasets for gross domestic product and Human Development Index over 1990–2015," *Scientific Data*, February 2018; and Global Human Settlement Layer database, European Union, accessed June 1, 2024. We defined demographic groups using the current thresholds of income groups and urbanization levels from the World Bank. Low-income regions have GDP per capita less than $4,000, middle-income regions have GDP per capita ranging from $4,000 to $12,000, and high-income areas have GDP per capita exceeding $12,000. Population in cities exceeds 1,500 people per square kilometer and more than 50,000 people in total, while towns have a population density between 300 and 1,500 people per square kilometer and total population of more than 5,000. All other areas are classified as rural. For population projections at the one-square-kilometer level, we relied on the medium-fertility variant from the UN *World Population Prospects* and differentiated population growth between rural and urban areas using country-level data on urban population shares from the UN *World Urbanization Prospects* (2018). For GDP projections, we used SSP2 projections from Tobias Geiger et al., "Continuous national gross domestic product (GDP) time series for 195 countries: Past observations (1850–2005) harmonized with future projections according to the Shared Socioeconomic Pathways (2006–2100)," *Earth Systems Science Data*, April 2018, Volume 10, Number 2. For consistency across time periods, the demographic classification of each pixel is not changed over time and is based on today's classification.

25 In this report, we refer to wildfire weather mostly as "wildfires," and drought in agricultural areas as "drought." Since our analysis focuses on the

primary impacts of drought on agricultural crop yields—occurring mainly in rural areas, though sometimes extending to nearby towns—we scale the drought exposure according to the proportion of each grid cell classified as cropland in those areas. Cropland is identified using the European Space Agency (ESA) Climate Change Initiative (CCI) Plant Functional Type (PFT) data set at a 300-meter resolution in 2020. The cropland fraction (referred to as "GRASS-MAN" in the original data set) is bilinearly interpolated to our one-square-kilometer grid, resulting in an estimated global cropland area of approximately 2.1 billion hectares. Similarly, wildfires can occur only in places with vegetation cover (trees or grassland). To determine vegetation cover, we use the same data set and methodology as for drought. For tree fraction, we sum the four tree plant functional types (PFTs) to obtain total tree fraction. Grass is taken from the GRASS-NAT PFT. We do not include shrub cover because global coverage is negligible.

26 The resiliency gap is defined as the share of people left unprotected due to gaps in implementing the most protective solution against each hazard we studied. Resiliency gaps in protecting people from heat, wildfires, and drought hazards are measured at the country level. To measure these gaps, we assess specific solutions by hazard: air conditioning for heat stress, early-warning system for heat waves, undergrounding for wildfires, irrigation for drought. Protection from flooding is measured at the level of one square kilometer.

27 Dividing the world into nine demographic groups also serves as a way to illustrate how vulnerable people are to hazards across regions. However, income and urbanization levels represent only one way to capture vulnerability, by signaling both how hazards affect them and their ability to respond. Similarly, the World Bank considers people vulnerable to climate hazards as those with a propensity or predisposition to be adversely affected. In its measurement, this is captured through two key dimensions: (1) the physical propensity to experience severe losses, proxied by limited access to essential infrastructure such as water and electricity; and (2) the inability to cope with and recover from losses, proxied by indicators such as low income, limited education, lack of financial inclusion, and absence of social protection systems. See Miki Khanh Doan et al., *Counting people exposed to, vulnerable to, or at high risk from climate shocks*, Policy Research Working Paper number 10619, World Bank, November 2023. Another approach is the Notre Dame Global Adaptation Initiative (ND-GAIN) framework, which defines vulnerability through three components: exposure to physical climate risks; sensitivity, or the degree to which a country depends on climate-sensitive systems such as rain-fed agriculture and freshwater resources; and adaptive capacity, which reflects the ability to cope and recover, shaped by factors like income levels, governance quality, and institutional strength.

28 *The future of cooling: Opportunities for energy-efficient air conditioning*, International Energy Agency, 2018; Giacomo Falchetta et al., "Inequalities in global residential cooling energy use to 2050," *Nature Communications*, September 2024; Giacomo Pavanello et al., "Air-conditioning and the adaptation cooling deficit in emerging economies," *Nature Communications*, September 2024; Lucas Davis et al., "Air conditioning and global inequality," *Global Environmental Change*, May 2021; and Marina Andrijevic et al., "Future cooling gap in shared socioeconomic pathways," *Environmental Research Letters*, September 2021.

