Too Hot to Think Straight, Too Cold to Panic

Landing the Economic Case for Climate Action with Decision Makers

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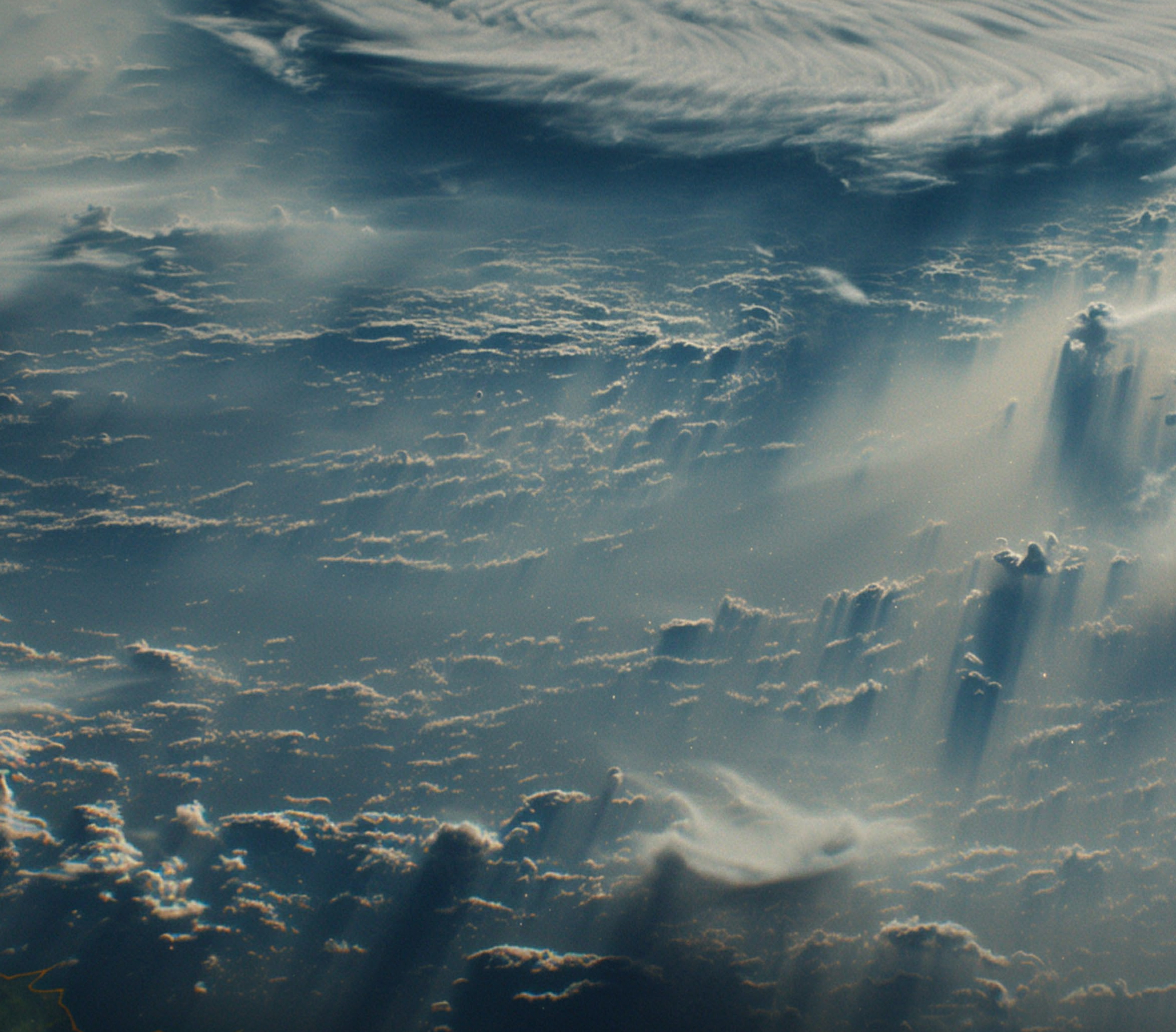

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Authors' Note

In writing this report, we deliberately chose to focus on two alternative scenarios for 2100: the 3°C path scientists project we are currently on and a below 2°C path. We chose below 2°C as the alternative endpoint for three reasons. First, it is near the upper bound of the consensus that we need to achieve: 1.5°C or well below 2°C. Second, it is an endpoint where extensive modeling on climate impacts has been done. Third, staying below 2°C is challenging from an investment perspective and, therefore, serves as a good stress test of the economics.

But we want to highlight that while the analysis focuses on staying below 2°C, the economic logic holds and likely gets even stronger for reductions to levels above 2°C. That is because the mitigation costs per ton of CO_2e increase as temperature goals go down and some of the negative economic impacts and tipping point risks likely rise exponentially as temperatures rise.

At a time when changes in the geopolitical landscape and challenges with some climate technologies such as hydrogen raise some doubts about our abilities to achieve below 2°C goals, we should not lose sight of the economic benefits in this report for still improving from the trajectory we are on today. We hope the stress test economic case outlined in this report makes that clear, even for those who think it is unrealistic to achieve the full ambitions contained in this report.

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climaTRACES Lab is an interdisciplinary initiative at the University of Cambridge focusing on climate, nature, and sustainability research. Our data-driven research and policy engagement covers the following four themes: Communication & Communities, Macroeconomics & Sustainability, Green & Sustainable Finance, and Nature & Biodiversity. Collaborating with a network of climate and nature experts globally, we conduct cutting edge research for wider societal benefit, and create and test innovative policy communications formats that translate the evidence and multidisciplinary research generated by the lab for policy and industry audiences.

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Executive Summary

Governments, businesses, and people worldwide are paying the price for the storms, floods, heat waves, and droughts that are caused by climate change. Without the investment necessary to reduce further global warming, the economic growth and resilience on which the world relies will be severely diminished along with societies' ability to achieve their broader goals. This report sets out the economic case for climate action—and how we can make it influence decisions today.

The global average temperature has risen significantly since the industrial revolution.
This past year was 1.55°C above preindustrial levels and the hottest year on record. Global warming is increasing the frequency and intensity of extreme weather events and raising sea levels. Current policies put us on a trajectory for an increase of 3°C by the end of the century—which will cause severe damage to nature and harm to humanity. Alternatively, deep, rapid, and sustained reductions in emissions could limit warming to below 2°C.

The physical effects of climate change will significantly reduce economic productivity and damage economic assets this century.
Our analysis suggests that the cumulative economic output could be reduced by 15% to 34% if the global average temperature is allowed to rise by 3°C by 2100 rather than being limited to below 2°C. This is the equivalent of reducing annual GDP growth by about a half of a percentage point, on average.

Of course, there is uncertainty in such long-term estimates. On the positive side, our economies may be more resilient than we expect, and our adaptation efforts more effective, enabled by human ingenuity and technological advances in areas such as robotics, AI, and synthetic biology that could lower economic impacts. On the negative side, current models do not fully account for the economic damage of passing tipping points, such as the loss of coral reefs or the Amazon forest dieback.

Rapid and sustained global investments in mitigation and adaptation will reduce the economic damages and should come with a high return.
Mitigation slows global warming by cutting emissions; adaptation reduces vulnerability to the physical impacts of climate change. Investments in both must rise significantly by 2050—9-fold for mitigation and 13-fold for adaptation. We estimate that the total investment required equals 1% to 2% of cumulative economic output to 2100.

The return on this investment is compelling. The net cost of inaction—that is, the cost of not addressing climate change after accounting for the investment required for mitigation and adaptation—equates to 11% to 27% of cumulative economic output. To illustrate the magnitude of these costs: the average of this range is equivalent to three times global health care spending until 2100; one-eighth of it is equivalent to expected global military expenditures until 2100.

Despite the economic case for staying below 2°C, the world is not on track to do so.
We have observed five barriers to accelerated climate action. The first is that the political discussion often overlooks the economic case for climate action, particularly early on when the costs to reduce emissions are often quite high. But over time, climate change will slow growth and weaken resilience, undermining societies' broader objectives, including improving health care and strengthening security. The second is that many costs of climate action come before 2050, but the bulk of the economic benefits will be evident after 2050.

The third barrier is that the costs and benefits of climate action are unevenly distributed among countries. Even in the Paris Agreement, there is no global consensus on how emissions should be reduced. The fourth is that the transition threatens to create winners and losers within economies, requiring a just transition and equitable economic development. Finally, the fifth barrier is that the economic damages of climate change are not understood by economists to their full extent or with enough detail.

Fortunately, the barriers can be addressed with sustained effort from leaders in five areas:

- Reframing the debate on the costs of climate change
- Creating transparency on the net cost of inaction across all actors
- Strengthening national climate policies to accelerate mitigation and adaptation
- Reinvigorating international cooperation on climate change
- Advancing our understanding of the net cost of inaction

The Physical Impacts of Climate Change

Global warming is accelerating. From 2010 through 2019, the global average temperature rose 1.1°C relative to that of preindustrial times from 1850 through 1900. In the past ten years, the average increased to 1.3°C, and 2024 emerged as the hottest year on record, according to the World Meteorological Organization, with the average climbing even higher to 1.55°C above preindustrial levels.

This warming is driven by greenhouse gas emissions, including CO_2, which increased 19-fold globally since 1900,[1] with **40% emitted in the past three decades alone**. In a 2020 article, UNEP noted that our planet has not seen such high CO_2 levels in the last 800,000 years. Human activity, especially the combustion of fossil fuels, has caused this rise. **(See Exhibit 1.)** The global average will continue to rise with continued emissions. The current policies put the world on track for an average temperature that is about 3°C above preindustrial levels by 2100.

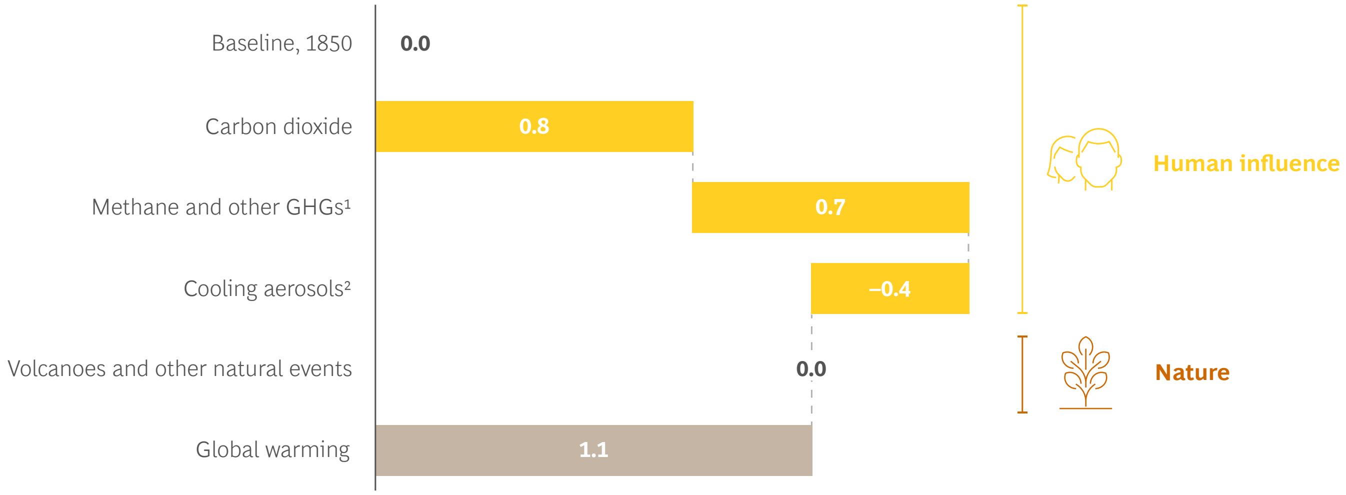
The climbing average temperature is causing physical impacts, such as rising sea levels and the increase in the frequency and severity of extreme events, including heat waves, storms, droughts, wildfires, and flooding. For example, sea levels have risen nearly 25 centimeters since 1880,[2] and extreme heat waves that occurred roughly once a decade before 1850 now occur three times as often and are, on average, 1.2°C hotter, according to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). **(See Exhibit 2.)**

1. Global Carbon Budget (2024); Hannah Ritchie and Max Roser, "CO_2 Emissions: How much CO_2 does the world emit? Which countries emit the most?" Our World in Data, January 2024.
2. Rebecca Lindsey, "Climate Change: Global Sea Level," NOAA, August 22, 2023.

EXHIBIT 1

Global Warming Since 1850 Has Been Driven by Human Influence, While Natural Events Have Had a Negligible Effect

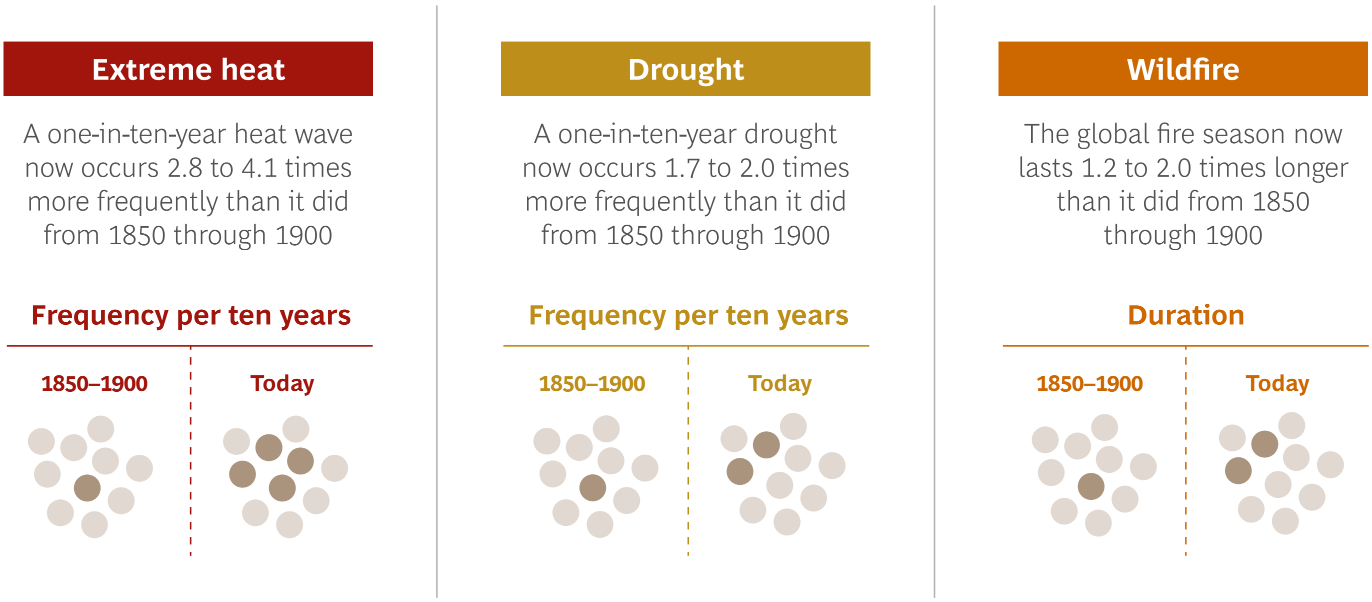
Contribution to average global warming, 2010–2019 (°C)



Sources: IPCC, Sixth Assessment Report (AR6); BCG analysis.
Note: GHG = greenhouse gas.
[1]Includes nitrous oxide and fluorinated gases.
[2]Predominantly cooling aerosols, but also other human drivers, including land use change and ozone.

