

Climate Finance Funding Flows and Opportunities

What Gets Measured Gets Financed

November 2022





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Foreword

To solve a problem, one must be able to size it, determine what is being done to address it, establish whether those measures are proving effective, and identify what more needs to be done. Yet in the case of climate finance, this is easier said than done.

There is wide consensus that mitigating the negative effects of climate change and adapting to them require much more capital investment than is currently being provided. Many elements of climate finance, however—including definitions of newer types of flows—remain open to interpretation.

Myriad organizations do excellent work estimating need, raising funding, reporting on results, and acting as a clarion call on one of the most important issues facing the world today. Government and private sector pledges to increase climate finance have never been larger or more numerous. Partnerships between private investors and public actors to unlock private capital abound. Regulations—especially those that create meaningful incentives, such as the Inflation Reduction Act (IRA) in the US—create necessary tailwinds for further financing.

On the other hand, observers often cite the lack of reliable and transparent tracking as a major barrier to increased investment. Estimates of need are often quoted in the aggregate over a horizon that extends out to 2030 or 2050. But disaggregated figures and distant time frames don't conform to most funders' investment practices. The inability to assess need on an annual basis makes it hard for climate finance practitioners to determine how much progress, if any, is being made toward closing the financing gap. Absent clear data, practitioners must resort to guesswork. But this can result in overestimates of progress in some cases and underestimates in others, and it can obscure categories of need where financing disparities are growing ever more acute. As public and private funders are increasingly being called upon to deploy catalytic forms of finance, it is more and more critical to know exactly where this capital is needed.

To provide some of this clarity, The Rockefeller Foundation is publishing its first report on the issue of climate finance measurement. Developed in coordination with Boston Consulting Group (BCG), we conducted an in-depth examination of the existing technical literature. Our aim was to provide industry practitioners with a comprehensive view of how climate finance needs are evolving relative to flows, identify where the most critical gaps in climate-finance data reporting are located, and where the need for taxonomic standards is most urgent. This report is developed by and directed to the industry practitioner audience, and it endeavors to bridge the knowledge gap in this space.

We are indebted to the many contributors whose expertise helped shape our understanding. In addition to BCG, they include:

- Gernot Wagner, Professor, Columbia Business School
- Bruce Usher, Professor, Columbia Business School
- The Lightsmith Group
- Climate Policy Initiative
- Sustainable Markets Initiative

- Jonathan Coppel, Tanguy de Bienassis, Emma Gordon, and Lucila Arboleya from the International Energy Agency
- Rocky Mountain Institute

Our calculations of baseline estimates of finance needs and flows on a global, sectoral, and regional basis rely on our own methodology and are not endorsed by these individuals or organizations.

The Rockefeller Foundation is dedicated to the principle that all people have the right to health, food, power, and economic mobility—rights jeopardized by global warming. BCG likewise believes that combating the climate crisis is the defining challenge of our time. Together, we seek to advance climate finance through better use of science and data and through collaboration with partners. By identifying and accelerating breakthrough solutions, we hope to improve the well-being of people everywhere.

Signed,

Maria Kozloski, The Rockefeller Foundation

Veronica Chau, Boston Consulting Group

Lily Han, The Rockefeller Foundation

Naomi Desai, Boston Consulting Group

Executive Summary

As the harmful effects of climate change grow more obvious, the need for imminent and sustained action has become increasingly urgent. Most investors across the public and private sectors recognize that effective action will require consistent, large-scale funding.

In September 2022, 500-plus investor groups affiliated with The Investor Agenda signed a statement urging governments to raise their climate ambitions and enact policies that use private capital to address the climate crisis. In addition, over 530 financial institutions, representing more than \$130 trillion in assets under management, have committed to aligning their portfolios to net zero by 2050, joining one of the seven financial sector net-zero alliances that make up the Glasgow Financial Alliance for Net Zero (GFANZ). These pledges can help fuel myriad innovations in nearly every industry sector.

Less clear are the actual numbers involved—the amount of financing needed to hit net-zero targets, the flows currently available and deployed, and the funding gap that remains. One fundamental challenge is the fact that determinations of financial need reflect cumulative estimates generated over a period of decades, while flows are estimated annually, resulting in a classic stock and flow challenge.

Over the past several months, The Rockefeller Foundation in collaboration with BCG aggregated data from across the climate finance arena, examined the methodologies of leading publications, and attempted to triangulate missing insights. Our approach captures capital need in the real economy and actual capital flows for both mitigation and adaptation and resilience (A&R). It covers key public and private sector sources of funding and breaks down financing gaps at the sectoral and regional levels.

Despite inherent limitations in data availability, the result of our analysis is a holistic, baseline view of the global climate finance landscape that reveals some important findings. Here is a summary of what we learned:

- **There is no consensus on how to measure and report climate finance.** The climate finance community applies the term climate finance loosely, and participants differ in the ways they classify proceeds' end uses. As a result, it's difficult to determine precisely how much capital is going toward mitigation and A&R initiatives, or to gauge the relative effectiveness of different decarbonization interventions, or to assess where the need for investment is most urgent. In addition, there are holes in data gathering because some capital flows are not reported as climate finance even though they could provide a positive mitigation or A&R benefit. This includes flows related to helping hard-to-abate sectors transition and flows that do not meet climate finance indicators such as having a direct impact on reducing greenhouse gas (GHG) emissions. Our estimates consider all types of financing with climate impact, but that wide lens means the estimates likely overstate mitigation and A&R investment flows. We try, where possible, to disaggregate different types of financing.
- **Significant data gaps result in an incomplete picture.** Data is poorly measured and tracked across climate finance today. The traceability challenge is exacerbated in areas such as energy efficiency and A&R infrastructure, where the benefit of climate interventions is harder to measure, and in sources such as the private sector, where disclosures are limited. To facilitate transparency, we detail our relative confidence in the data informing our estimates of actual financial flows. Financing from the private sector is particularly poorly traced, due in part to the general lack of mandatory disclosure. In addition, because financing needs stem from different decarbonization scenarios and cost estimates, data necessarily reflects assumptions.