29 An exception is coastal flood protection in North America, where only 22 percent of coastline exposed to flooding is protected, compared with 36 percent in India. The primary reason for this difference is that 87 percent of North America's exposed coastline is in rural regions, where constructing protective infrastructure such as sea dikes is often not cost-effective. By contrast, in India, just 63 percent of flood-exposed coastline is rural, and most existing protection is concentrated in urban areas, where higher levels of economic activity can justify protective measures.

30 For a discussion of risk preferences inferred from insurance choices, see Levon Barseghyan et al., "The nature of risk preferences: Evidence from insurance choices," *American Economic Review*, October 2013. Research finds that wealthier individuals tend to have better life and property insurance coverage. For instance, see Michael J. Gropper and Camelia M. Kuhnen, "Wealth and insurance choices: Evidence from U.S. households," *The Journal of Finance*, April 2025; and Giovanni Millo, "The S-curve and reality," *The Geneva Papers*, 2016.

31 We estimate the number of people protected from coastal and riverine floods by calculating the difference in two data sets: the "undefended" layer, which represents places inherently exposed to the hazard without any defenses, and the "defended" layer, which accounts for remaining exposure after implementing defenses such as levees, leveraging data from Fathom Global Flood Map Fathom 3.0, 2021. For pluvial flooding, we apply a similar approach, though the available data is at a coarser level of detail.

32 Total cost estimates include both capital expenditures amortized over the lifetime of the asset and the average annual operating expenses of deploying adaptation measures through 2050. Operating expenses for measures that scale with population growth are projected based on considering populations in 2020, 2030, and 2050, and linearly interpolating between these periods. We estimate spending on current protection for the 20 adaptation measures covered in this research. We compared our estimates of current adaptation spending with the Climate Policy Initiative's estimate of adaptation finance flows in 2023 ($130 billion–$152 billion), which includes both household products with "high adaptation likelihood" in CPI's taxonomy ($65 billion–$87 billion) and project-level finance ($65 billion). CPI's figure does not fully capture all the hazards and measures in our analysis, such as urban trees and cooling shelters. For measures directly comparable to CPI's estimate, our estimate of current spending is about $140 billion per year, which is in line with its estimate.

33 These figures represent the cost to protect against or adapt to damages from hazards. They do not represent the damages or losses incurred from those hazards. According to Bloomberg, global multi-hazard damages in critical impact channels such as property damage, business disruption, labor productivity, and crop yield losses amounted to approximately $1 trillion in 2020, which is consistent with our estimates considering exposure to hazards, typical damage functions in the literature, and resiliency gaps today. Swiss Re finds $177 billion in expected annual losses to property from flooding and $106 billion in losses to property from wildfires over 2014 to 2023. These figures also align with our estimates. For details, refer to Bloomberg NEF, *Ranking resilience: Assessing country climate adaptation*, October 2025; Swiss Re, *Changing climates: The heat is (still) on*, February 2024; and Swiss Re, *Focus on natural catastrophes: Wildfires*, January 2025.

34 For each region, demographic group, and hazard, we assess the most protective measure, accounting for physical feasibility (for example, mangroves can prevent flooding only at certain latitudes), and cost-effectiveness (benefit-to-cost ratios, or BCRs, where benefits represent the average annual losses avoided and costs are measured as annual capital and operating expenses). A measure is deemed cost-effective if its BCR exceeds 1.5. Where multiple solutions were deemed cost-effective, we considered those that offered the highest possible protection among available options.