EXHIBIT 2

Today's Climate Has Already Changed Compared with the Time of the Industrial Revolution



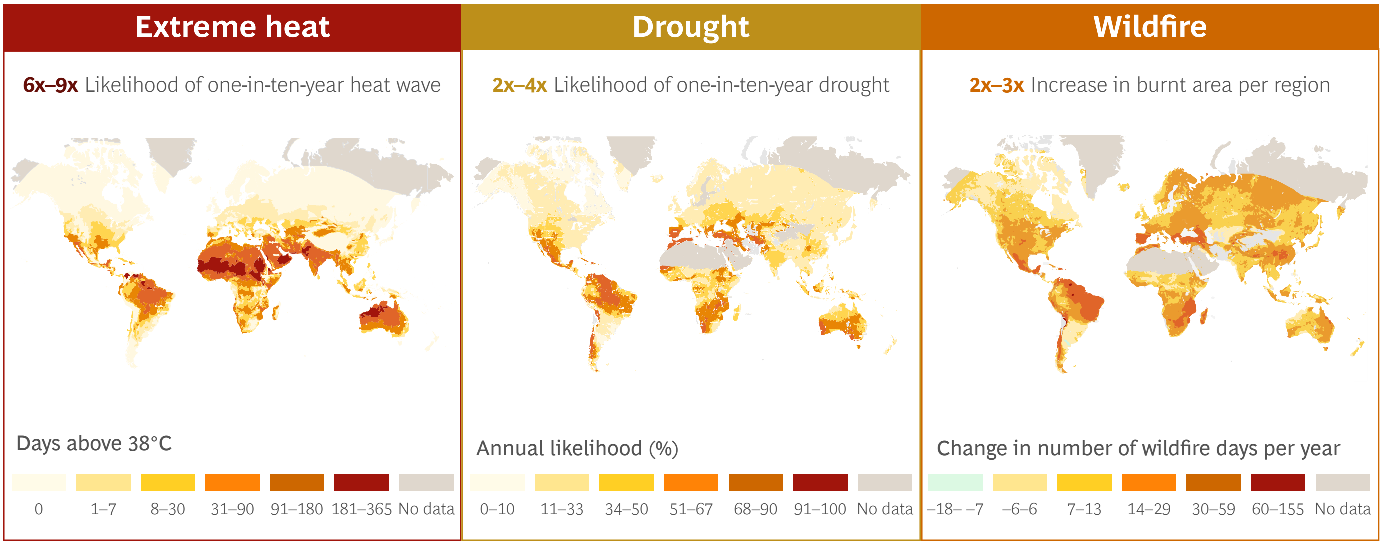
Sources: IPCC, Sixth Assessment Report (AR6); BCG analysis.

The world has made progress in limiting global warming. Before 2015, we were on track for 4.3°C of warming by 2100;[3] today we are on track for 3°C. Nonetheless, on this path, climate hazards are expected to increase both in frequency and intensity in every region of the world, although the nature and severity of the impacts will vary. **(See Exhibit 3.)**

The physical impacts of climate change are imposing social costs. Those impacts include the direct loss of life and health challenges, such as disease proliferation in a warmer, wetter world and increased risk of heatstroke. In a 2024 article, the World Economic Forum (WEF) noted that by 2050, heat waves are forecast to account for nearly 1.6 million deaths—mostly in the US, Central America, southern and western Africa, the Middle East, India, Southeast Asia, and Northern Australia. There's also the risk of large-scale displacements, territorial loss, or the loss of culture, heritage, and identities. For example, the Inuit peoples, indigenous to Arctic regions, and their way of life are under threat as the amount of ice in polar regions continues to decline.

EXHIBIT 3

Physical Risks Will Intensify if the Average Global Temperature Reaches 3°C Higher Than Preindustrial Levels



Sources: IPCC, Sixth Assessment Report (AR6); NOAA; Probable Futures; BCG analysis.

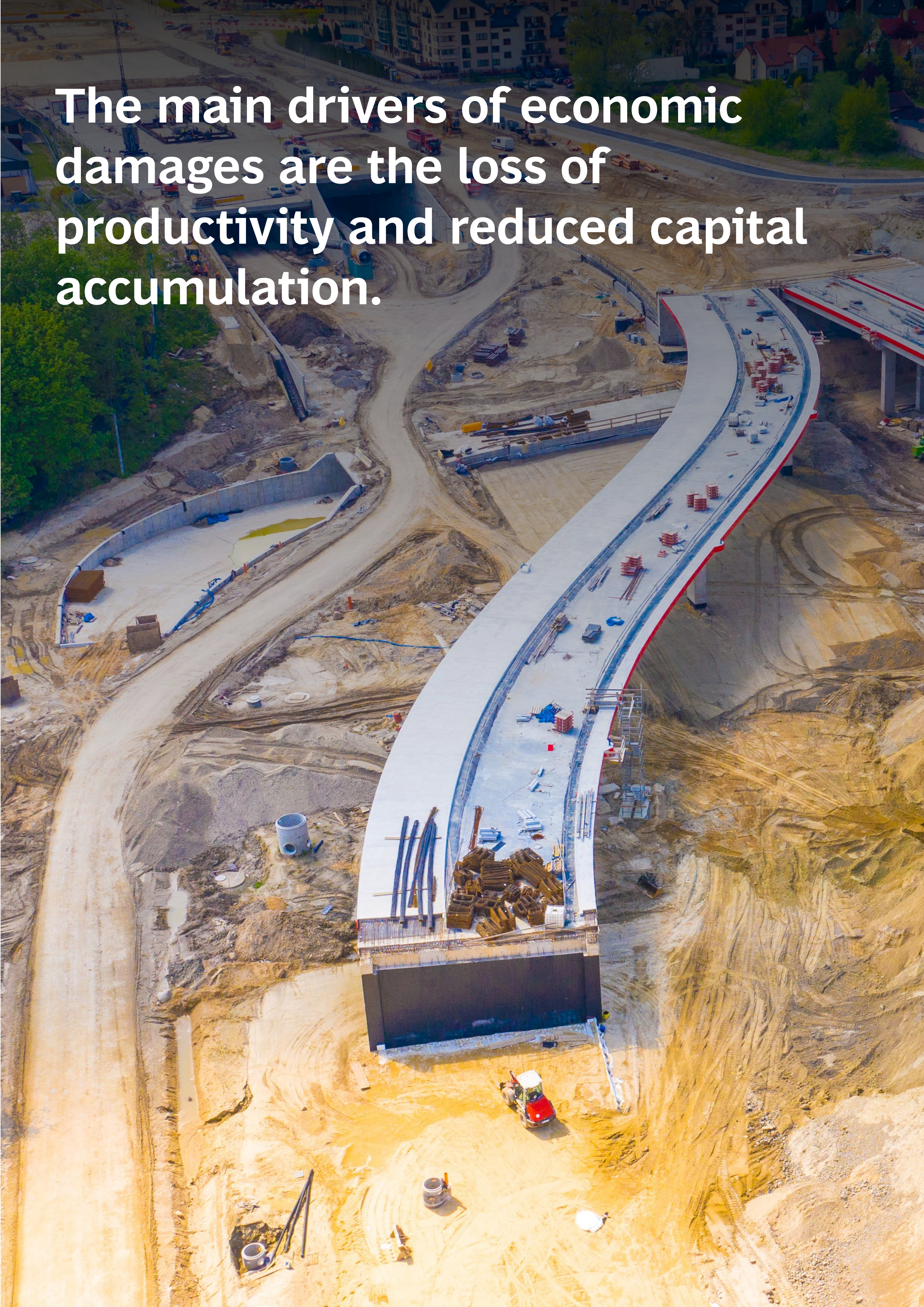
3. "Long-term Climate Change: Projections, Commitments and Irreversibility," IPCC, 2013; projections under RCP8.5 scenario.

This report focuses on the less-well-appreciated economic costs of climate change:

- **Damage to Natural Assets and Ecosystem Services.** Biodiversity levels would decline, affecting materials and food, protection from extreme events, carbon sinks, water and air filtration, and resources for drug development.
- **Damage to Capital Stock.** Harm to property, infrastructure, assets, and natural services would occur.
- **Productivity Loss.** The challenges facing labor (heat stress, for example), the redirection of capital to nonproductive activities such as seawalls, and the decline in land quality and agricultural yields would impair productivity.
- **Supply Chain and Trade Disruption.** The production and distribution of goods and services would be interrupted.
- **Financial Instability.** Sectors vulnerable to climate change could face asset devaluation and liquidity and credit risk. Uncertainty about climate impacts on investments could fuel market volatility.

Despite the significant social and economic costs of climate change that are becoming more and more tangible, most leaders focus on the short term—a perspective that Mark Carney, the prime minister of Canada, once called the tragedy of the horizons. To overcome this short-term thinking and improve decision making, we believe what's needed is a holistic view that quantifies the costs of not acting against climate change. In this report, we seek to address this gap by partnering with climaTRACES Lab at the University of Cambridge and Cambridge Judge Business School to build on recent economic research. (**See Appendix 1.**)

The main drivers of economic damages are the loss of productivity and reduced capital accumulation.



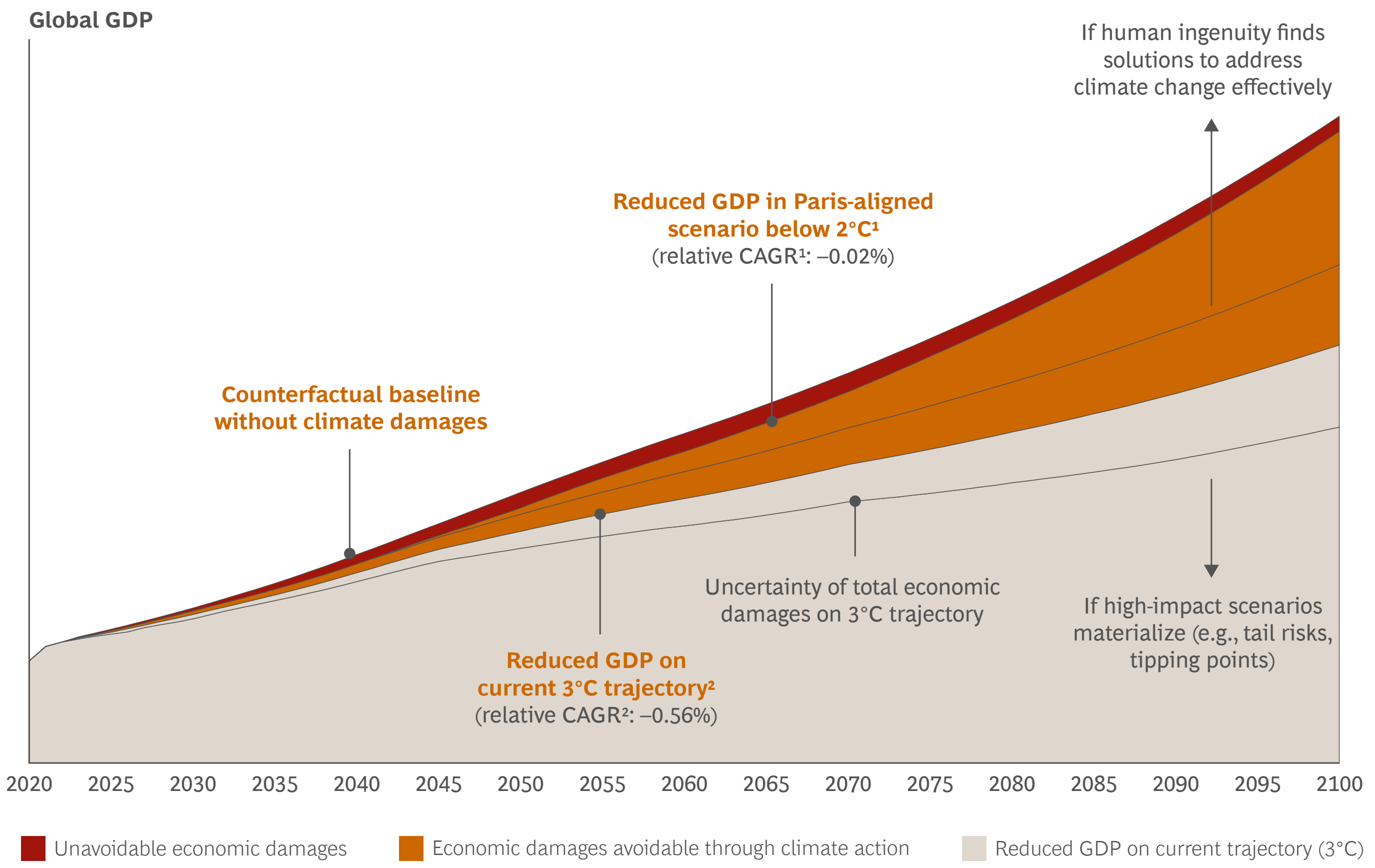
The Economic Damages of Climate Change

Allowing the global average temperature to rise by 3°C by 2100, rather than limiting it to below 2°C, could reduce cumulative economic output by 15% to 34%. We have compared three scenarios to assess the potential economic damage of climate change **(see Exhibit 4)**:

- The baseline scenario assumes no further economic damage from climate change, nor further adaptation needs. This scenario is counterfactual and does not account for real-world climate impacts.
- In the best-case scenario—the rise in the global average temperature is below 2°C by 2100—GDP growth is estimated to decelerate by 0.02% per year relative to the baseline scenario. This results in an unavoidable cumulative GDP loss of up to 4%.
- In the alternative scenario—the global average rises by 3°C by 2100—GDP growth would lose about a half of a percentage point, on average, per year relative to the baseline. This results in a cumulative economic output loss of 15% to 34%. This scenario reflects avoidable losses compared with a counterfactual baseline without climate damages.