- **Despite these limitations, our analysis reveals a seismic shortfall in climate finance.** To attain net zero, public and private sector entities across the globe will need approximately \$3.8 trillion in annual investment flows through 2025. Our analysis—derived from an examination of data from government and development organizations, financial institutions, private companies, and other investors—suggests that the capital deployed provides only about 16% of the total climate finance required to mitigate negative climate effects and adapt processes and infrastructure worldwide. Even when we looked through a wider lens that includes transition finance and financing deployed to intermediaries that target climate impact, our analysis found that financing need outweighed flows by 66%.
- **The deficit extends to all areas of climate action, but some are more acute than others.** While gaps in climate finance are widely recognized, shortfalls that catalytic investors can target are less conspicuous. This report highlights places where overall gaps are likely to close (such as electric vehicles) and where they are widening (such as fuel cell technology). It also explores geographic disparities. Just as negative climate impacts fall disproportionately on emerging markets and developing economies (EMDEs), so do funding gaps, owing to higher project and sovereign risks. A&R is also severely underinvested. Primarily because of its challenging financial returns profiles and unclear bankability, A&R receives only about one-tenth of the \$410 billion to \$560 billion in annual financing that it requires.
- **Improved data can drive climate finance.** To close the financing gap, the climate finance community requires more data on where proceeds are being deployed. Data confidence is especially challenging for flows in certain end uses of proceeds and from certain sources. Data deficits could worsen the net-zero pace for slow-to-abate sectors that already face significant climate finance gaps. Addressing the systemic and structural challenges that impede transparency and traceability will require intensive efforts. The public and private sectors must come together to create enabling policies that offer the right incentives and to innovate more effective ways to measure and attribute benefits to nascent but important technologies.

This report discusses each of these findings in detail. We believe that transparency is a crucial catalyst. By providing a clear fact base into the state of climate finance, we hope to spur greater collective action in attaining net zero.

Objectives of This Report

This report has three goals:

- Aggregate existing and complementary data on climate finance needs and deployment, consolidating disparate sources and reconciling their methodological differences to provide a more complete picture of the nature of financing gaps across markets and types of financing needs.
- Highlight where data on climate finance is most in need of refinement.
- Create a replicable methodology that can give the climate finance community the basis for continual insight.

A number of public and private sector organizations report on the topic of climate finance. As is true in many other dynamic fields, however, a key challenge involves connecting the dots across a diverse body of research. This report attempts to address this gap. Unavoidably, this effort will be imperfect, but we hope that enabling greater transparency on current methods and limitations will provide a basis for collective action and allow the field to build on our work.



Methodology

We collected and compared commonly cited estimates from leading sources, examined underlying definitions and methodologies, and used a synthesized set of these forecasts to inform our analyses.

1.1 Definition of climate finance

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate finance as deployment of capital that supports GHG abatement and sequestration, and protects human and ecological systems from the harmful effects of climate change.¹ We use this definition in our report because it focuses on real-world impact—ways in which financing can reduce aggregate global emissions and support people’s ability to withstand climate impacts.

Our analysis considers three main pools of capital.² (See Exhibit 1.) The first is climate finance—capital that meets the UNFCCC’s climate finance criteria. The second is transition finance that contributes to climate mitigation or A&R outcomes but does not meet the UNFCCC’s definition. The third is financing that may not satisfy the conditions of climate or transition finance because end uses of proceeds cannot be traced with sufficient clarity. This could include balance-sheet financing that a company uses to develop low-carbon technologies. In other cases, the end use of proceeds may not reduce carbon emissions enough to deliver a material climate impact. An example of this might be a general loan made to a midsize company to finance various energy efficiency upgrades. This category of untraceable or insufficiently material climate investments requires considerably greater examination by standard setters and climate finance practitioners alike because it is the category with the highest potential for greenwashing. Where possible, our analyses aim to distinguish between these various forms of financing.