35 We assessed 25 current-trajectory emissions scenarios, based on policies announced or implemented, from the IPCC, the Network for Greening the Financial System (NGFS), and the International Energy Agency (IEA) to reflect the wide range of climate estimates. These scenarios suggest that 1.5°C of warming relative to preindustrial levels would be reached somewhere between 2025 and 2035, when warming is measured as a 20-year average centered on a given year and relative to a preindustrial average. In 2030, temperatures

under the 25 scenarios range from 1.45°C to 1.55°C. In the IPCC scenarios, the median level of warming by 2050 is 2.0°C, and in the more recent NGFS and IEA scenarios, it is 2°C. By 2100, the temperature estimates from the same set of models are 3.0°C (average across IPCC scenarios, with a maximum of 3.7°C), 2.9°C (NGFS and IEA Current Policies), and 2.5°C (IEA Stated Policies). The IPCC and NGFS scenarios are based on the assumption that currently announced policies are preserved. For NGFS, this covers national climate policies that were legislated and supported by instruments as of March 2024. For IPCC scenarios, the specific policies reflected vary by model. The IEA Current Policies scenario (2025) considers only policies already adopted in legislation and regulation, assuming no future changes, even where governments have indicated their intention to do so, and takes a cautious perspective on the pace at which new energy technologies are deployed and integrated into the energy system. The Stated Policies scenario draws on a wider interpretation of the policy environment, incorporating not only enacted measures but also formally proposed ones and other official strategy documents that signal the intended policy direction. For details, see IEA, *World Energy Outlook 2025*, November 2025.

36 Moreover, some measures implemented today—for example, stormwater networks—can have multiple-decade lifetimes, making it prudent to consider how hazards could evolve a few decades out, to avoid costly retrofits down the road.

37 Total cost estimates include both capital expenditures amortized over the lifetime of the asset and the average annual operating expenses of deploying adaptation measures through 2050. The UN Environment Programme's *Adaptation Gap Report 2025* estimates $310 billion in annual adaptation costs through 2035. While differences in time period, geographic coverage, and scope limit comparability, aligning our analysis to UNEP's scope yields about $110 billion annually—broadly consistent once non-overlapping categories are excluded. UNEP also cites at least $250 billion in private-sector costs, such as residential cooling in low- and middle-income countries, closely matching our $290 billion estimate.

38 Places exposed to nonsurvivable heat generally are also exposed to heat stress and heat waves, and adaptation measures for those hazards also offer protection against nonsurvivable heat. The costs of protecting against nonsurvivable heat are therefore included within the costs of other heat hazards. For droughts and heat waves, protection levels are defined by the occurrence of acute events; however, to ensure that adaptation costs reflect typical operating conditions, estimates are based on average-year hazards rather than extreme ones. As a result, for these hazards—and for heat stress, a chronic hazard modeled on an average year—costs in any given year may be higher than the annual averages presented here.

39 The cost of protecting against different hazards depends on the thresholds at which those hazards trigger adaptation responses typical in developed economies, and therefore on how we have chosen to define when protection is needed against hazards. For example, we have defined exposure to drought in line with research literature from the IPCC as a one-in-20-year event reflecting a local minimum in moisture in the soil, rather than an absolute measure of soil water content, since agricultural activity is based on the local climate and change relative to that climate is what is most relevant to the adaptation response. Exposure to heat stress, by contrast, is based on absolute physiological thresholds related to human productivity loss. Again, this is because such a threshold is linked to what triggers an adaptation response (see sidebar "The hazards we examine"). The fact that heat stress has been defined as an absolute threshold and drought as a relative one could partly explain why the adaptation costs associated with heat are higher than the costs associated with drought.

40 Climate change can influence coastal flooding through several physical mechanisms, including potential changes in storm surge intensity, tropical cyclone activity, and wave climate. We rely on Fathom's global coastal flood module. Here, climate change is represented through projected changes in mean sea level. Local estimates of future sea-level change are derived from regional AR6 sea level projection data based on CMIP6 models and applied to baseline mean sea levels. See Oliver E. J. Wing et al., "A 30 m global flood inundation model for any climate scenario," *Water Resources Research*, August 2024; and IPCC, *Special Report on the Ocean and Cryosphere in a Changing Climate*, Cambridge University Press, 2019.