EXHIBIT 4

On a 3°C Trajectory, the Economic Damages from Climate Change Could Reach up to 34% of Cumulative GDP by 2100



Sources: NGFS; CPI; UNEP; IPCC; World Bank; BCG analysis.
Note: Initial estimates—not actual GDP figures; investments were not considered. All effects are relative to the counterfactual baseline without climate effects (2023 GDP with IPCC AR6 WGIII growth assumptions; global GDP growth [ppp] range from 2.5% to 3.5% per year in the 2019–2050 period and 1.3% to 2.1% per year 2050–2100 [5th–95th percentile]). GDP losses under current policies scenario was linearly adjusted between 2045–2070.
[1] 2025–2100.
[2] Reduced GDP is based on climate damages (after adaptation) excluding required investments in mitigation and adaptation.

Our estimates are based on a review of the economic literature and are aligned with the Network for Greening the Financial System (NGFS).

We chose not to apply cash flow discount rates to our model given their subjective nature and the absence of a consensus on whether their use is appropriate in the context of climate change. We have also kept them out for clarity, conscious that readers may impose their own. **(See Appendix 2 and Appendix 3.)**

Ultimately, these estimates come with uncertainties. On the positive side, our economies may be more resilient than we expect, and our adaptation efforts more effective to adapt to a 3°C scenario. Human ingenuity and technological advances in areas such as robotics, AI, and synthetic biology could lower economic impacts. On the negative side, current models do not fully account for all sources of damage, for instance passing tipping points, such as the loss of coral reefs or the Amazon forest dieback.

This top-down estimate aligns with our bottom-up calculations of the economic damage for specific countries and regions, supported by our project work. We have found that these damages may amount to 25% of GDP by 2050. Thus, our estimates support the range of the top-down global assessments. **(See Exhibit 5 and Exhibit 6.)**

EXHIBIT 5

A Southeast Asian Country Could Suffer GDP Losses of 18% to 25% by 2050

Project scope

A Southeast Asian country was facing severe climate risks, compounded by its reliance on coastal and natural resources and 18% of its population living in poverty. BCG partnered with a bilateral development organization and the country's Climate Change ministry to develop a national adaptation plan and an adaptation and resilience project pipeline.

Country climate profile

1. Twice the global sea level rise expected
2. Heat index of about 40°C by 2050
3. 70% increase in typhoon frequency and 20% more extreme precipitation

Economic damages	Social damages	Environmental damages
>70 Number of unproductive days by 2050, with some areas reaching over 200	**$180 million** Potential relocation costs due to sea level rise	**Water scarcity** Leading to loss of biodiversity
15% Share of communication infrastructure estimated to be damaged along with 8% of energy infrastructure	**10%** Share of critical health care infrastructure exposed to pluvial floods	**Increasing temperature** Risking coral bleaching in oceans and the degradation of the ecosystem

Source: BCG analysis.

EXHIBIT 6

GDP Losses of 17% by 2050 Are Possible for a West African City

Project scope

A coastal city faced severe climate risks, compounded by extreme poverty (65%) and a dense population. Its reliance on critical infrastructure supporting 75% of national imports further heightened its vulnerability, requiring urgent action. BCG supported a city government to develop a deep and localized understanding of climate impacts, derive an adaptation and resilience (A&R) plan, build a pipeline of A&R projects, and catalyze climate finance.

City climate profile

1. Extreme precipitation causing flooding of 4 meters annually
2. Average temperature estimated to increase by 1°C by 2050
3. Sea level rise expected of 3 meters by 2050 due to its coastal location

Economic damages	Social damages	Environmental damages
>10% Share of the transportation network and power grid estimated to be damaged	**>400** Number of health centers expected to be disrupted	**82%** Share of wetlands affected, potentially leading to biodiversity losses
700 kilometers Length of roads potentially damaged; 26 jetties and ports possibly inundated	**>$6 billion** Relocation costs driven by inundation of more than 70 water supply assets	
44 Number of productive days lost per year		

Source: BCG analysis.

Reduced Productivity Drives Economic Damages

The loss of productivity and reduced capital accumulation, rather than merely the destruction of physical assets, are the main drivers of economic damages. From 2000 to 2023, the reported economic losses from natural disasters attributed to climate change were $700 billion in the US.[4] The estimated productivity losses from climate change were almost six times greater over the same period: $4 trillion. Moreover, all sectors of the economy were negatively affected by climate change between 1963 and 2016, and they will be further impacted as the global average temperature continues to rise.[5] **(See Exhibit 7.)**

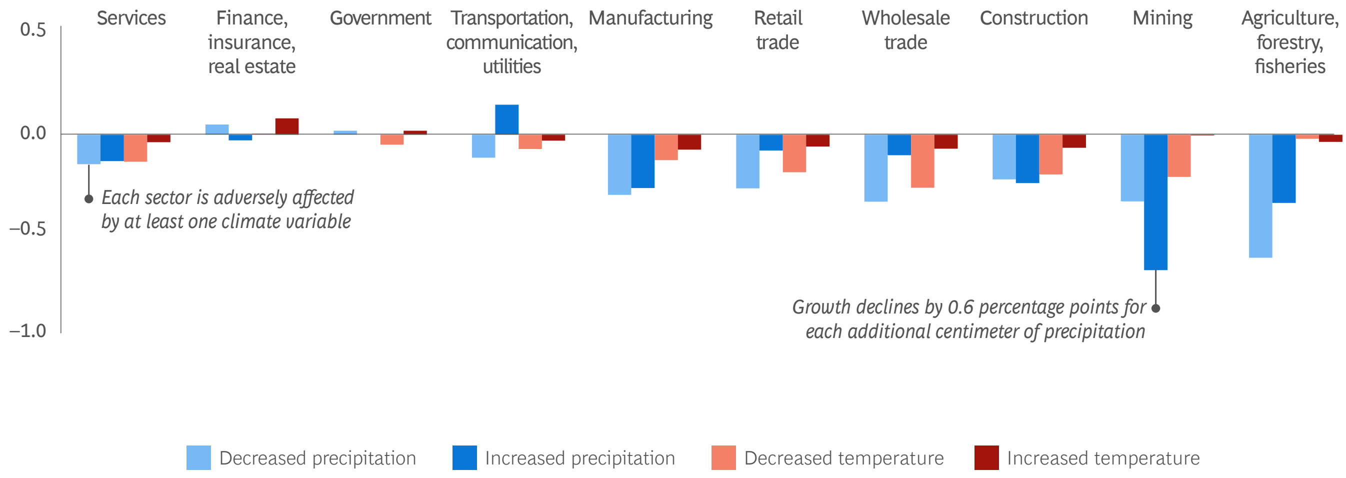
Other literature supports these findings. For example, climate variations such as extensive periods of rain and snow, high heat, and severe winds caused production volatility in US automobile plants and had adverse effects on labor productivity.[6] These effects extend beyond the US and the automobile sector. Extreme weather is affecting agricultural production and being reflected in commodity prices. The prices for olive oil and cocoa, for example, have more than doubled over the past two years due to droughts in production areas, according to a 2024 WEF article.

4. "Billion-Dollar Weather and Climate Disasters," NOAA, undated; numbers have been adjusted for inflation.
5. Mohaddes K., Ng R., Pesaran M., Raissi M., Yang J. (2023) "Climate change and economic activity: evidence from US states," *Oxford Open Economics*, Volume 2, 2023.
6. "Severe Weather and Automobile Assembly Productivity," Columbia Business School Research Paper No. 12/37, July 4, 2012.

EXHIBIT 7

Climate Change Undermines Growth Across Sectors

Average impact of climate variability on annual growth of income by sector in US, 1963–2016 (pp)



Sources: "Climate change and economic activity: evidence from US states," Oxford Open Economics, 2023; BCG analysis.
Note: pp = percentage point.

Economic Damages Are Likely Underestimated

There are several reasons to believe that climate change will cause more severe economic damages—and sooner—than the current 3°C trajectory **(see Appendix 4)**:

- **Limitations of Current Scientific Predictions.** Climate change would occur faster than expected if climate sensitivity is underestimated (for example, if the temperature is affected by greenhouse gases more than expected) and tail risks materialize (such as unlikely but catastrophic events). For example, there is a 10% risk that the global average temperature could increase by 6°C by 2100.

- **Limitations of Current Economic Model Predictions.** Current models are not sophisticated enough to capture the compounding economic damages of climate change at higher temperatures or account for spillover effects across countries and regions, according to a 2019 IPCC special report. For example, climate disruptions in a major food-producing region could cause price shocks in other regions, resource shortages, and even political unrest.

- **Limitations of Modeling Physical Risks.** Current models do not holistically include climate tipping points and feedback loops. Some tipping points activate feedback mechanisms that amplify climate changes. Also, they can be interconnected—crossing one increases the likelihood of triggering others.

Without sufficient mitigation efforts, evidence suggests that we are in danger of triggering 8 tipping points by 2050. **(See the sidebar "What 2050 Could Look Like.")** And by 2100, if the Earth's temperature has risen by 3°C, we are likely to be in danger of crossing yet another 5. **(See Exhibit 8.)** Of these 13 tipping points, the following are expected to have the most significant economic consequences:

- **Extinction of Tropical Coral Reefs.** Between 70% and 90% of the world's coral reefs could die on a 1.5°C global warming trajectory.[7] The Climate Foundation estimates that about 1 billion people depend on the fisheries supported by coral reefs for their livelihoods and face a potential loss of $375 billion annually in goods and services.

7. McKay et al, "Exceeding 1.5°C global warming could trigger multiple climate tipping points," *Science*, September 9, 2022.

What 2050 Could Look Like

By 2050, a 3°C warming trajectory will profoundly alter daily life worldwide, driving extreme heat, water scarcity, and frequent climate events. These changes will disrupt livelihoods, damage infrastructure, strain food and water supplies, and escalate health risks. Here, we take a look at some likely outcomes in six countries.

US

- The number of days with a maximum daily temperature above 35°C may surge by nearly 50%. Currently, temperatures crossed that threshold approximately 15 days per year (an average from 2010 through 2024); the World Bank estimates that the number is likely to increase to 22 in 2050.
- In 2020, extreme heat conditions in Phoenix, Arizona, made intense outdoor activity unsafe for approximately 85 days. By 2050, this figure may rise to approximately 100 days annually.[1]
- Wildfires may double in size by 2050, compared with that of today (an average from 2010 through 2023), affecting 9 million to 12 million acres, with Western states bearing the greatest impact.[2]

Colombia

- The average maximum temperature across Colombia is likely to increase from the baseline average of approximately 28.5°C (an average from 1995 through 2014) to 30.1°C in 2050, according to a 2021 climate risk country profile by the World Bank.
- By 2050, 10% to 47% of the Amazon rainforest may be threatened by multiple compounding climate risks, including droughts and fires.[3]
- By 2050, the duration of dry spells (which are the maximum number of consecutive dry days) in Colombia may increase by about 10% from the current average for 1994 through 2014, according to the World Bank's Climate Change Knowledge Portal.

Niger

- The number of tropical nights that have a temperature above 29°C are likely to increase to about 56 annually by 2050, up more than four times the average of 12 nights per year from the baseline (an average from 1950 through 2014), according to the World Bank.
- By 2050, 5% to 7% of the population of Niger may experience annual heat waves, up from 2.5% in 2010. The Potsdam Institute for Climate Impact Research estimates that heat-related mortality could reach 6 deaths per 100,000 people per year in the country.
- Niger is likely to lead West Africa in internal climate migration, primarily driven by drought. As many as 19.1 million people, out of a total population of 27 million, may be displaced by 2050, according to a 2024 climate fact sheet by the Climate Centre.

Italy

- Extreme sea levels—temporary surges above the average local sea level due to storms or high tides—may rise from 1.12 meters currently to 1.39 meters by 2050, according to the G20 Climate Risk Atlas for Italy, subjecting coastal regions to increasingly severe waves and storms.
- By 2050, 480,000 people are likely to experience annual coastal floods, up from 430,000 today, as mentioned in the G20 Climate Risk Atlas.
- Sandy shorelines may retreat by 17.4 meters along 3,000 kilometers of coastline by 2050, according to the G20 Climate Risk Atlas and the Climate Change Post.

1. The Provide climate risk dashboard, Climate Analytics; De Ridder et al, "UrbClim—a fast urban boundary layer climate model," *Uban Climate*, 2015.
2. Abatzoglou et al, "Projected increases in western US forest fire despite growing fuel constraints," *Nature*, November 2, 2021.
3. Flores et al, "Critical transitions in the Amazon forest system," *Nature*, February 14, 2024.