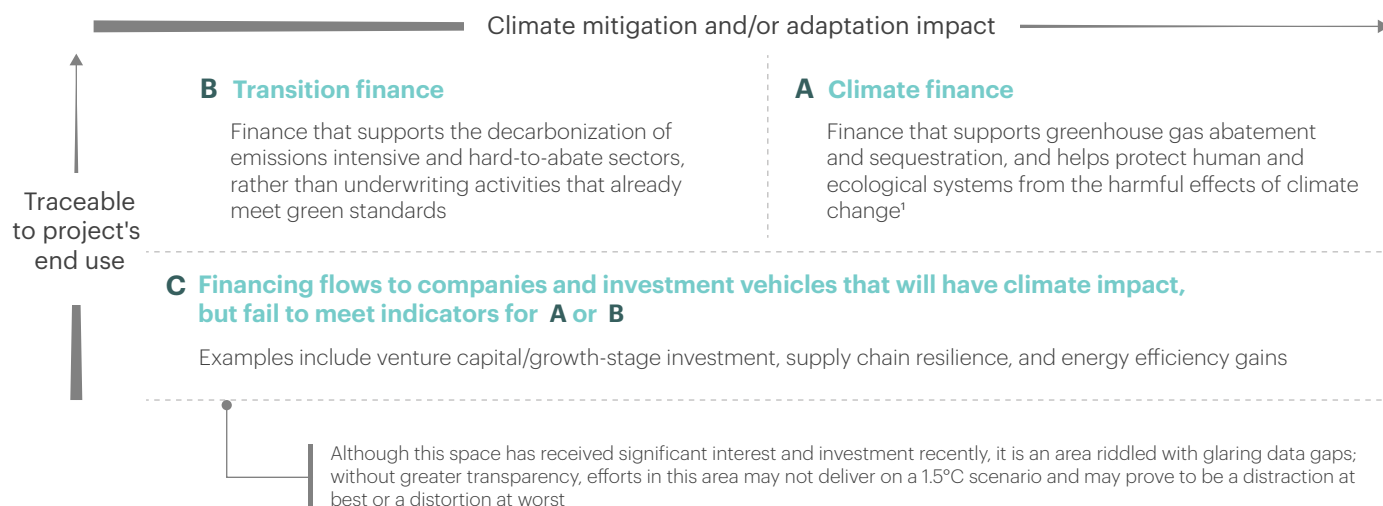
1. *Climate change* refers to alterations in the composition of the global atmosphere that can be attributed directly or indirectly to human activity. This is in addition to the natural variability in climate observed over comparable time periods.
2. We estimate climate finance on the basis of CPI data, in conformity with UNFCCC criteria. Estimates from other forms of finance with climate impact come from complementary data sources such as NetBase Quid, BCG’s Center for Growth and Innovation Analytics, and ClimateWorks Foundations.



Poor data measurement and data tracking in climate finance make it difficult to determine the relative effectiveness of decarbonization interventions.



Exhibit 1 - Three Main Pools of Capital That Have Climate Impact



Sources: UNFCCC Standing Committee on Finance; CBI and Credit Suisse, “Financing Credible Transitions—A Framework for Identifying Credible Transitions”; Climate Policy Initiative.

¹ Aligned to UNFCCC’s definition of climate finance. Estimates are based on Climate Policy Initiative data.

For purposes of this report, climate finance is directed at two primary needs. (See Exhibit 2.) They are as follows:

- Mitigation—activities necessary to limit climate change and achieve global net zero, including renewable energy generation, electric vehicles (EVs), and reduced industrial carbon emissions
- A&R—activities that help people anticipate, respond to, and recover from the unavoidable effects of climate change

Cross-cutting or dual-mandate investments combine mitigation and A&R. A holistic definition of climate finance that encompasses these areas will become increasingly relevant as more experts advocate for a resilient net-zero future focused on measures and transversal investments that simultaneously reduce emissions and increase our adaptive capacity to cope with the effects of climate change.

Loss and damage that occur as a result of climate-related events are not typically considered part of climate finance, since such funding tends to focus on rebuilding what existed before. However, rebuilding that adopts a “build back better” approach to improve physical assets can contribute to mitigation and A&R finance. These activities are embedded in our analysis, but since it is difficult to tease them apart, we have excluded loss and damage from our formal definition.

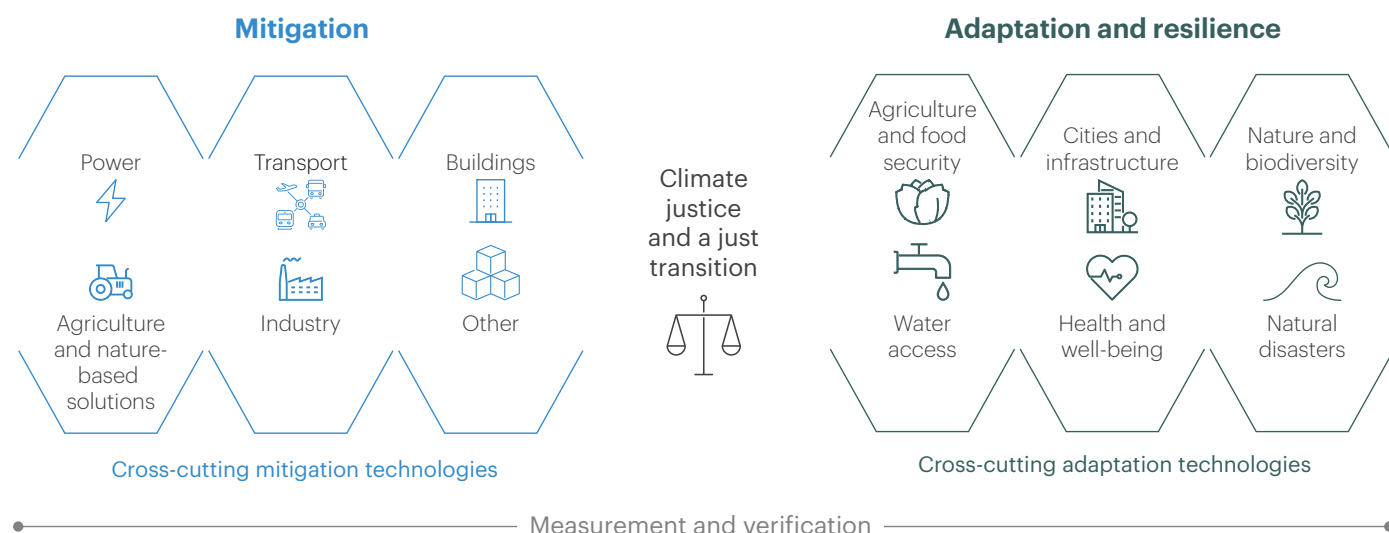
1.2 Observations on the data

Our estimates reflect the current extent and current limitations of climate finance data and financial flow tracking, most of which involve publicly reported data self-designated as climate finance and capital flows in financial markets.