41 Extensive research supports the conclusion that the population in places exposed to heat at 2°C will be large and that relatively fewer people will require protection from coastal flooding by 2050. As the planet warms, hot days rise across much of the globe. See Oriana Chegwidden and Jeremy Freeman, "Modeling extreme heat in a changing climate," (carbon)plan, September 2023; Chao Li et al., "Rapid warming in summer wet bulb globe temperature in China with human-induced climate change," *Journal of Climate*, July 2020; and Qiaohong Sun et al., "Global heat stress on health, wildfires, and agricultural crops under different levels of climate warming," *Environment International*, July 2019. For heat waves, global and regional analyses show that moving from 1.5°C to 2°C of warming substantially increases frequency, duration, and population requiring protection to developed-economy standards. See Alessandro Dosio et al., "Extreme heat waves under 1.5 °C and 2 °C global warming," *Environmental Research Letters*, April 2018; Simone Russo et al., "Half a degree and rapid socioeconomic development matter for heatwave risk," *Nature Communications*, January 2019; and Ahmed Al Izzi Alnaqshbandi et al., *The coldest year of the rest of their lives: Protecting children from the escalating impacts of heat waves*, UNICEF, October 2022. For coastal flooding, global modeling combining tides, surge, wave setup, and sea-level rise indicates some increase in the amount of land at risk, yet the population expected to require protection is expected to remain a small share of the global total today and in 2050, smaller than the same number for heat-related hazards. See Ebru Kirezci et al., "Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st century," *Scientific Reports*, July 2020; and Robert J. Nicholls et al., "A global analysis of subsidence, relative sea-level change and coastal flood exposure," *Nature Climate Change*, April 2021, Volume 11, Number 4.

Our analysis of coastal flooding includes sea-level rise, which increases flood levels as higher mean sea levels allow storm surges and tides to reach farther inland. Here we include only the increase in mean sea levels tied to the "transient" sea-level response, meaning the sea level at the time of the event. We do not examine the additional impacts attributable to "committed" sea-level rise, which is the additional increase in mean sea levels that follows a given warming level for some duration due to the climate system's inertia (ocean heat uptake and ice-sheet adjustment). By 2050, it is projected to rise by 0.24 meter under IPCC marker scenario RCP2.6 (≈ 1.7°C warming at 2050) and 0.32 meter under RCP8.5 (≈ 2.4°C at 2050) relative to 1986–2005, and by 2100, by 0.43 meter to 0.84 meter. This could increase the number of people exposed to coastal flooding after 2100, though exposure is highly dependent on population growth scenarios. See "Sea level rise and implications for low-lying islands, coasts and communities," Figure 4.2, in IPCC, *Special Report on the Ocean and Cryosphere in a Changing Climate*, 2019; and Robert J. Nicholls et al., "A global analysis of subsidence, relative sea-level change and coastal flood exposure," Nature Climate Change, April 2021.

42 Researchers estimate that air conditioners represented almost 4 percent of global greenhouse gas emissions in 2022 and that their energy use could quintuple emissions by 2050. Air conditioning contributes an estimated 1,950 million tons of CO_2-equivalent per year. Of this total, 531 million tons arise from the energy used to reduce air temperature (sensible cooling) and 599 million tons from the energy used to remove humidity (latent cooling). The remaining emissions reflect refrigerant leakage and embodied emissions associated with manufacturing and transporting air-conditioning equipment. Looking ahead, the authors project that humidity-load emissions could increase roughly fivefold by

2050, driven by population growth and rising air-conditioning ownership, while holding grid emissions intensity and equipment and building efficiencies constant and excluding additional warming and humidity from climate change. See Jason Woods et al., “Humidity’s impact on greenhouse gas emissions from air conditioning,” *Joule*, April 2022, Volume 6, Number 4.

43 See European Union, *Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks*, November 2007.

44 See Food and Agriculture Organization of the United Nations, *Overcoming water scarcity with sustainable irrigation*, FAO Agricultural Development Economics Policy Brief Number 32, 2020; and Franklin Simtowe et al., “Impacts of drought-tolerant maize varieties on productivity, risk, and resource use: Evidence from Uganda,” *Land Use Policy*, November 2019, Volume 88, Article 104091.

45 Currently, air conditioners are among the most effective solutions for protecting against heat, particularly for indoor workers. We estimate annual cooling needs in 2050 of roughly 2,400 TWh, which is in line with estimates from the IEA. See IEA, *World Energy Outlook 2024*, October 2024. Heat pumps offer a more energy- and emissions-efficient alternative but remain costlier up front and are not yet widely scaled, so our cost estimates overall likely represent a lower bound, to the extent that heat pumps become the preferred solution going forward. Other, more affordable active cooling options—such as evaporative coolers and fans—as well as passive cooling measures can also serve as energy- and emissions-efficient substitutes, but they are significantly less effective. There is enormous opportunity to enhance the efficiency of cooling technologies. See *The future of cooling: Opportunities for energy-efficient air conditioning*, International Energy Agency, 2018; and Giacomo Falchetta et al., “Inequalities in global residential cooling energy use to 2050,” *Nature Communications*, September 2024.