India

- Very wet monsoon seasons occurred once a decade (an average from 1965 through 2015). Their frequency may increase by a factor of eight after 2050.[4]
- By 2050, extreme sea levels may rise from 2.05 meters today to 2.31 meters. This would submerge approximately 1,000 square kilometers of coast, making an area populated by more than 20 million people unlivable, according to the G20 Climate Risk Atlas for India.
- Climate factors such as increasing precipitation and humidity may elevate the risk of dengue transmission. The G20 Climate Risk Atlas also notes that this may potentially threaten over 98% of the population by 2050.

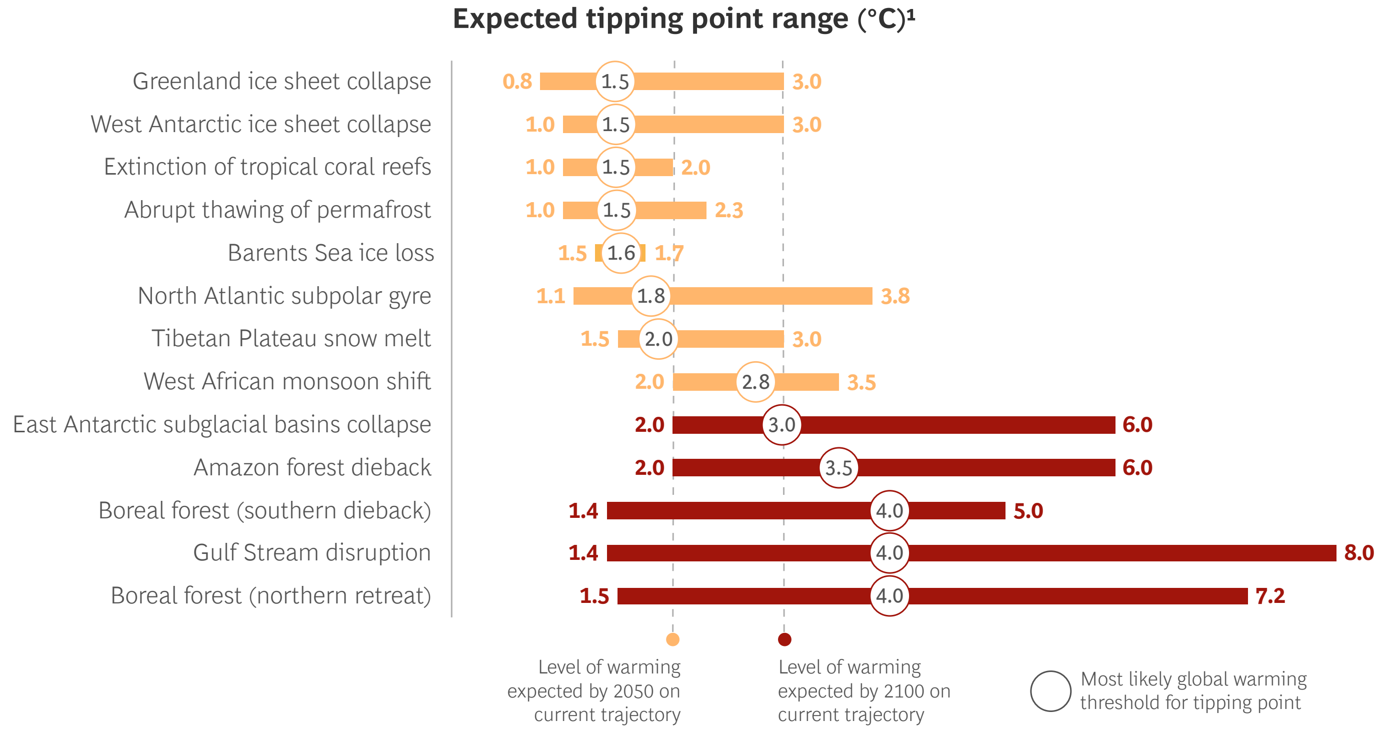
Indonesia

- The maximum daily temperature may increase significantly, rising from a baseline of 31.7°C (an average from 1950 through 2014) to 33.1°C by 2050, according to the World Bank.
- Labor productivity, already reduced by 10% in peak months due to global warming today, could decline another 20% by 2050. A World Bank climate risk country profile in 2021 estimated that heat deaths in the region could increase nearly sevenfold by 2050.
- Water scarcity in Indonesia is likely to intensify. In 2010, 14% of districts reported no surplus water, a figure that the World Bank estimated would increase to 31% by 2050.

4. Katzenberger et al, "Intensification of Very Wet Monsoon Seasons in India Under Global Warming," Geophysical Research Letters, American Geophysical Union, 2022.

EXHIBIT 8

The World May Reach 13 Tipping Points by 2100



Sources: "Exceeding 1.5°C global warming could trigger multiple climate tipping points," *Science*, 2022; BCG analysis.
[1]Expressed in global warming level relative to preindustrial times.

- **Abrupt Thawing of Permafrost.** The Boreal permafrost stores about a trillion tons of carbon in the upper three meters of the frozen soil.[8] On our current 3°C trajectory, a Boreal permafrost thaw could release 14 gigatons of CO_2 equivalent and increase global warming by 0.12°C by 2100.

- **Tibetan Plateau Snow Melt.** Losing 50% to 70% of glacier mass by 2050 would affect more than 1 billion people in Asia who rely on these water sources for drinking, agriculture, and energy.[9] In addition, the loss of glacier mass will disrupt the alpine ecosystem, threatening endemic species.

- **Amazon Forest Dieback.** As drought and heat dry out the forest, the Amazon basin would convert into a savanna and begin releasing more CO_2 than it absorbs, accelerating global warming. Even a partial dieback could release about 110 gigatons of CO_2 equivalent and increase the global average temperature by 0.1°C.[10]

- **Gulf Stream Disruption.** The Atlantic Meridional Overturning Circulation is a key part of the ocean's circulation system that distributes heat globally. A collapse would create extreme temperatures and unpredictable weather patterns that could hurt agricultural production and result in food shortages.

8. "Tipping Elements – big risks in the Earth System," Potsdam Institute for Climate Impact Research, undated.
9. Chen et al, "Southeast Asian ecological dependency on Tibetan Plateau streamflow over the last millennium," *Nature Geoscience*, 2023.
10. McKay et al, "Exceeding 1.5°C global warming could trigger multiple climate tipping points," *Science*, September 9, 2022.

The Business Case for Climate Action

Both mitigation and adaptation are crucial to minimizing the economic consequences of climate change:

- **Mitigation** reduces net global greenhouse gas emissions to slow global warming; it is no longer needed when net zero is reached. Mitigation actions include, for example, increasing energy efficiency, electrification, and reforestation.

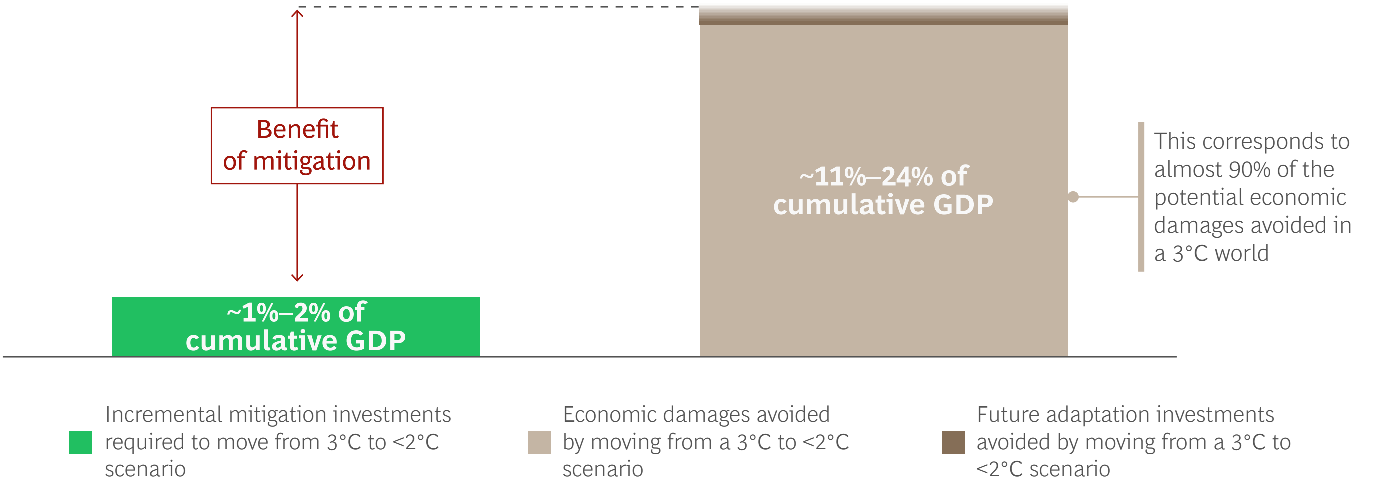
- **Adaptation** reduces the vulnerability of human or natural systems to climate hazards by adapting and increasing their resilience. Adaptation actions include, for example, building seawalls, sowing drought-resistant crops, and installing cooling solutions.

The Investments Required for Climate Action

Mitigation is the most cost-effective means of reducing the economic damages of climate change. **(See Exhibit 9.)** According to our analysis, by investing an incremental 1% to 2% of cumulative GDP in mitigation by 2100 and limiting global warming to below 2°C, the world can avoid economic damages of 11% to 24% of cumulative GDP. This corresponds to nearly 90% of the potential avoidable economic damages expected if we continue on the current trajectory of 3°C. In other words, mitigation investments could return as much as 5 to 14 times the original investment over the same period. Unfortunately, the payback period is measured in decades, and the application of a discount rate would reduce the returns. We explore this barrier later.

EXHIBIT 9

Investments in Mitigation Avoid Economic Damages and Future Adaptation Costs



Sources: NGFS; UNEP; CPI; IPCC; World Bank; BCG analysis.
Note: All effects are relative to the counterfactual baseline without climate effects (2023 GDP with IPCC AR6 WGIII growth assumptions; global GDP growth [ppp] range from 2.5% to 3.5% per year in the 2019–2050 period and 1.3% to 2.1% per year in the 2050–2100 period [5th–95th percentile]); temperature scenario refers to 2100.

While increased mitigation action avoids higher adaptation costs, some adaption costs will still be necessary even in a best-case scenario (keeping global warming to below 2°C) given the economic damages already locked in. Of course, in a 3°C scenario, adaptation costs would be greater still, although reliable estimates aren't possible since the impacts are highly localized. Moreover, recent work on the adaptive investment effect shows that redirecting investment from productive to adaptive capital further reduces economic growth, enhancing the benefits of mitigation actions that avoid higher adaptation needs even more.[11]

To limit warming to below 2°C, global annual CO_2 emissions need to be decreased from more than 50 gigatons of CO_2 to less than 30 gigatons of CO_2 by 2030 and reach carbon neutrality in roughly 30 years. According to the Climate Policy Initiative, this requires significant mitigation investment: 7% of global GDP ($10.5 trillion annually) each year by 2050. This investment is necessary to make across sectors, particularly transport (29%), energy (25%), and buildings and infrastructure (24%). In 2021 and 2022, just 1% of global GDP ($1.2 trillion) was invested in mitigation, which means that annual mitigation finance flows must increase by a factor of nine by 2050.[12] So far, most mitigation spending has occurred in the East Asia and Pacific region (41%), Western Europe (28%), and the US and Canada (14%).

While this funding gap is significant, it's not quite as large as it sounds. Not all of the additional investment required is net new. Approximately 20% can be redirected from high-emission investments and subsidies. **(See Exhibit 10.)**

In addition to mitigation, we must invest enough in adaptation to minimize the economic damages associated with the global average temperature rising to below 2°C by 2100.

Global adaptation finance flows have grown at a compound annual rate of as much as 30% in some regions from 2019 through 2022.[13] **(See Exhibit 11.)** Still, adaptation finance flows were under 0.1% of global GDP ($60 billion to $90 billion) in 2021 and 2022. We estimate that adaptation investments must reach 0.5% of cumulative GDP by 2050 ($1.2 trillion).

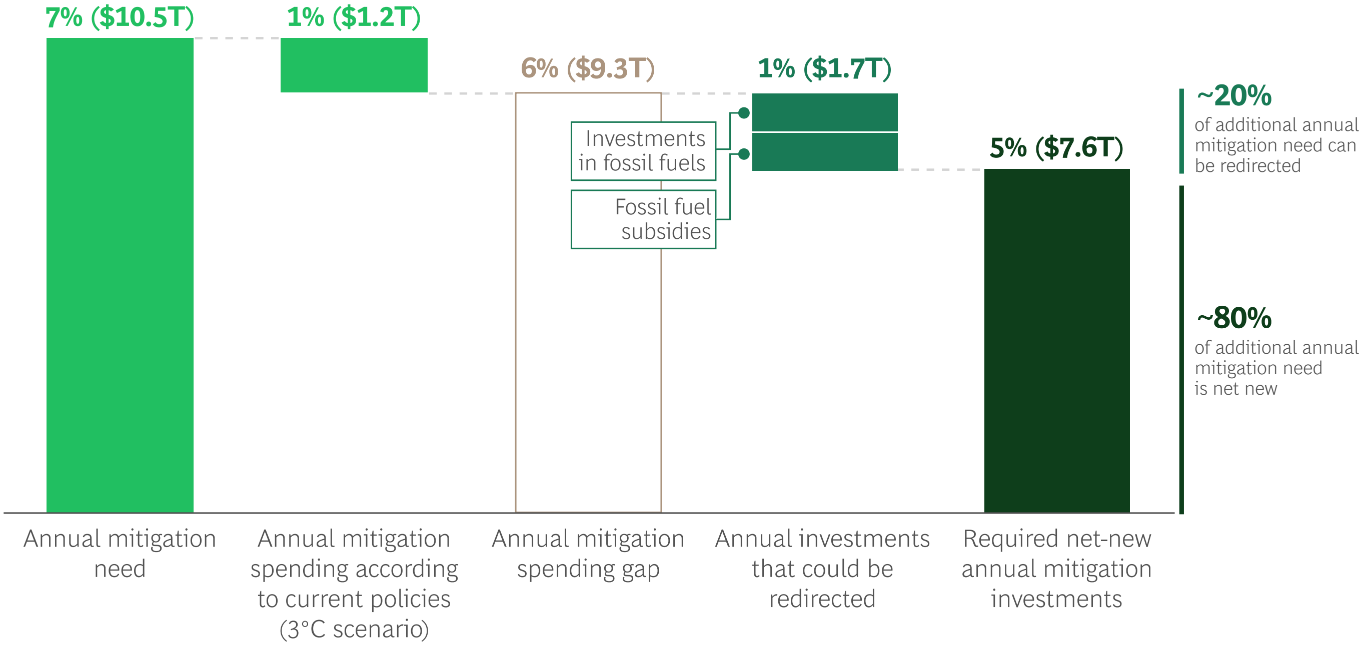
To close this funding gap, annual adaptation finance flows need to increase by a factor of 13 by 2050. By 2100, this equals about 0.3% of cumulative GDP. Thus, we estimate that with less than 1% of cumulative global GDP in adaptation costs, between 1% and 6% of cumulative GDP losses can be avoided by 2100.