We collected and compared commonly cited estimates from leading sources, examined underlying definitions and methodologies, and used a synthesized set of these forecasts to inform our analyses. (See Appendix 9.1 for a complete list of estimates selected for this report.) We adjusted third-party estimates in some cases to enhance the comparability of the data across sources. (See Appendix 9.10 and Appendix 9.11 for an overview of our methodological approach.) We also employed time-based estimates to reflect nuances in instances where annual investment will need to ramp up meaningfully between now and the latter half of this decade.

A number of public and private sector organizations have estimated needs. (See Table 1.) But only a handful have undertaken the significant levels of data collection required to estimate flows, and CPI is the only one that looks at all climate-relevant sectors with regard to both mitigation and adaptation.

Exhibit 2 - Two Main Areas of Climate-Finance Need



Source: BCG analysis.

Table 1 - Sample Organizations and Reports Published on Financing Flows or Needs

Organization	Report title	Description
Global Financial Markets Association (GFMA)	Climate Finance Markets and Real Economy	Estimated \$100 trillion to \$150 trillion investment needs from 2020 to 2050 to transition to a low-carbon economy and created a call to action for public, social, and private sectors to significantly scale the deployment of climate finance
International Energy Agency (IEA)	World Energy Investment 2022	Provides IEA's most up-to-date view on the state of the financing with climate impact and assesses potential risks and opportunities across energy-related sectors
	Net Zero by 2050 Roadmap	Provides an often-cited view of a pathway to net zero, including investment required over time by sector
Climate Policy Initiative (CPI)	Global Landscape of Climate Finance	Report published biennially that provides the most comprehensive overview of global climate finance flow across mitigation and A&R
UN Environment Programme (UNEP)	Adaptation Gap Report	Annual science-based assessment of the global progress on adaptation planning, financing, and implementation, providing the most frequently cited figures of adaptation finance needs annually

UNEP	<u>State of Finance for Nature</u>	Tracks global trends in public and private investment in nature-based solutions, with the goals of improving data quality and identifying opportunities for governments, businesses, and financiers
World Bank (WB)	<u>Country Climate and Development Reports</u>	Identifies important sources of GHG emissions and methods to transition to a low-carbon economy, including a look at risks and opportunities; the organization also coauthors reports with other organizations on specific climate change topics such as contributions by MDBs to the end use of proceeds with climate impact and mobilization of private sector investment into A&R
Carbon Disclosure Project (CDP)	<u>CDP database</u>	Global disclosures system devoted to helping companies and cities with their environmental impact disclosures. CDP assesses responses and provides a score to each respondent; the organization also publishes reports analyzing progress against climate change and required climate finance using the findings from submitted disclosures
International Monetary Fund (IMF)	<u>MF Fiscal Monitor</u>	Overview of public finance development, and at times assesses A&R infrastructure finance needs
	<u>Global Financial Stability Report</u>	Provides a view of the blended finance that is needed to direct greater climate finance to emerging market projects
Organization for Economic Cooperation and Development (OECD)	<u>Aggregated Trends of Climate Finance Provided and Mobilized by Developed Countries</u>	Assesses ESG rating and investments, climate transition risks and opportunities, and environmental integrity of climate commitments and transition plans; analyses focus on international development finance in support of climate action in developing countries

Source: BCG analysis.

Knowledge gaps are especially glaring for flows in certain end uses of proceeds and sources. Tracking mitigation finance in the agriculture, buildings, and industry sectors is difficult because of limited data availability—especially from the private sector—as well as because of methodological issues regarding what activities and solutions (such as energy efficiency gains) should be accounted for. Other challenges to tracking A&R finance include context dependency, uncertain causality, and lack of agreed-upon taxonomies and impact metrics. These systematic gaps and the assumptions used to bridge them may distort estimated investment flows and needs.

We have assessed our relative confidence in the data informing our estimates of actual finance flows. (See Exhibits 3 and 4.) Our data confidence estimates are informed by definitional clarity and coverage, data granularity, source quality, and the degree to which the end uses of proceeds—such as a project or company, mitigation or A&R, sector, or region—are clearly specified. (See Appendix 9.2 for further detail.)