46 Protection levels are measured assuming well-designed and effective implementation for each adaptation measure in the channel of impact that it is implemented to address. Refer to the “Library of adaptation measures” for details on the impact channels used to assess each adaptation measure’s protection levels. It is important to note, however, that actual impacts can vary significantly by location. In some places, the protection level can be lower than the estimated average. For example, small island developing states may face hard limits such as loss of marine and coastal biodiversity, ecosystem degradation, and water insecurity alongside other impacts including disruptions to livelihoods and infrastructure destruction. See “Small islands,” in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022. Our estimates of protection levels apply only to the hazards analyzed and do not cover others such as hurricanes or ocean acidification. And of course, adaptation measures are not always optimally designed or universally implemented, even where they may be cost-effective. Moreover, factors such as risk awareness, affordability, and institutional capacity often limit adoption. The World Bank provides an empirical review of multiple academic studies on adaptation in low- and middle-income regions, finding that such measures reduce damages by an average of 46 percent. See Jonah Rexer and Siddharth Sharma, “Climate change adaptation: What does the evidence say?,” World Bank, March 2024.

47 “Benefits” in the BCR estimation are the annual average losses avoided by implementation of adaptation measures, estimated as the expected annual value of damages. Average annual damages are drawn from research literature and represent the impact of climate hazards on human capital, physical capital, and natural capital, typically including both direct and second-order impacts. Because micro-level damage functions across hazards in the literature often understate some impacts, particularly natural capital—such as the economic value of marine ecosystems—and are unlikely to fully capture hard limits of adaptation, such damages are outside the scope of our analysis, and our estimates of BCRs are limited to the damages they include. See Yida Sun et al., “Global supply chains amplify economic costs of future extreme heat risk,” *Nature*, March 2024, and Ebru Kirezci et al., “Global-scale analysis of socioeconomic impacts of coastal flooding over the 21st century,” *Frontiers in Marine Science*, January 2023, for examples of literature that estimates damages from hazards. At the macro level, the task of estimating damages is complicated by model limitations, differing estimates of how physical risks translate into economic damages, interactions with demographic and technological trends, and the potential for tipping points and nonlinear climate impacts, creating significant uncertainties. The IPCC’s Sixth Assessment Report, reviewing more than 20 estimates, found that global GDP loss at 4°C of warming could range from just above 0 percent to more than 30 percent. See “Key risks across sectors and regions,” Figure 16.12, in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022. In some cases, these estimates reflect damages after accounting for those avoided through adaptation.

48 See International Labour Organization, *Heat at work: Implications for safety and health*, July 2024; and US Occupational Safety and Health Administration, *Heat: Prevention: Engineering controls, work practices, and personal protective equipment*, accessed November 20, 2025.

49 Our assessment of places exposed to hazards is grounded in our threshold definitions, which are based on typical adaptation planning in developed economies. While the exact thresholds used may vary, the conclusion that more places will be exposed to hazards as the global temperature warms is well established, and our estimates align closely with existing evidence in research literature. See, for example, Simone Russo et al., “Half a degree and rapid socioeconomic development matter for heatwave risk,” *Nature Communications*, January 2019; and Jonathan Spinoni et al., “Global exposure of population and land-use to meteorological droughts under different warming levels and SSPs: A CORDEX-based study,” *International Journal of Climatology*, July 2021.

50 Local heat extremes are defined as the local 99th percentile daily maximum temperature at 1.1°C, provided it is at or above 32°C.

51 To estimate overall BCRs at 1.1°C, 1.5°C, and 2°C, we aggregated the BCRs of individual adaptation measures, which vary across warming levels depending on avoided damages at specific hazard intensities, total exposure, and costs.

52 When referring to adaptation costs per person, we refer to the cost per person in places exposed to at least one hazard at 1.1°C and 2°C through to 2050.

53 The adaptation cost per person protected remains broadly similar at 2°C, although severity increases in some places. This is because the severity increase is offset by a shift in the mix of people protected, from higher-cost hazards such as heat stress today to lower-cost hazards like heat waves at 2°C.