11. Mohaddes K. and Williams R., "The adaptive investment effect: Evidence from Chinese provinces," *Economics Letters*, August 2020.
12. Buchner et al, "Global Landscape of Climate Finance 2023," Climate Policy Initiative, November 2, 2023.
13. Buchner et al, "Global Landscape," 2023.

EXHIBIT 10

About 20% of the Additional Investments Needed for Mitigation Can Be Redirected from Elsewhere

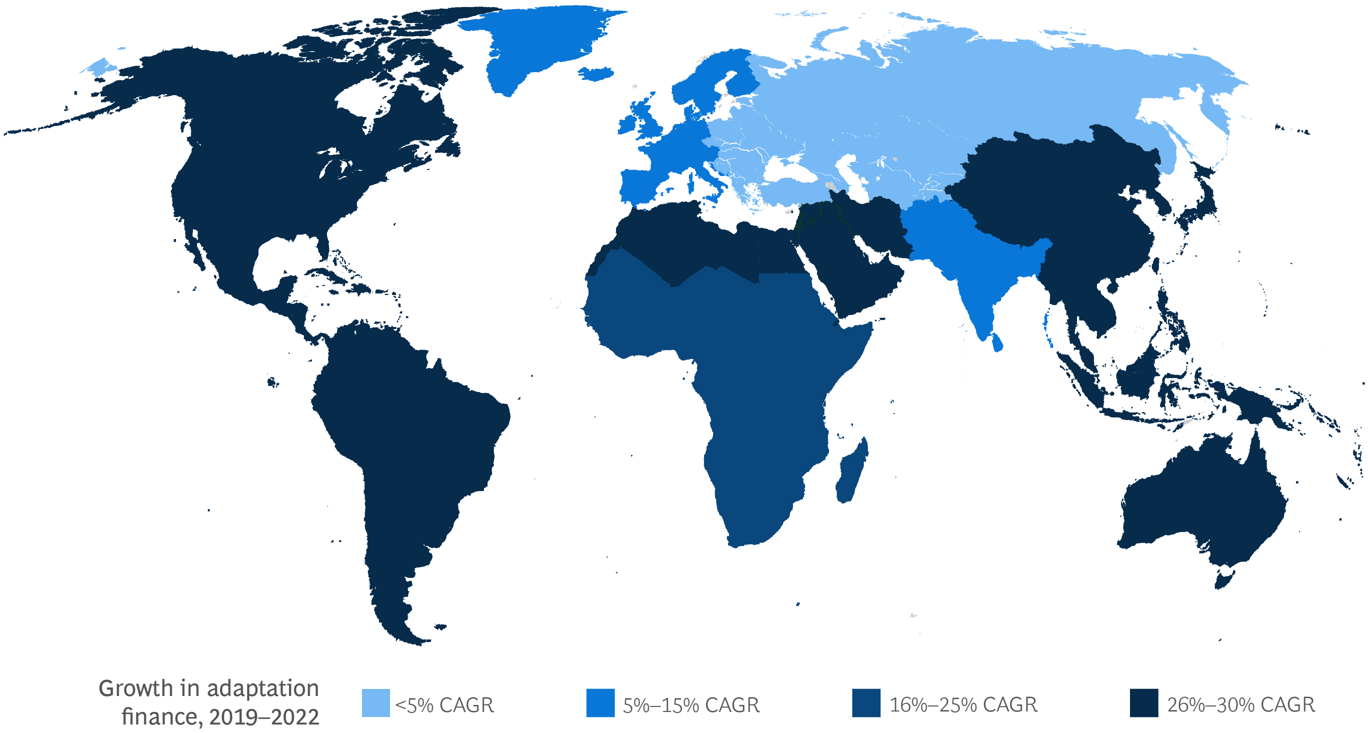
Annual mitigation need and spending by 2050 (cumulative GDP)



Sources: CPI; IMF; BCG analysis.

EXHIBIT 11

Spending on Adaptation Is Rising Globally, but a Significant Funding Gap Remains



Sources: Climate Policy Institute; BCG analysis.
Note: Categorization was based on funding destination, not on funding source; dual-benefit finance was not considered; all amounts were in current or nominal US dollars.

The water and wastewater sectors have received almost half of the adaptation funds ($31 billion), and these investments have provided measurable returns. On the basis of findings from the World Bank,[14] the Global Facility for Disaster Reduction and Relief, the Global Commission on Adaptation, and our work with the Global Resilience Partnership, the returns for every dollar invested in adaptation range from $2 to $15.

The Net Cost of Inaction

The net cost of inaction compares our estimates for global economic damages by 2100 if the average temperature stays on its 3°C trajectory with the reduced economic damages if the average temperature remains below 2°C.

In other words, the net cost of inaction is the amount of economic growth the world could forfeit if we don't make the necessary mitigation and adaptation investments to keep the global average temperature below 2°C.

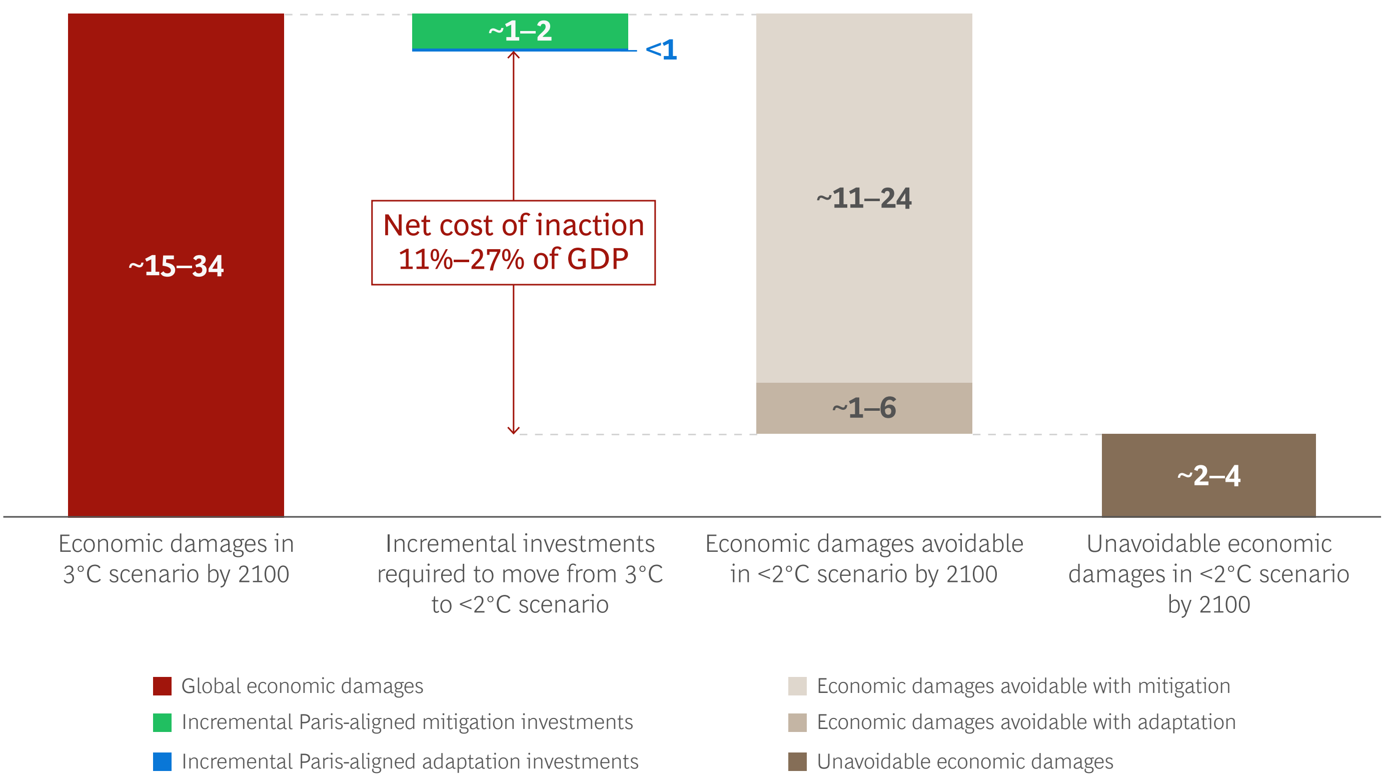
We estimate the net cost of inaction to be 11% to 27% of cumulative GDP from 2025 to 2100, significantly outweighing mitigation and adaptation investments of 1% to 2% of cumulative GDP. (**See Exhibit 12 and the sidebar "What Could the Saved Economic Output Buy?"**)

We should note that economic damages of 2% to 4% of cumulative GDP cannot be avoided, even on a below 2°C trajectory. Some economic damages—such as increased frequency of extreme weather—are already locked in by residual global warming from past decisions.

EXHIBIT 12

The Net Cost of Inaction Amounts to 11% to 27% of Cumulative Economic Output from 2025 to 2100

Climate change costs and investments (cumulative GDP, %)



Sources: NGFS; UNEP; CPI; IPCC; World Bank; BCG analysis.
Note: All effects relative to counterfactual baseline without climate effects (2023 GDP with IPCC AR6 WGIII growth assumptions; global GDP growth [ppp] range from 2.5% to 3.5% per year in the 2019–2050 period and 1.3% to 2.1% per year in the 2050–2100 period [5th–95th percentile]).

14. Tall, et al, "Enabling Private Investment in Climate Adaptation and Resilience: Current Status, Barriers to Investment and Blueprint for Action," World Bank Group, March 2, 2021.

What Could the Saved Economic Output Buy?

Protecting 11% to 27% of cumulative economic output represents a massive opportunity for humanity. With the average of that economic output, we could make significant achievements.

Triple spending on health care globally. We could triple global health care spending until 2100, including funding for hospitals, medicines, emergency care, and family doctors.[1]

Fund global expenditures on defense. With one-eighth of the savings, we could cover expected global military expenditures until 2100.[2]

Cover infrastructure investment needs globally. With one-seventh of the savings, we could cover global infrastructure investment needs across sectors until 2100, including energy, telecommunications, transport, and water.[3]

1. Assuming an annual spending of 10.3% of global GDP in a below 2°C scenario; based on “Global spending on health: Coping with the pandemic,” World Health Organization, 2024.
2. Assuming a consistent annual global expenditure of 2.3% of GDP in a below 2°C scenario; based on “Trends in World Military Expenditure, 2023,” by Tian et al, Stockholm International Peace Research Institute, 2023.
3. Assuming an investment need of $3.5 trillion in 2025, increasing by 2% annually due to inflation; based on “Forecasting infrastructure investment needs and gaps,” Global Infrastructure Hub, undated.

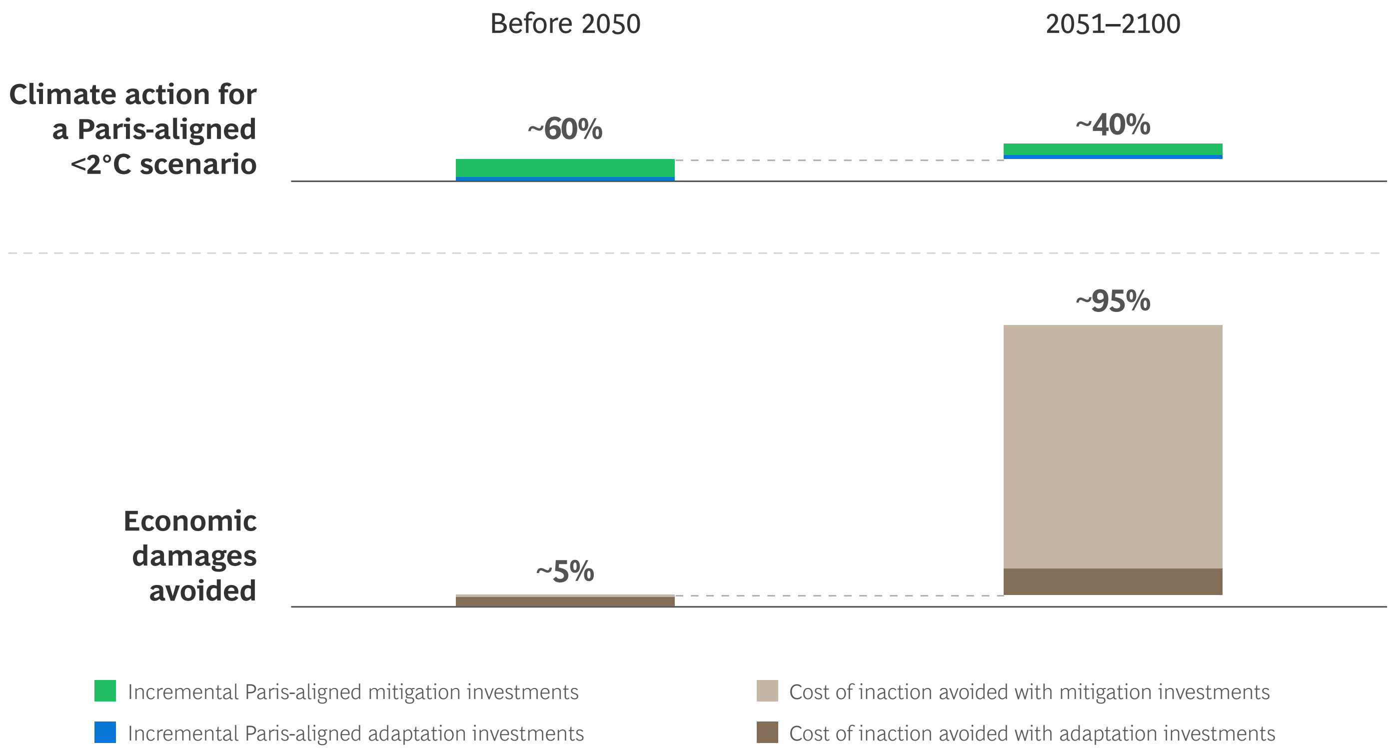
Early Action Is Crucial to Capture Environmental Returns

Early action—investing about 60% of what is required—can avoid 95% of the cost of inaction that can incur after 2050. **(See Exhibit 13.)** And while the returns on investments before 2050 are moderate (5% to 7% of cumulative GDP on top of current investments avoid economic damages equivalent to 3% to 10% of GDP), they may be stronger than estimated.