Exhibit 3 - Assessment of Data Confidence for Sources of Capital

Segment	Data confidence	Rationale	
Mitigation	Public finance	<p>Capital source coverage ●</p> <p>Data granularity ●</p> <p>Source quality ●</p> <p>Clarity of end use ●</p>	<ul style="list-style-type: none"> • Broadly well-documented disclosures from governments and intergovernmental organizations with clear articulation of the sources of capital (e.g., MDBs, DFIs); but more ambiguous for domestic flows and for global-south-to-global-south flows (e.g., China to Africa) • Leverages aggregated project-level primary data; however, data is not systematically tracked, and extrapolations are sometimes applied where data gaps exists • End use of proceeds is not comprehensively tracked and obfuscated by intermediaries (e.g., government-backed funds, ministries) that vary in completeness
	Private finance	<p>Capital source coverage ●</p> <p>Data granularity ●</p> <p>Source quality ●</p> <p>Clarity of end use ●</p>	<ul style="list-style-type: none"> • Leverages primary bond data and secondary data from other types of investments • Relatively lower coverage of investment flows, as it is highly contingent on adequate disclosure from many independent private actors (e.g., commercial banks, corporates) • End use of fund proceeds (e.g., infrastructure, private equity, venture capital) is better tracked than direct investment from asset owners (only ~2/3 of fund limited partners disclose investment size), and multiple types of investors co-invest in funds, limiting visibility into the source of capital • Direct use of proceeds in corporates' own operation and/or supply chain is seen as normal course of business, with no clear threshold on what to count, and often not fully or uniformly disclosed
A&R	Public finance	<p>Capital source coverage ●</p> <p>Data granularity ●</p> <p>Source quality ●</p> <p>Clarity of end use ●</p>	<ul style="list-style-type: none"> • Government sources—especially international sources (e.g., MDBs and DFIs)—are relatively well tracked, including on capital flow into regions and sectors; coverage of domestic A&R finance is more limited • Leverages aggregated primary data; granularity is limited, as adaptation is often overlooked due to relatively small climate finance flows (vs. mitigation) • Insight into end use of proceeds varies; e.g., infrastructure project costs vary by region, and data availability varies project by project, making the full landscape difficult to capture
	Private finance	<p>Capital source coverage ●</p> <p>Data granularity ●</p> <p>Source quality ●</p> <p>Clarity of end use ●</p>	<ul style="list-style-type: none"> • Insight into private sector flow toward given regions and sectors; however, visibility into actors behind capital flow (e.g., commercial bank vs. institutional investor) is lacking • Limited to no tracking mechanism for adaptation costs in the private sector's own operations; leverages subjective self-reported data with no standardized metrics (e.g., time frame and magnitude considered may vary company by company) • Disclosure can be irregular and cost of response is rarely updated to reflect the current situation • End use of proceeds (e.g., disaster recovery costs) is not well tracked

● Low ● Medium ● High

Source: BCG analysis.

Note: DFI = development financial institution; MDB = multilateral development bank.

Exhibit 4 - Data Confidence Assessment by Mitigation Sector

Segment	Data confidence	Rationale															
 Power	 <ul style="list-style-type: none"> Capital source coverage ● Data granularity ● Source quality ● Clarity of end use ● 	<ul style="list-style-type: none"> • Leverages project-level data and some top-down estimates of energy capacity expansion • Extrapolations for unit costs are applied where project investment is not specified • Exact primary source of capital is unknown, but public/private nature of source is tracked • Data sources are partially defined, but methodology and allocations are less clear (not replicable) • End use subsectors are clear, but some key categories are combined/less granular 															
 Agriculture and nature-based solutions	 <ul style="list-style-type: none"> Capital source coverage ● Data granularity ● Source quality ● Clarity of end use ● 	<ul style="list-style-type: none"> • Top-down approach leveraging expert-reviewed scaling factors to estimate share of nature-based solutions investment (operating expenses and capital expenses) in relevant categories covering public and private capital • Leverages limited secondary data but clearly articulates selection criteria/considerations • Data sources/methods are well documented but reliant on assumptions and difficult to replicate • Dual-mandate activities (i.e., covering both mitigation and A&R) are considered under nature-based solutions • Subsector flows from public sector are thoroughly tracked; private sector more ambiguous 															
		<table border="1"> <thead> <tr> <th>Shared characteristics</th> <th>Sector-specific characteristics</th> </tr> </thead> <tbody> <tr> <td> <table border="1"> <thead> <tr> <th>Segment</th> <th>Data confidence</th> <th>Rationale</th> </tr> </thead> <tbody> <tr> <td>  Buildings </td> <td>  <ul style="list-style-type: none"> Capital source coverage ● Data granularity ● Source quality ● Clarity of end use ● </td> <td> <ul style="list-style-type: none"> • Rather than tracking project-level data, investments are estimated by calculating the amount of capital required within large projects or products to exceed baseline energy efficiency standards (e.g., minimum performance legally allowed), resulting in a low threshold for emissions abatement impact • Calculations based on proprietary model and sources not linked to specific estimates </td> </tr> <tr> <td>  Transport </td> <td>  <ul style="list-style-type: none"> Capital source coverage ● Data granularity ● Source quality ● Clarity of end use ● </td> <td> <ul style="list-style-type: none"> • Electric vehicles (EVs) represent largest share of flows and are well tracked; 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● Low ● Medium ● High

Source: BCG analysis.

This is a pivotal decade for organizations and communities around the world to advance from pledging support for climate initiatives to deploying them, and it is a make-or-break period for companies to take concerted action on decarbonization and in building more-resilient value chains.



The State of Climate Finance Gaps

This report reflects our efforts to better understand the nature of climate finance gaps and to identify where action to improve data is needed. These insights can shape the actions of practitioners, catalytic investors, and policymakers. To size the climate finance gap by sector, we contrasted existing annual estimates of flows with comparable annual estimates of needs. (We used 2020 estimates because that year had the greatest amount of data available.)