54 US private-sector employees earned $36.53 per hour on average in August 2025, according to the Bureau of Labor Statistics, or the equivalent of $130 for 3.6 hours. Minimum-coverage auto insurance premiums in the United States are $806 per year, according to Bankrate, and $130 is equivalent to about 16 percent of that cost. “Average hourly and weekly earnings of all employees on private nonfarm payrolls by industry sector,” Bureau of Labor Statistics, accessed October 9, 2025; and Shannon Martin, “Average cost of car insurance in October 2025,” Bankrate, September 10, 2025.

55 In Bangladesh, monthly household income is roughly $266, of which $130 is roughly half, and households devote 43 percent of their income to food, according to the “Household Income and

Expenditure Survey 2022," Bangladesh Bureau of Statistics, April 2023.

56 See, for example, Thijs Endendijk et al., "Flood experience and access to insurance contribute to differences in homeowners' post-disaster adaptation in a cross-border region of Western Europe," *Communications Earth & Environment*, June 2025.

57 Office of Governor Gavin Newsom, "Governor Newsom signs legislation investing additional $170 million to prevent catastrophic wildfires, issues executive order to fast-track projects," Governor of California News, 2025; and Pooja Menon, "PG&E unveils $73 billion spending plan to meet surging data-center energy demand," Reuters, September 29, 2025.

58 Daniel Nohrstedt et al., "Exploring disaster impacts on adaptation actions in 549 cities worldwide," *Nature Communications*, 2022.

59 Rijkswaterstaat, "Room for the River," Rijkswaterstaat, Government of the Netherlands, 2019; Dutch Water Sector, "Room for the River Programme," 2019; and Jeroen Frank Warner, Arwin van Buuren, and Jurian Edelenbos, eds., *Making Space for the River: Governance Experiences with Multifunctional River Flood Management in the US and Europe*, IWA Publishing, 2012.

60 We estimated the cost of maintaining current protection levels under the assumption that existing patterns of current protection for both climate hazards and demographic groups remain constant. Each demographic group is assumed to continue spending at the same rate, relative to adaptation costs, required to achieve developed-economy protection standards. This estimate is slightly higher than today's level—about 35 percent of the total protection costs against extreme weather events—due to a shift in the mix of costs from less protected hazards such as wildfires today to more protected hazards like heat stress.

61 We estimated the cost of increasing adaptation spending with income growth under the assumption that current adaptation spending as a fraction of GDP across demographic groups and hazards remains constant.

62 Emerging Asia encompasses Afghanistan, Bangladesh, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, the Philippines, Thailand, Vietnam, and other emerging Asian and Pacific Island countries.

63 World Bank, *Economics of adaptation to climate change: Synthesis report*, 2010.

64 *Water governance in the Netherlands: Fit for the future?*, OECD Studies on Water, June 2014; and J. S. Stijnen et al., "The technical and financial sustainability of the Dutch polder approach," *Journal of Flood Risk Management*, March 2014.

65 Rebecca Hersher, "How flood sirens could have saved lives in Texas," NPR, July 11, 2025; Alejandra Martínez, "Texas cities have limited flood-warning systems. Sirens alone aren't a solution, experts say," *Texas Tribune*, July 11, 2025; and "Missouri Hydrology Information Center (MoHIC)," Missouri Department of Natural Resources, accessed November 20, 2025.

66 *Rising to the challenge: Success stories and strategies for achieving climate adaptation and resilience*, World Bank, 2024.

67 Compared to a baseline of 100 percent productivity, which occurs at temperatures at or below 24°C wet-bulb globe temperature. See Peter Brode et al., "Estimated work ability in warm outdoor environments depends on the chosen heat stress assessment metric," I*nternational Journal of Biometeorology*, April 2017; and Brenda Jacklitsch et al., *Occupational exposure to heat and hot environments*, US Department of Health and Human Services, February 2016.