Current models are most likely underestimating climate damage before 2050 and may overestimate the costs of mitigation and adaption (if, for example, technologies improve). In these cases, the returns on early climate action would be stronger even in the near term. Another reason for immediate action is that climate damages expected after 2050 would have financial impacts even earlier, as companies factor in future risks. For example, insurers' decreasing willingness to offer coverage in fire- or flood-prone regions is being priced into insurance contracts.

EXHIBIT 13

Most Climate Investments Are Required Before 2050, but Most Economic Benefits Will Be Realized After 2050



Sources: NGFS; UNEP; CPI; IPCC; World Bank; BCG analysis.
Note: All effects are relative to the counterfactual baseline without climate effects (2023 GDP with IPCC AR6 WGIII growth assumptions; global GDP growth [ppp] range from 2.5% to 3.5% per year in 2019–2050 period and 1.3% to 2.1% per year in 2050–2100 [5th–95th percentile]).

The Barriers to Accelerated Climate Action

Despite the clear economic case for limiting the global average temperature increase to below 2°C, we are heading toward an increase of 3°C by 2100. Why? We believe there are five fundamental barriers to climate action, all of which can be overcome with targeted action.

The Political Discussion Often Overlooks the Economic Case

On the basis of our engagement with leaders across the globe, it is evident that the economics are not consistently and comprehensively addressed in the political discussion of climate change.

According to our analysis of public speeches during the past three annual conferences, global leaders are more likely to frame climate action in social and moral terms, while the economic implications are not emphasized or even mentioned. Only about half of the speeches highlighted the economic damages caused by climate change, only about a third attempted to quantify them, and only about two out of ten made an economic case for investing in climate action based on the economic consequences of delay. They were more likely to emphasize shorter-term tradeoffs in public spending and growth.

The political discussion often overlooks the economic case

The costs come before 2050, but the bulk of benefits occur later

The costs and benefits are unevenly distributed among countries

The transition threatens to create winners and losers within economies

The economic damages are not fully explored by economists

The visible and rising economic toll of extreme weather and our growing confidence in attributing specific events to climate change is beginning to shift the discussion. Collaborative efforts by organizations such as National Center for Atmospheric Research (NCAR), World Weather Attribution (WWA), and Climate Central play a crucial role here.

The Costs Come Before 2050, but the Bulk of Benefits Occur Later

Leaders need to prepare for payback periods measured in decades—at least in terms of avoided economic damages. This undermines climate action since such a far-off payback is beyond most leaders' time horizons and plays into innate human biases:

- **A Preference for the Present.** Climate change policies and investments address long-term, hypothetical risks, while politicians, businesses, investors, and voters prioritize short-term goals such as elections and profits.

- **A Tendency for Optimism About the Future.** Humans tend toward optimism that future solutions will solve climate problems.

This barrier to action, however, is lowering as climate change progresses. A rapidly growing proportion of the population will be alive after 2050; children born in 2025 will experience approximately 90% of their adult lives between 2050 and 2100 (assuming an average lifespan of 75 years) when the impact of climate change is expected to become severe. Even people ages 30 to 50 years old today will experience a marked increase in economic damages within their lifetime. Seniors are already disproportionally more affected, particularly by extreme heat. In the US, over 80% of heat-related deaths occur among individuals aged 60 and above.[15] Heat-related deaths are also concerning for other G20 member countries because, according to a 2019 UN report, these nations account for more than 70% of the world's older population.

Meanwhile, financial institutions (such as insurance companies) and credit rating agencies are making the costs of tomorrow felt today. Rising climate risks are making insurance less affordable. By 2040, premiums are expected to nearly triple to $1.3 trillion, widening the portion of potential uninsured financial losses and leaving vulnerable regions less able to recover from disasters. Indeed, Swiss Re Institute attributes about a quarter of that cost increase to climate-related risks.[16]

At the same time, climate change could also affect financial markets, for example by causing lowered sovereign credit ratings. It is estimated that 59 countries already face an average 0.68-notch downgrade by 2030. While many economic costs of climate change will materialize in the future, the fiscal and public debt implications could occur on a much earlier timeline. Further, they could be exacerbated over time—81 sovereigns face an average downgrade of 2.18 notches by 2100; heavily affected countries include China, Chile, and India.[17]

Such downgrades would increase borrowing costs and have other significant repercussions, including less available public funding due to increased debt repayments, higher borrowing costs for businesses, and, potentially, reduced investor interest in the jurisdiction, all making it more expensive to cope with climate change in the future. In fact, climate change is already affecting sovereign creditworthiness: in a December 2024 article, Corporate Maldives reported that Moody's confirmed the Maldives' rating of Caa2 with a negative outlook, citing the impact of rising sea levels on the Indian Ocean archipelago's vital tourism sector.

15. Stephanie Dutchen, "The Effects of Heat on Older Adults," *Harvard Medicine*, 2021.
16. Holzheu et al, "sigma 4/2021 - More risk: the changing nature of P&C insurance opportunities to 2040," Swiss Re Institute, September 5, 2021.
17. Klusak et al, "Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Creditworthiness," *Management Science*, August 2023.

Lastly, the tipping points discussed earlier may impose higher costs before 2050. The negative effects of crossing some of those tipping points would be felt rapidly in the next few decades.[18] For example, coral reef die-off is estimated to occur within ten years.[19] Repeated thermal stress undermines the resilience of coral reefs, impacting marine biodiversity, fisheries, and the coastal protection that they offer.[20] Immediate action is needed to avoid these transgressions.

The Costs and Benefits Are Unevenly Distributed Among Countries

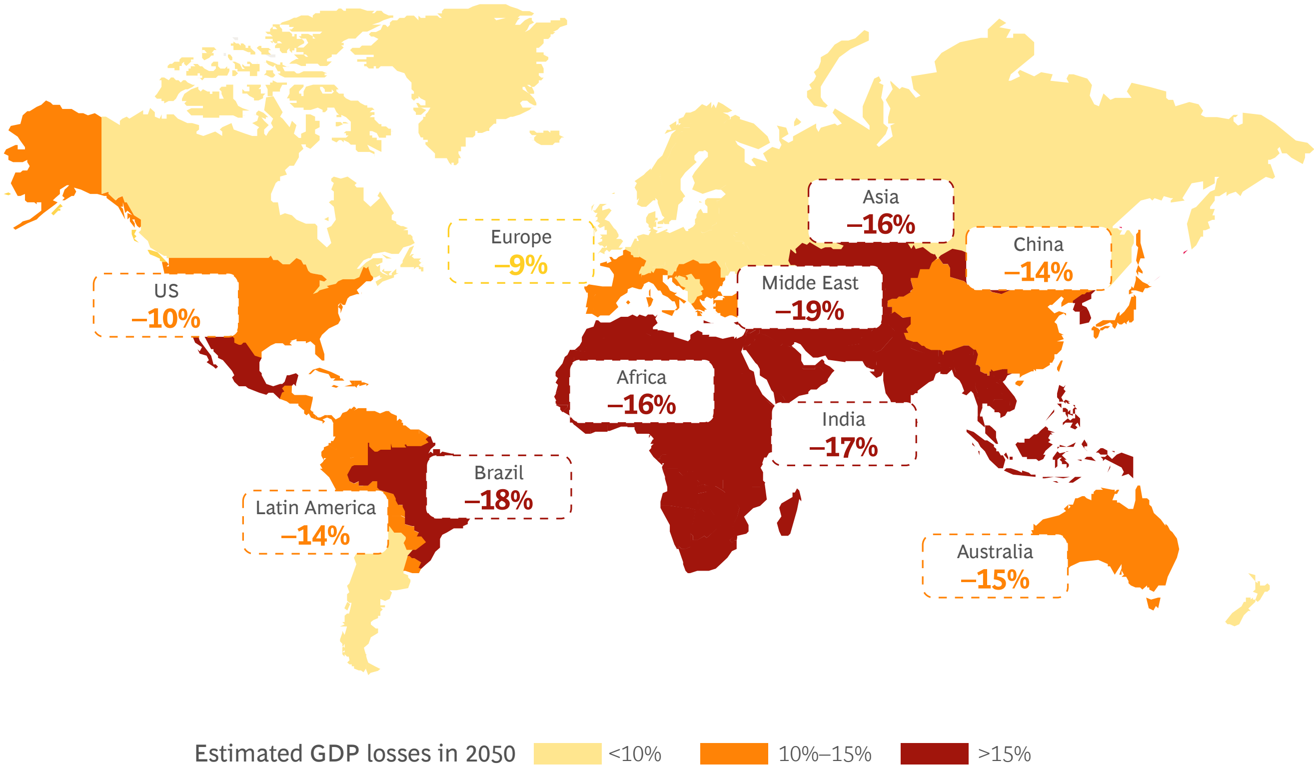
The Paris Agreement's premise is that all countries must reduce emissions in order for all to reap the benefits of mitigation. However, even with the Paris Agreement, there is no consensus among the signatories about how emissions should be reduced.

Moreover, even if all countries act in parallel, the costs and benefits of doing so are unevenly distributed. Voices in the Global North may argue that they should not bear the costs of economic damages predominantly felt in the Global South, according to a 2023 report by the World Inequality Lab. Similarly, voices in the Global South can argue that they should not be expected to bear responsibility for addressing a crisis to which they have historically made a minimal contribution. The same report notes that G20 countries have contributed about 75% of global GHG emissions, while Africa as a continent is responsible for just 4%.

However, there is a growing realization that no country can escape the physical and economic damages of climate change. **(See Exhibit 14.)** First, even though the *relative* economic burden is higher in the Global South, the Global North faces greater *absolute* GDP losses due to its larger economies. According to the NGFS, Africa's GDP would take a 16% hit by 2050, while US economic damage would amount to just 10% of GDP. But this equates to approximately $4.3 trillion in losses for the US and $1 trillion for all of Africa.

EXHIBIT 14

All Regions and Countries Will Face Economic Losses Because of Climate Change, but the Amounts Will Vary



Sources: NGSF; BCG analysis.
Note: NGSF model estimates 2050 GDP losses relative to each country's baseline. In cases where country-specific data was unavailable, the corresponding regional average was applied.

18. McKay et al, "Exceeding 1.5°C global warming could trigger multiple climate tipping points–paper explainer," Climate Tipping Points, September 9, 2022.
19. McKay et al, "Exceeding 1.5°C global warming," 2022.
20. Pearce-Kelly et al, "Assessment of warm-water coral reef tipping point thresholds," Earth System Dynamics, European Geosciences Union, January 2, 2024.

Second, global supply chains expose the Global North to economic damages originating in the Global South. The OECD reports that about 70% of international trade involves global value chains with essential services, raw materials, and components crossing borders multiple times. This complex network of trade routes is heavily exposed to climate change. For example, 29% of global manufacturing hubs are exposed to climate hazards and many of the top 30 ports face risks from rising sea levels.

The amount of global economic damages may justify unilateral or plurilateral action. For example, the G20 countries represent roughly 75% of global GHG emissions and about 85% of global GDP today. If the G20 members were to slow climate change through unilateral mitigation, it may be economically net positive, even if other countries did not equally participate in mitigation action.

The Transition Threatens to Create Winners and Losers Within Economies

It's likely that the energy transition will be economically disruptive, creating winners and losers within and among countries.

For example, the costs of carbon pricing incurred through taxes or cap-and-trade fees hurt high-carbon actors more than low-carbon companies, giving the latter a competitive advantage. Indeed, low-carbon companies have already been using this economic advantage to rapidly capture market share in many sectors, including energy and automotive, according to 2024 reports by the International Energy Agency.

Moreover, the transition also creates new market opportunities, with the rise of electric vehicles (EVs) as a prime example. The IEA notes that in 2023, global EV sales neared 14 million, marking a 35% year-on-year increase. The EV market has significantly boosted regional economies. China exported 1.2 million EVs in 2023—an 80% increase over the prior year's EV exports, while Thailand has positioned itself as a growing EV hub. It aims to attract $28 billion in foreign investment over four years, according to the IEA. This pivot has created opportunities for OEMs to gain market prominence while posing significant challenges for legacy carmakers. For example, the transition by regional economies to support EVs could disrupt the supply chains of automakers that remain focused on internal combustion engines.

At the same time, many assets could become obsolete or unusable due to shifting demands, new technologies, and policy changes, including coal plants, oil reserves, and gas pipelines. For example, according to a recent **WEF report**, in a below 2°C transition, by 2030, about 35% of the stock value of upstream fields would be at risk of write-offs, about 20% of coal plants, and about 15% of blast furnaces. These early retirements would hurt the producers, the banks and pension funds that lend to and invest in them, and the countries that depend on fossil fuel exports. At the same time, all industries face potential economic damages if we do not transition in time. The same WEF report estimates that under the current trajectory, physical impacts would threaten 5% to 25% of annual EBITDA by 2050 across all sectors and regions.