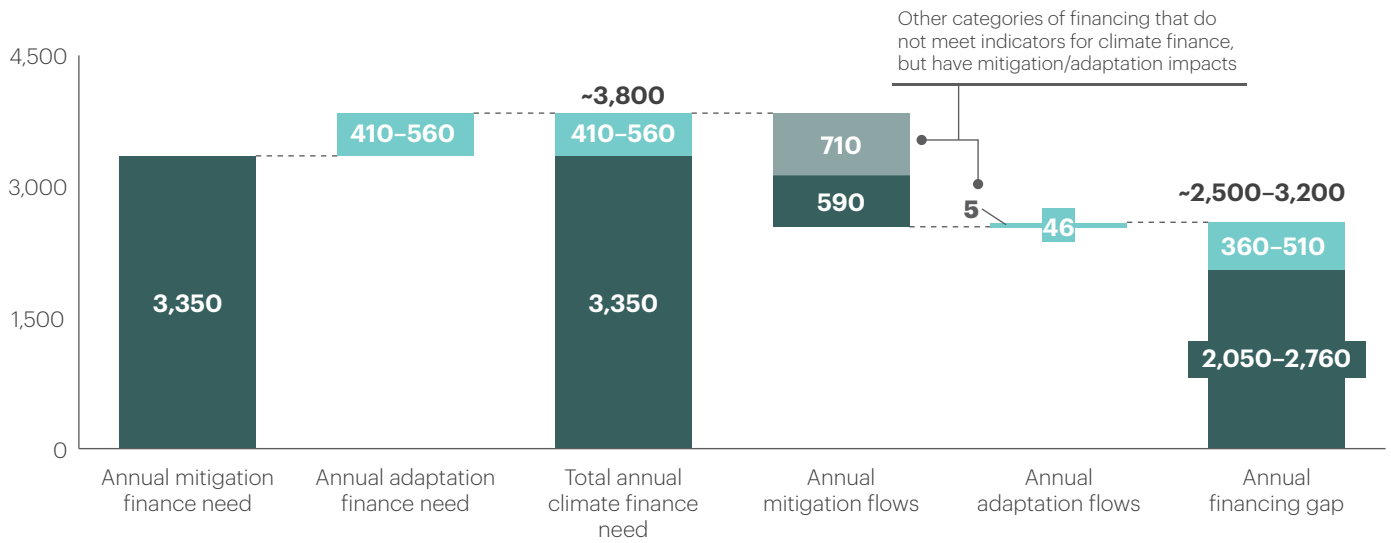
Our analyses found that the finance shortfall extends to every area of climate action. (See Exhibit 5.) For example, mitigation initiatives will require an average annual investment of roughly \$3.4 trillion from 2020 to 2025. CPI climate finance estimates for mitigation efforts alone (roughly \$570 billion) suggest an overall financing gap of 83%. When we include data sources that consider some forms of transition finance and some forms of “other” financing, as defined in Chapter 1 of this report, we arrive at a figure of \$1.3 trillion, or a financing gap of 66%.

For their part, A&R efforts will require approximately \$410 billion to \$560 billion annually through 2030. However, estimates from CPI and the United Nations Environment Programme (UNEP) suggest that only about \$46 billion, or one-tenth of this need, is being met annually. Our data suggests that additional private sector flows amount to less than \$5 billion.

We calculated needs for all sectors except agriculture and nature-based solutions by extrapolating average annual need estimates for 2026 to 2030 calculated by the International Energy Agency (IEA). We based our assessment of investment needs in agriculture and nature-based solutions on data from the Global Financial Markets Association (GFMA) and the UNEP. Our estimates cover the period from 2020 to 2050 and assume that cumulative investment need is evenly distributed across time. Although any estimate of investment need is inherently predictive and relies on decarbonization scenarios, we believe these estimates provide important directional insights.

Exhibit 5 - In 2020, the Climate Finance Gap for Mitigation and Adaptation Was \$2.5 Trillion to \$3.2 Trillion

Annual financing in 2020 (\$billions)



Source: BCG analysis.

Going forward, industry practitioners must strive to standardize definitions for individual areas of climate finance and refine estimated investment flows. Doing so will permit a more reliable “ground truth” to emerge.



3

Examining Sources of Climate Finance Flows

According to the data we examined, institutions and individuals globally contributed \$632 billion in climate finance in 2020, with public and private sector flows contributing about 50% each to this total. Flows that have a positive impact on climate but do not meet the UNFCCC’s climate finance criteria likely contributed an additional \$680 billion in financing.

In tracking the flow of capital, we used data from CPI as the basis of our climate finance estimates (flows that satisfy UNFCCC’s climate finance criteria). CPI is the leading authority on tracking and analyzing climate finance flows. Its data is widely cited and its sources well detailed.³ CPI’s 2020 estimates focus exclusively on climate finance. To avoid double counting, CPI’s methodology eliminates financing flows that cannot be traced back to a primary transaction or a project-specific end use of proceeds; and to prevent potential greenwashing, it excludes retrofits and efficiency improvements that lock in future GHG emissions.