68 There is debate on how climate change affects income and GDP—by affecting income levels, growth, or both. See "Key risks across sectors and regions," Figure 16.12, in *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2022; Maximilian Kotz, Anders Levermann, and Leonie Wenz, "The economic commitment of climate change," *Nature*, April 2024; Corey Lesk et al., "Compound heat and moisture extreme impacts on global crop yields under climate change," *Nature Reviews Earth & Environment*, December 2022; and Michele Fornino et al., *A multi-country study of forward-looking economic losses from floods and tropical cyclones*, International Monetary Fund Working Paper number 141, July 2024.

69 Ministry of Finance, Government of India, "Budget at a glance 2025–26," 2025.

70 "Sub-Saharan Africa maintains resilient growth but faces urgent jobs challenge," World Bank, October 7, 2025.

71 Advanced Asia spans Australia, Japan, New Zealand, Singapore, South Korea, and other advanced Asian and other Pacific Island countries.

72 Floods and wildfires show relatively limited increases in the geographic expanse of places exposed under 2°C of warming, though the severity of these conditions could shift in places that are already exposed. For wildfires, this is explained by the fact that many places are already exposed to wildfire weather today, meaning that further warming expands this footprint only modestly. This may seem surprising given that wildfire events do not happen every year in all affected locations, but fire occurrence depends on both suitable weather and the coincidence of ignition and fuel availability. However, warming is expected to slightly increase the duration of wildfire-conducive conditions by about a week on average in affected areas. In the case of floods, the slower response of hydrological systems means changes in exposure emerge more gradually than for heat-related hazards. Nonetheless, the frequency of some flood types can increase sharply—for instance, a coastal flood that occurs once every 100 years today could occur about once every 13 years under 2°C of warming. See John T. Abatzoglou, A. Park Williams, and Renaud Barbero, "Global emergence of anthropogenic climate change in fire weather indices," *Geophysical Research Letters*, January 2019, Volume 46, Number 1; Ebru Kirezci et al., "Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st century," *Scientific Reports*, July 2020; Robert J. Nicholls et al., "A global analysis of subsidence, relative sea-level change and coastal flood exposure," *Nature Climate Change*, April 2021, Volume 11, Number 4; and Jun Rentschler, Melda Salhab, and Bramka Arga Jafino, "Flood exposure and poverty in 188 countries," *Nature Communications*, June 2022, Volume 13.

73 Estimates from multiple sources suggest damage functions for heat stress that are seven times more than heat waves at 1.1°C, on average. See, for example, Yida Sun et al., "Global supply chains amplify economic costs of future extreme heat risk," Nature, March 2024; and Ludovic Subran et al., Global boiling: Heatwave may have cost 0.6pp of GDP, Allianz SE, August 2023.

74 EU30 consists of the 27 member states of the European Union, plus Norway, Switzerland, and the United Kingdom. Other Europe and Central Asia includes Kazakhstan, Russia, Turkey, Ukraine, Uzbekistan, and other countries in the region.

75 Queensland, Australia, provides government grants to help flood-affected homeowners retrofit with flood-resilient materials and relocate critical services, See Queensland Government, "Resilient Homes Fund: Resilient Retrofit program," accessed November 20, 2025. Toronto's Eco-Roof Incentive Program provides grants of C$100 per square meter for green roofs (up to $100,000) and between $2 and $5 per square meter for cool roofs (up to $50,000); the programs have supported more than 65 eco-roof projects since 2009. Toronto City Government, "Eco-Roof Incentive Program," accessed November 20, 2025.

76 New York City's Cooling Assistance Benefit provides eligible households with a window air conditioner or fan (including installation) to help keep homes cool. To qualify, a household must

meet Home Energy Assistance Program income and other requirements and either include a person with a documented medical condition exacerbated by extreme heat or include a "vulnerable member" based on age (60 years or older, or under age 6). "HEAP cooling assistance," City of New York, accessed October 6, 2025.

77 "Funding Thames Estuary 2100: Costs and investment," Government of the United Kingdom, 2023.

78 "Managing future flood risk and Thames Barrier: Thames Estuary 2100," Government of the United Kingdom, April 2023.

79 For more on the uncertainties in climate models, see David Stainforth, *Predicting Our Climate Future: What We Know, What We Don't Know, and What We Can't Know*, Oxford University Press, 2023.

80 "Heat wave relief and warnings based on apparent temperature," Seoul Metropolitan Government, July 11, 2023; Kim Youngwon, "Seoul City to provide 50,000 won in cooling cost support per household," Asiae, July 23, 2025; "Housing Repairs Program," City of Phoenix, accessed November 20, 2025; and "Weatherization Assistance Program," City of Phoenix, accessed November 20, 2025.