Also, countries heavily invested in high-carbon industries are worried about what the energy transition would mean for the local labor market, yet recent research shows that the transition may, on an aggregate level, have a positive effect on the labor market. The transition is expected to create 14 million new jobs globally in energy supply by 2030. Additionally, it may generate 16 million roles in existing sectors such as construction (driven by efficiency upgrades) and in emerging industries such as hydrogen production. However, this comes at the price of 5 million jobs in legacy industries, such as those involved in fossil fuel production. A just transition is needed to support affected workers and communities through reskilling, redeployment, and economic diversification initiatives.[21]

21. Laura Cozzi and Brian Motherway, "The importance of focusing on jobs and fairness in clean energy transitions," IEA, July 6, 2021.

The Economic Damages Are Not Fully Explored by Economists

The economics of climate change have been laying the groundwork for policy tools such as carbon pricing and cap-and-trade systems. Recent methodological advances make it possible to quantify the socioeconomic damages of climate change in greater detail. Complex integrated assessment models blend climate science, economics, and energy systems to evaluate mitigation and adaptation strategies.[22] At the same time, the rise of climate econometrics has transformed the field by utilizing empirical models and historical data to capture real-world connections, such as those between temperature and GDP, and do counterfactual analysis based on climate scenarios from climate scientists.

However, the economic models most likely underestimate economic damages on the aggregate, regional, and local levels. As a proof point, as methodologies have steadily improved, estimates for economic damages have been continuously revised upward. For instance, the earlier work of many economists estimated relatively modest GDP losses.[23] More recent work estimated significantly higher potential damages of up to 24%.[24] While there has been some progress from the OECD and Potsdam Institute for Climate Impact Research to take climate tipping points into account, for example, most publications do not model climate tipping points or cascading socioeconomic damages.

And it's still difficult to translate global economic damages to the country and company level. While the UK's Climate Change Committee has quantified the transition-related operational expense savings for a net zero pathway and found that capital investments reinvest themselves by 2050, few other countries or regions have published a similar study.

As a result, there is a wide range of estimates and methodologies that fail to build a consensus, according to the IPCC AR6 working group. However, standard setters, such as the NGFS, are working with leading academic and research institutions, such as the Potsdam Institute for Climate Impact Research, to streamline insights from economic modeling for financial institutions.

22. Markandya and González-Eguino et al, "Integrated Assessment for Identifying Climate Finance Needs for Loss and Damage: A Critical Review 2019," *Loss and Damage from Climate Change*, November 29, 2018; Chapagain et al, "Climate change adaptation costs in developing countries: Insights from existing estimates," *Climate and Development*, January 12, 2020.
23. William D. Nordhaus, "An Optimal Transition Path for Controlling Greenhouse Gases," *Science*, 1992; Mendelsohn et al, "Comparing impacts across climate models," *Integrated Assessment*, March 2000.
24. Kahn et al, "Long-term macroeconomic effects of climate change: A cross-country analysis," *Energy Economics*, December 2021; Mohaddes et al, "Rising Temperatures, Melting Incomes: Country-Specific Macroeconomic Effects of Climate Scenarios," *Cambridge Working Papers in Economics*, June 4, 2024.

Five Priorities for Leaders

We have identified five priorities that are critical to tackling the barriers identified earlier.

Reframing the Debate on the Costs of Climate Change

Academia, civil society, policymakers, and businesses need to reframe the debate on climate action to better reflect the strong economic case for climate action. Specifically:

- Create a consensus on the economic case for climate action and communicate it clearly to decision makers (through the IPCC assessment cycle, for example).

- Emphasize the net cost of inaction when communicating with citizens, shareholders, and other stakeholders.

- Put the economic case for climate action on the agenda at the United Nations Climate Change Conference (or COP) and other multilateral meetings, such as Finance Ministers for Climate Action, which brings ministers together to discuss how to integrate climate considerations into economic policies.

Reframing the debate on the costs of climate change	Creating transparency on the net cost of inaction for all actors	Strengthening national climate policies to accelerate mitigation and adaptation	Reinvigorating international cooperation on climate change	Advancing our understanding of the net cost of inaction

Creating Transparency on the Net Cost of Inaction for All Actors

Regulators, investors, and businesses need to increase transparency on the net cost of inaction for companies and countries to ensure tomorrow's risks are reflected in today's decisions. Specifically:

- Individual businesses should file climate risk reports that are robust, streamlined, and harmonized, building on established standards.
- Treasuries and central banks should routinely and transparently assess the macroeconomic and fiscal implications of climate change.
- Insurers should use forward-looking risk assessments to gauge rising physical climate risks and the opportunities for adaptation. They should communicate these assessments to all relevant stakeholders early and, ultimately, reflect them in premiums.
- Insurers could also collaborate with businesses to support cost-benefit analyses for transition projects and other climate initiatives.
- Sovereign credit rating agencies should ensure that the implications of rising physical climate risks are communicated to governments and, ultimately, reflected in ratings.

Strengthening National Climate Policies to Accelerate Mitigation and Adaptation

Governments should work with urgency to close the gap between their current policies and what is necessary to limit warming to well below 2°C. Governments have a role to play in managing the political economy of the transition so investment returns materialize over the long term. According to a 2024 report by WEF, specific areas of action could include:

- **Recognize and raise the price of carbon.** Start above the marginal cost of abatement to incentivize private-sector decarbonization, and raise the price to ultimately reflect its full external costs as a pollutant. In doing so, carbon border adjustment measures could help avoid carbon leakage and maintain public support, but they will become less important as carbon pricing spreads and harmonizes.
- **Scale incentives to strengthen the business case for green investment and mobilize human ingenuity to accelerate mitigation and adaptation efforts.** This would be particularly helpful in critical but less mature technologies such as green hydrogen, energy storage, and regenerative agriculture. Ultimately, the costs of these technologies will fall with scale and experience, reducing the need for public investment.
- **Aid a just transition to net zero.** Implementing large-scale upskilling and reskilling programs to retain, retrain, and redeploy workers from legacy industries, such as fossil fuel, can help ease the transition. At the same time, governments and businesses can provide consumers with affordable and accessible low-carbon alternatives to protect vulnerable populations and enable informed, sustainable choices.
- **Prioritize funding and policies to help communities cope.** Accelerating adaptation and resilience can be facilitated by prioritizing funding and policies that help communities and ecosystems cope with climate risks. While private investments play a critical role, and insurers could help de-risking measures, public investments are particularly essential for nonrevenue-generating assets.

Reinvigorating International Cooperation on Climate Change

Governments should broaden and deepen their cooperation on climate action to facilitate the speed and scale of the global response, despite the uneven distribution of its costs and benefits. Businesses also have an important role to play to support international climate cooperation. Specifically:

- **Deliver on the commitments made at COP29 in Baku.** Rapidly mobilize financial resources for climate action in emerging markets and developing countries, with core funding from bilateral and multilateral institutions.
- **Submit detailed, comprehensive, and ambitious national climate plans.** Nationally determined contributions (NDCs) should be submitted ahead of COP 30 in Brazil. NDCs play a critical role in building trust among parties to the Paris Agreement.
- **Include proper targets in NDCs.** Sector targets, policy frameworks, financial plans, and project pipelines should be included in the next round of NDCs to more effectively unlock private and international finance for climate action.
- **Work toward a global consensus.** Business should build on the COP 28 UAE Consensus and the progress made in previous COPs to reach a global consensus on sectoral- and technology-specific pathways to net zero based on the lowest-cost route. Make carbon trading operational under Article 6 of the Paris Agreement (which sets out how countries can pursue voluntary cooperation to reach their climate targets) to funnel finance into the lowest-cost abatement opportunities globally. Also, as agreed to at COP 28, set targets to triple renewables and double energy efficiency by 2030.
- **Find areas of practical cooperation despite rising competition.** For example, set common standards in areas such as carbon accounting and reporting and in their own operations.

Advancing Our Understanding of the Net Cost of Inaction

This report demonstrates that the cumulative economic costs of climate change by 2100 are estimated to outweigh the required investment in climate action by a factor of 4 to 15 (without applying discount rates). While the economic case for climate action is already clear at the aggregate level, economic research continues to advance our understanding and confidence. Looking ahead, we see four areas where further research would be valuable:

- **Locational Specificity.** Determining the economic costs of climate change for specific countries, subnational regions, and economic sectors would improve decision making at those levels.
- **Nearer-Term Costs.** Forecasting the economic costs during this century if we cross the most proximate tipping points (such as the loss of coral reefs) may significantly increase our estimate of the net cost of inaction and focus adaptation efforts.
- **Impacts on Economic Activity.** Broadening the study of climate change dangers from focusing mainly on physical risks to include threats to economic activity more generally would provide valuable economic insights.
- **Compounded Effects.** Understanding the compounding impacts of climate change on the global economy this century may significantly increase our estimate and enable policymakers and business to adapt. For example, more comprehensive multisector dynamic models could estimate how prolonged droughts might reduce agricultural yields, disrupt supply chains, and increase food prices globally.

Appendix 1
The Methodology

Together with Cambridge Judge Business School and the University of Cambridge's climaTRACES Lab, we aimed to deepen the understanding of the long-term economic consequences of climate inaction by building upon well-established findings, models, and estimates from both academia and policy institutions. To achieve this, we reviewed the latest economic literature and engaged experts in the field, ensuring that our approach was grounded in the most current and robust data available.

In our calculations, we made a decision not to discount future cash flows. All monetary values are presented in constant 2022 US dollars and have been adjusted for inflation to maintain consistency across time periods. GDP figures are provided using market exchange rates, facilitating direct and meaningful comparisons between different economies.

Our analysis focuses on two contrasting scenarios:

- **Global Warming of Less Than 2°C.** We chose the below 2°C scenario for three reasons. First, it is near the upper bound of the consensus that we need to achieve 1.5°C or well below 2°C. Second, it is an endpoint where extensive modeling on climate impacts has been done. Third, staying below 2°C is challenging from an investment perspective and, therefore, serves as a good stress test of the economics. In the Intergovernmental Panel on Climate Change (IPCC) framework, this corresponds to the Shared Socioeconomic Pathway SSP2–2.6 or a lower Representative Concentration Pathway. Within the Network for Greening the Financial System (NGFS) scenarios, it is equivalent to the "Net Zero 2050" pathway.

- **Global Warming of 3°C.** This scenario assumes that mitigation and adaptation efforts remain at their current levels. In the IPCC's scenario logic, it corresponds to SSP2–4.5 or a higher Representative Concentration Pathway. In the NGFS framework, this scenario is aligned with "Current Policies." When it comes to estimating economic damages, we acknowledge that the climate economic literature spans a broad range of estimated economic damages for a trajectory of 3°C warming by 2100. With improving methodology and underlying climate science, estimates in recent studies tend to increase the level of economic damages.[25]

For this report, we have relied on the estimates of the NGFS in their Phase V scenario (published November 2024). The NGFS is a working group of central banks and is widely respected in both academic and policymaking circles, making it a reliable foundation for our estimates. The NGFS scenarios are developed in partnership with a consortium of leading academic and research institutions, including the Potsdam Institute for Climate Impact Research (PIK), the International Institute for Applied Systems Analysis (IIASA), the National Institute of Economic and Social Research (NIESR), and Climate Analytics. This collaboration ensures that the scenarios are grounded in the most advanced scientific and economic modeling available.

In our physical risk analysis, we included only chronic physical risks (as advised by the NGFS) to prevent double counting due to correlations between chronic and acute risks that the NGFS identified in its updated damage function. Leveraging recent literature in the medium end of the spectrum of estimated economic damages allows us to avoid extreme assumptions while maintaining the rigor and comprehensiveness necessary for economic assessments. The NGFS provides a balanced and detailed approach using state-of-the-art suite-of-models methodology, which connects best-in-class models to provide a comprehensive assessment of climate risks and their economic damages. Specifically, the NGFS employs integrated assessment models to derive the effects of climate policies on key transition-relevant sectors such as energy, transportation, and buildings. These models optimize energy systems, land and water use based on long-term trends in population growth, and economic production.

For our cumulative numbers, we have applied the estimates to an underlying counterfactual baseline of GDP growth over time. We have derived growth assumptions from the IPCC's Sixth Assessment Report (AR6), specifically from Working Group III. For the period until 2050, we assume an average annual global GDP growth rate of 3%, with a likely range between 2.5% and 3.5%. This growth rate aligns with the historical annual economic growth observed since 1980, reflecting a continuation of established economic trends. From 2051 to 2100, we estimate a slower average annual growth rate of 1.7%, with a likely range between 1.3% and 2.1%. This anticipated deceleration is mostly attributed to economic maturity and slowing population growth. Our growth assumptions are consistent with estimates from other reputable institutions, including the World Bank Group, the OECD, and the International Monetary Fund.

25. Kahn et al, "Long-term macroeconomic effects of climate change: A cross-country analysis," *Energy Economics*, December 2021; Mohaddes et al, "Rising Temperatures, Melting Incomes: Country-Specific Macroeconomic Effects of Climate Scenarios," *Cambridge Working Papers in Economics*, June 4, 2024.

To evaluate the climate action investments needed, we interpolated data from the Climate Policy Initiative's (CPI) Global Landscape of Climate Finance. This comprehensive report provides an analysis of current global investments in climate-related activities.

For our business-as-usual scenario—corresponding to a trajectory of more than 3°C of global warming—we assume that today's investment levels continue unchanged through to 2100. This assumption reflects a continuation of existing trends without significant scaling up of climate finance efforts.

For the scenario aiming to limit global warming to less than 2°C, we referred to CPI's Top-Down Climate Finance Needs assessment. This report estimates the total investment required to meet global climate goals, drawing from a wide array of sources and methodologies. Both CPI reports are respected meta-analyses that synthesize findings from numerous studies, making them valuable resources in both academic research and policy development. This report models mitigation investments until 2050. For mitigation investments beyond 2050, we base our assumptions on the NGFS Net Zero 2050 scenario, which estimates reaching global net zero CO_2 emissions around 2050 while continuing to deploy carbon capture and storage. Depending on the sector, ongoing investments are assumed beyond 2050, gradually declining over time. Investments in CO_2 removal from the atmosphere are not included.