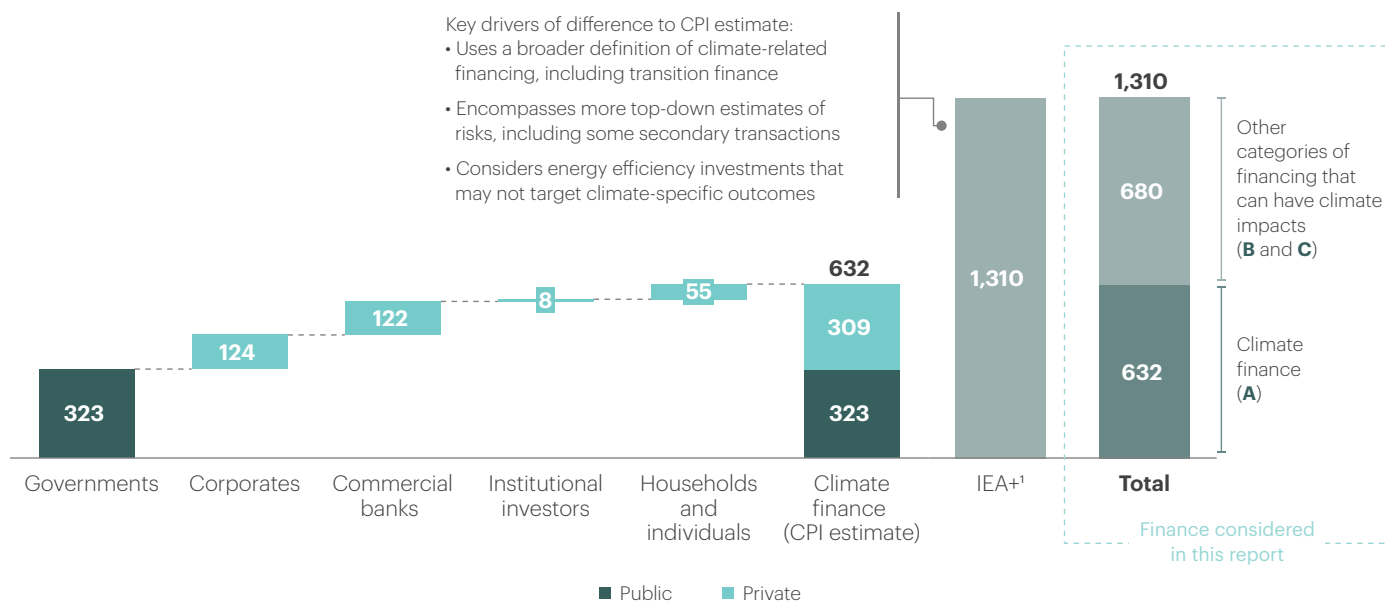
As outlined in section 1.1 and in Exhibit 1, our analysis considers additional complementary data sets. We used data sets from credible organizations where there was a reasonable level of confidence that financing proceeds were aligned to net-zero pathways, and we have noted the amounts and sources to create a more complete picture for industry practitioners. (See Appendix 9.4 and Appendix 9.6 for a complete list of sources and their underlying methodologies.) Our analyses are necessarily imperfect, given gaps in climate finance disclosures, but we endeavored to be as granular as possible.

Our bottom-up analysis determined that institutions and individuals globally contributed just over \$1.3 trillion in climate-related capital financing in 2020. (See Exhibit 6.) The delta between this figure and CPI’s \$632 billion estimate is due primarily to methodological differences. Our analyses took broader definitions of climate finance, secondary transaction data, and energy efficiency investments into account and considered sources of flows channeled through intermediaries. (See Appendix 9.3 for a list of intermediary actors.)

3. CPI publishes the “Global Landscape of Climate Finance” report biennially, and its analyses average data across two years. For our reporting, we use the year 2020 to refer to CPI’s 2019–2020 data, and we use the later of the two years covered in each of CPI’s earlier reports.

Exhibit 6 - Primary Sources of Capital Flow into Climate Finance in 2020

Climate investment flows in 2020 (\$billions)



Sources: CPI Global Landscape of Climate Finance 2021; BCG analysis.

Note: Our analysis considers both climate finance and additional financing with climate impact. The bolded letters A, B, and C in this exhibit refer to the categories identified in Exhibit 1.

¹Data is primarily from IEA but also includes some estimates (from \$0.9 billion in carbon capture, utilization, and storage and \$1.3 billion in low-carbon hydrogen transport investment) from BloombergNEF.

3.1 Private Sector

Private sector sources deployed roughly \$323 billion in climate finance in 2020. Additional data sets beyond CPI suggest that the total amount of deployed capital may be higher. However, the incremental amounts involved may not have directly measurable decarbonization or adaptation impact and for that reason we did not factor them into our analyses.

Data suggests that corporates accounted for the largest source of private finance in 2020—roughly \$124 billion. Of that amount, \$87 billion came from balance-sheet financing, although this amount has been declining over the past several years, due in part to greater access to debt financing from banks.

Corporates are also deploying venture capital in support of climate-related initiatives. Some of this venture capital may be going toward early-stage initiatives that don't yet satisfy UNFCCC criteria today, even though they may eventually do so. As these flows are bundled into successive funding rounds, there is some risk of double counting. To avoid that result, we did not consider these flows in our analyses. Nevertheless, they are a helpful indicator in understanding where climate finance may ultimately be deployed and in identifying

currently underfunded sectors. Our analysis, informed by additional data sources such as NetBase Quid, BCG's Center for Growth and Innovation Analytics, and ClimateWorks Foundations, suggests that an additional \$47 billion in corporate venture capital may be supporting climate-related efforts.

For instance, green-tech financing grew fourfold from 2017 to 2021, with corporate venture capital accounting for about 60% of flows into this space. We expect interest in green-tech innovations such as climate intelligence, fuel cells, smart grids, and other low-emission technology—as well as carbon capture, utilization, and storage (CCUS)—to remain strong going forward.