81 "Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)," Ministry of Jal Shakti and Ministry of Agriculture and Farmers Welfare, Government of India, 2024; and "National Mission for Sustainable Agriculture (NMSA)," Department of Agriculture and Farmers Welfare, Government of India, 2024.

82 *What is a PACE loan?*, US Consumer Financial Protection Bureau, September 2024.

83 "Zoning for coastal flood resiliency," Department of City Planning, New York City, May 2021; "Order of August 4, 2021, relating to the energy and environmental performance requirements for building construction in metropolitan France and approving the calculation method provided for in Article R. 172-6 of the Construction and Housing Code," Government of France, August 15, 2021.

84 Insurance Institute for Business & Home Safety (IBHS), *FORTIFIED Home Program Overview*, 2023.

85 "Raj reopens IG canal to supply drinking water to border dists," *Times of India*, May 14, 2025.

86 Cornelis van Leeuwen et al., "Climate change impacts and adaptations of wine production," *Nature Reviews Earth & Environment*, April 2024; Marcelo Teixeira, "Brazil poised to lead global robusta coffee farming on expansion potential, report says," Reuters, October 2, 2025; Roman Grüter et al., "Expected global suitability of coffee, cashew and avocado due to climate change," PLoS ONE, January 2022; and Craig Saueurs, "Climate change is redrawing the global wine map. Here's what it means for your future vintages," Euronews, April 18, 2025.

87 We estimated the cost of maintaining current protection levels under the assumption that existing patterns of current protection for both climate hazards and demographic groups remain constant. Each demographic group is assumed to continue spending at the same rate, relative to adaptation costs, required to achieve developed-economy protection standards.

88 *What are resilience bonds and how can they protect us against climate crises?*, Global Center on Adaptation, July 2020; and *Private-public partnerships (PPPs) for adapting and maintaining infrastructure and services*, Climate-ADAPT, 2025.

89 Miami Forever Bond, Miami.gov, accessed November 18, 2025.

90 "Tokyo Metropolitan Government to issue world's first Climate Bond Certified using the Resilience Criteria and Taxonomy," Climate Bonds Initiative, October 2025.

91 For example, the Global Adaptation and Resilience Investment (GARI) initiative and MSCI's climate-resilience taxonomy. See Global Adaptation and Resilience Investment Working Group, *The Unavoidable Opportunity: Investing in the Growing Market for Climate Resilience Solutions*, March 2024; "Climate bonds taxonomy," Climate Bonds Initiative, accessed November 30, 2025; "EU taxonomy for sustainable activities," European Commission, accessed November 30, 2025; and Ami Woo et al., *Report – Taxonomy of climate change adaptation*, UN Environment Programme, 2021.

92 Avery Ellfeldt, *California insurers begin giving discounts for fire-proofed homes*, E&E News (Climatewire), September 19, 2024.

93 *Insuring against extreme heat: Navigating risks in a warming world*, World Economic Forum, January 2025; and Reema Nanavaty and Prerna Saxena, "How heatwaves have sparked new ways for women farmers in India to protect their crops," World Economic Forum, March 25, 2025.

94 *Managing the climate change–fueled property insurance crisis*, Center for American Progress, April 2025; and *Enhancing the insurance sector's contribution to climate adaptation*, OECD, March 2023.

95 "Background note for principles on investment and financing for water-related disaster risk reduction," High-level Experts and Leaders Panel on Water and Disasters and OECD, June 2019; Diana Radu, "Approaching disaster risk financing in a structured way," European Economy Discussion Paper number 201, European Commission, May 2024; and Carolyn Kousky, Erwann O. Michel-Kerjan, and Paul A. Raschky, "Does federal disaster assistance crowd out flood insurance?," *Journal of Environmental Economics and Management*, January 2018.

McKinsey Global Institute
December 2025

Designed by the McKinsey Global Institute

mckinsey.com/mgi

@McKinsey_MGI
@McKinseyGlobalInstitute
@McKinseyGlobalInstitute

Subscribe to MGI's LinkedIn newsletter,
Forward Thinking: mck.co/forwardthinking