To evaluate adaptation investments, we extended our data sources beyond the Climate Policy Initiative (CPI) to include the United Nations Environment Programme's (UNEP) Adaptation Gap Report and the UNEP Adaptation Finance Update. By incorporating data from both CPI and UNEP, we aim to develop a more robust and comprehensive estimate of the investments required for effective climate adaptation.

Appendix 2

Modeling the Economic Damages of Climate Change

To understand how the economic damages of climate change are estimated, it is helpful to understand how the economic models work. Economic models are based on historical climate and economic data. They establish relationships between historical economic data, climate data, and climate science to simulate how changes in emissions impact the average global surface temperature and, in turn, how the rise of the average global surface temperature causes economic damages. To do so, they usually combine several models; we discuss two for simplicity. (**See the exhibit.**)

The simplified climate model estimates how different levels of CO_2 emissions impact climate variables, including temperature and precipitation.

The economic model estimates the emissions of the global economy and a counterfactual GDP in the absence of climate change, among other variables.

A damage function connects outputs from both models and estimates how changes in climate variables—such as temperature, precipitation, and extreme weather events—affect physical (chronic) risks.[26] It also evaluates their impact on economic output, including their lagged effects, which can persist for up to ten years after the event.[27]

Economic Models Assess Economic Damages from Climate Change on the Basis of Climate Science and Historical Economic Data

Simplified climate model

Input: Physical laws driving natural systems, e.g., carbon cycle and climate sensitivity estimates[1]

Description: Models climate system, i.e., relation between emissions and temperature

Output: Climate variables and temperature and precipitation, among other types

Economic model

Input: Historical economic data and assumptions, e.g., population and baseline economic growth and technological change

Description: Models economic system, e.g., energy use, sector production, GDP, consumption, investment, prices, and land use

Output: Emissions and counterfactual GDP without climate change, among other types

Damage function

Input: Historical data of economic growth and climate variables (temperature variability, annual precipitations, number of wet days, and extreme daily rainfall)

Description: Translates temperature rise into GDP losses using the damage factor (top-down, empirical macroeconomic estimation of the effects of climate variables on GDP growth)

Output: Damage factor (as a function of climate variables)

GDP losses

Input: Counterfactual GDP, temperature path, and damage factor

Description: Translates changes in climate variables into GDP losses, including their lagged effects

Output: GDP losses (calculated by multiplying counterfactual GDP by damage factor)

Sources: NGFS; BCG analysis.
Note: Counterfactual GDP refers to an estimated GDP without climate change.
[1]Climate sensitivity describes how much of the Earth's surface will warm for a doubling in the atmospheric CO_2 concentration.

26. Kotz et al, "The economic commitment of climate change," [Retracted] *Nature*, April 17, 2024. Kotz et al's research has been retracted due to data and methodological issues identified after publication. The authors have resubmitted a revised version for peer review, which widens the range of uncertainty around estimated climate damages while leaving the central (median) estimate broadly unchanged.
27. "NGFS long-term scenarios for central banks and supervisors," NGFS, November 2024.

Appendix 3

The Difficulty with Discount Rates

Discount rates for future cash flows are commonly used in economic modeling to reflect preferences for immediate benefits, potential investment returns, and uncertainty about future outcomes. But concerns with using discount rates in this report are as follows:

- Discounting is inherently subjective and contentious, with no consensus on the appropriate rate. For example, a prominent study proposed 4% to 5%,[28] while others advocated for 1.4%.[29]

- Traditional discounting fails to capture the full implications of climate change. High discount rates could significantly undervalue its long-term impacts, leading to insufficient action.

- Climate change impacts are global and span extended timeframes, making it challenging for standard discounting methods to accurately account for the widespread and long-term effects.

- The profound societal consequences of climate change, including impacts on ecosystems, economies, and human welfare, require approaches that go beyond traditional discounting to value long-term outcomes effectively.[30]

By excluding discount rates from this report, we have provided a neutral framework for stakeholders to apply the rates that they choose.

28. William D. Nordhaus, "An Optimal Transition Path for Controlling Greenhouse Gases," *Science*, 1992.
29. Nicholas Stern, "Stern Review Final Report on the Economic of Climate Change," Her Majesty's Treasury of the UK Government, October 2006.
30. Christian Tarsney, "Does a discount rate measure the costs of climate change?" Cambridge University Press, 2017.

Appendix 4

The Limitations of the Current Models

The current models have three significant limitations that make it possible that climate change will cause more severe economic damages—and sooner—than our baseline scenario. Here are details of these three limitations.

Limitations of Current Climate Scientific Predictions

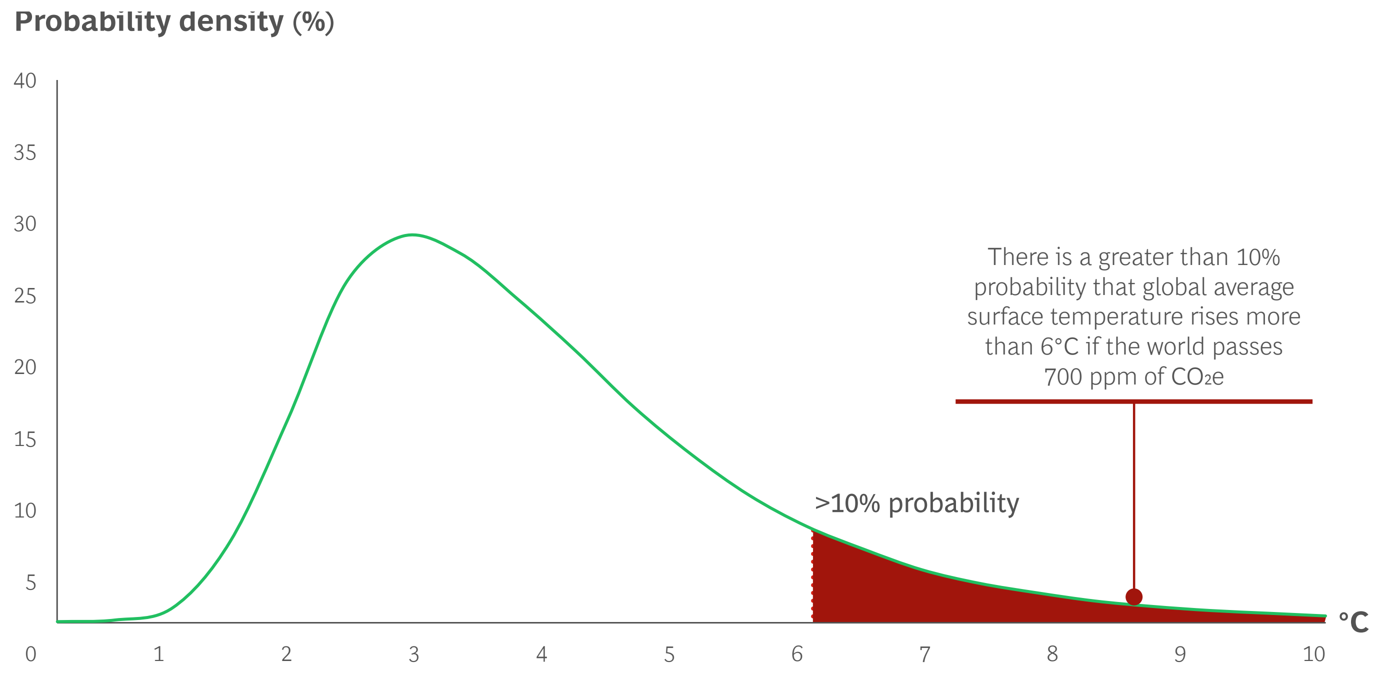
There is uncertainty about the climate system's dynamics and climate science inputs that are used in economic models. There are low-probability but high-impact events at each stage of global warming, so-called fat tail risks. These are not adequately represented in economic models, which tend to focus on average outcomes.

Many climate impacts, such as extreme temperature rises or severe weather events, may follow a fat-tailed distribution. This means that while these catastrophic outcomes are rare, they are not negligible, and they are significantly more likely than expected under normal distribution models. At the same time, they could lead to disproportionately large damages.

One example of a tail risk is equilibrium climate sensitivity. ECS refers to the long-term change in the Earth's global average surface temperature that would result from a sustained doubling of atmospheric CO_2 concentrations compared with preindustrial levels. It represents the climate system's sensitivity to changes in greenhouse gas levels. Climate sensitivity predicts the likelihood of different temperature paths. Under current policies, CO_2 levels may double by 2050 to 2070, likely causing a 3°C warming. However, due to uncertainties, there's a 10% chance of more than a 6°C warming by 2100 under the same emissions profile. **(See the exhibit.)** While current models focus on lower temperature increases, the potential outcomes at 6°C suggest severe environmental and societal disruption. Global warming of 5°C to 6°C could trigger a catastrophic biodiversity loss, potentially comparable to the Permian extinction 252 million years ago, which wiped out about 90% of marine and terrestrial species.

Current economic models (and therefore cost-benefit analyses by policymakers) do not focus on tail risks. Some economic models may include stochastic processes for tail risks, but these events are discounted due to their low probability, minimizing their impact on GDP loss estimates. Due to the catastrophic nature of the risks we are facing, we should take on a risk-centric approach by better representing the often-overlooked tail risks in economic modeling.

If Tail Risks Materialize, Climate Change Will Be More Severe



Sources: Wagner "Climate Shock"; BCG analysis.
Note: ppm = parts per million; CO_2e = carbon dioxide equivalent. Tail risk is the chance of loss due to a rare event.

Limitations of Current Economic Model Predictions

Comprehensive economic models, such as integrated assessment models (IAMs), underestimate the full range of risks. They do not adequately represent a number of factors:

- **Simplification of Models.** IAMs do not capture specific climate details (for example, the diminishing efficiency of carbon sinks and the exact timing between an impulse of CO_2 emissions and warming). They only include a simplified climate module. That's because maintaining a global, long-term perspective in models requires tradeoffs, leading to simplified representations of key processes (such as the carbon cycle) rather than detailed, specialized analyses.

  For example, IAMs often assume linear carbon absorption by sinks (for example, forests and oceans), despite evidence that these lose efficiency as they saturate. The result of underestimating atmospheric CO_2 is an underestimation of global warming and thus economic damages.

- **Historical Evidence.** Economic models are based on historical data on how the economic system has reacted to temperature increases. However, the current pace and scale of global temperature increases, alongside more frequent and intense extreme weather events, means that there may be limited historical precedent for how modern economies will react to such conditions.

  For instance, extreme heat waves can push some areas toward uninhabitability within a few decades, potentially resulting in population displacement and diminished economic productivity, where there has not been such a threat before. Likewise, regions that are accustomed to changes in weather, such as those brought about by the El Niño–Southern Oscillation phenomenon, experience more intense conditions, with considerable economic damages. These unprecedented changes to modern economies make it difficult to accurately estimate the full view of economic damages.

- **Indirect and Cascading Effects.** Indirect and cascading effects are not or only partially modeled in most economic models. Current models typically focus on direct impacts, such as lost agricultural output or damaged infrastructure in a certain region, and depending on how trade is modeled, they may overlook the systemic risks that arise from the interconnected nature of global economies. Spillover effects in social and political realms that further complicate the economic risks of climate change are missing from the model.

  For example, climate disruptions in a major food-producing region could ripple through global supply chains, causing price shocks in other regions, resource shortages, and political unrest that could destabilize entire economies. These ripple effects could interact "with non-climatic risk drivers such as competition for land between urban expansion and food production, pandemics and conflict," according to the IPCC Climate Change 2023 Synthesis Report. These cascading economic, social, and political effects can multiply economic damages far beyond the initial event. Not modeling these spillovers leads to an understatement of the true economic risks posed by climate change.

- **Perfect Markets.** Economic models typically assume fully functioning markets and competitive market behavior, meaning that factors such as nonmarket transactions, information asymmetries, and market power influencing decisions are not effectively represented. Therefore, the models tend toward the goal of minimizing the aggregate economic costs of achieving mitigation outcomes, which may not be the goal for economic and political actors.

- **Broader Impacts.** Current economic models do not adequately represent effects beyond impacts on labor and land productivity and capital depreciation. Several factors are not explicitly accounted for, including biodiversity loss, ecosystem impacts, conflict, violence, and migration.

Limitations in Modeling of Physical Risks

Current economic models do not account for tipping points and feedback loops. Climate tipping elements are critical, large-scale components of the Earth's system that are characterized by a threshold behavior. These systems appear to remain stable with increasing global temperature, but then at a particular global temperature threshold—a tipping point—very small additional disturbances can tip them into a qualitatively new state.

- **Irreversible Damage.** This threshold behavior is often based on self-reinforcing processes that, once tipped, can continue without further external forces. It is thus possible that an element of the Earth's system remains changed, even if the background climate falls back below the threshold.

- **Feedback Loops.** Some tipping elements activate feedback mechanisms that amplify climate changes, and tipping points can be interconnected—crossing one can increase the likelihood of triggering others.

While these tipping points are not reflected in current economic models, the first studies attempting to model the economic costs of crossing single tipping points indicate that the economic damages of crossing certain tipping points might be severe. For example, a conservative assessment by the World Bank of a potential collapse of selected nature services, such as wild pollination, marine fisheries, and timber provision by native forests, estimates a 2.3% *annual* decline of global real GDP until 2030.

Ecosystem tipping points also pose the potential for systemic risks, as the loss of multiple ecosystem services may combine, making it difficult for any entity to adapt or mitigate the effects of large-scale environmental degradation. Economic literature suggests that recent efforts to model the economic damages of such ecosystem shifts likely underestimate the risks, partly because they overestimate the ability to adapt.

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TOO HOT TO THINK STRAIGHT, TOO COLD TO PANIC: LANDING THE ECONOMIC CASE FOR CLIMATE ACTION WITH DECISION MAKERS