Commercial banks contributed about \$122 billion of total private-sector climate finance in 2020, of which \$69 billion came from balance-sheet financing. It is unclear, however, how much of this sum represents incremental new money. A portion of the \$122 billion estimate likely includes capital that was relabeled as green under new taxonomies (such as green bonds) but was not truly additive. Looking ahead, some of the largest banks have made bold financing commitments (estimated at \$7 trillion through 2030), although many of these are likely to be delivered through capital markets activity rather than direct balance-sheet lending.

Climate-related lending is not well tracked at present. Complicating factors include a lack of climate- or transition-finance labeling, other taxonomic issues, and a lack of internal systems to measure how core banking products are helping commercial banking clients decarbonize.

Despite their large share of assets under management, institutional investors and funds accounted for just \$8 billion of total private-sector climate finance. Likely reasons include fiduciary mandates that limit risk taking, capitalization requirements, and the absence of strong policy incentives.

Households and individual investors contributed about \$107 billion of financing in 2020. (A further \$8 billion in philanthropic grantmaking comes from individuals and foundations, but we do not consider this amount in our analysis, to avoid potential double-counting.) These numbers reflect the shift in individual investor behaviors to lower-emitting alternatives. Interest in sustainable investment is growing. A survey by Morgan Stanley found that 85% of individual investors are interested in this asset class.¹ But only 52% of them currently actively deploy capital toward it. Creating impact reports that provide investors with concrete proof points could spur greater engagement.

3.2 Public sector

Governments and intergovernmental organizations deployed about \$323 billion in climate finance in 2020, accounting for approximately 51% of total flows. Other reports suggest a slightly higher figure than CPI does. For example, the IEA estimate is \$363 billion, and UNFCCC's is \$367 billion. Current data from all of these sources likely underestimates the amount of climate capital invested by public actors today, since existing reporting, especially for domestic finance, is fragmented.

Overall, governments are deploying increasing amounts of financing toward climate action, with Western European governments leading the charge. CPI estimates that Western European countries collectively invested \$43 billion in 2020 toward domestic and international initiatives. In addition, the European Commission plans to apportion 30% of its budget for climate action initiatives from now until 2027. The US is also likely to pick up the pace of its domestic climate-finance investment. The IRA, passed in August 2022, includes \$369 billion of

funding for clean energy and climate investment. This amount is incremental to the \$1 trillion Infrastructure Investment and Jobs Act, which includes, among other climate investments, more than \$62 billion to support clean-energy initiatives, \$66 billion in rail funding, and \$15 billion for electric vehicle chargers and low-emission public transport.

Although roughly two-thirds of total public sector funding is being deployed by governments in the global north toward initiatives in that region, most of the remaining \$100 billion flows from member countries of the Organization for Economic Cooperation and Development (OECD) to emerging markets and developing economies (EMDEs).

The global south is also deploying domestic financing. Collectively, these countries accounted for roughly 85% of the \$120 billion total investment flow from national development finance institutions (DFIs) in 2020. Other channels of domestic financing include flows from government-backed entities (\$59 billion globally) such as state-owned enterprises and state-owned financial institutions. These intermediaries have played an outsize role in the energy sector, accounting for about 60% of energy investment in China and more than 40% in EMDEs as a whole, according to the IEA.

Globally, growth in public investment seems to be picking up after a period of slowdown, likely owing to the pandemic. CPI estimates that investment in 2020 increased by just 7% over the prior year, substantially lower than the 40% annual growth recorded in 2018 and 2016. Low-carbon energy investment is now recovering—growing by 64% in 2021 compared with 2020—and data from the IEA suggests that it will rise by 11% in 2022.

Looking ahead, we expect investment flows from government entities to continue growing in this critical decade, as emphasized at COP26. Countries and governments attending COP26 reaffirmed their commitments to limit global average temperature increases to 1.5°C and to accelerate action toward this goal. However, attempts to increase investments at the required pace may be constrained by fiscal challenges related to the pandemic and rising fuel costs.

Mitigation Finance

Mitigation is an investment-hungry endeavor, and current financing is not satiating that need. To meet net-zero targets, a systemic change in financial and behavioral actions across sectors is necessary. This report sheds additional insight into where some of the most acute financing gaps are today and where, based on IEA scenarios, those gaps are likely to widen.

4.1 Current state of mitigation finance by sector

Financing gaps were similar across most sectors, but they vary more distinctly at the subsector level, where technological and operational obstacles have different effects on specific decarbonization levers. (See the sidebar “How We Derived Our Estimates.”) Notably, our data suggests that the financing gap in the industry sector is likely to remain relatively small compared with other sectors through 2025. However, the industry sector’s needs will probably accelerate quickly as efforts to finance emerging technologies such as CCUS and low-carbon hydrogen grow.

If investment flows do not change from today’s levels, our analysis points to a mitigation finance gap of \$2.8 trillion (or \$3.5 trillion if considering only capital under UNFCCC’s climate-finance indicators) during the second half of the decade. (See Exhibit 7.) Even if all Announced Pledges Scenario (APS) climate targets are achieved on time and necessary investment is fully mobilized—an optimistic scenario—the resulting financing would still leave an annual investment gap of just over \$1.8 trillion during the second half of the decade. The resulting gap would extend to nearly all sectors and subsectors, though to varying degrees. For example, investment in battery-electric vehicles (BEVs) under the APS is set to accelerate considerably, meeting roughly 65% of need by 2030. But investment in CCUS under the APS is on track to address only 10% of expected need in industry by the end of the decade.

How We Derived Our Estimates

For each sector, we prepared two analyses:

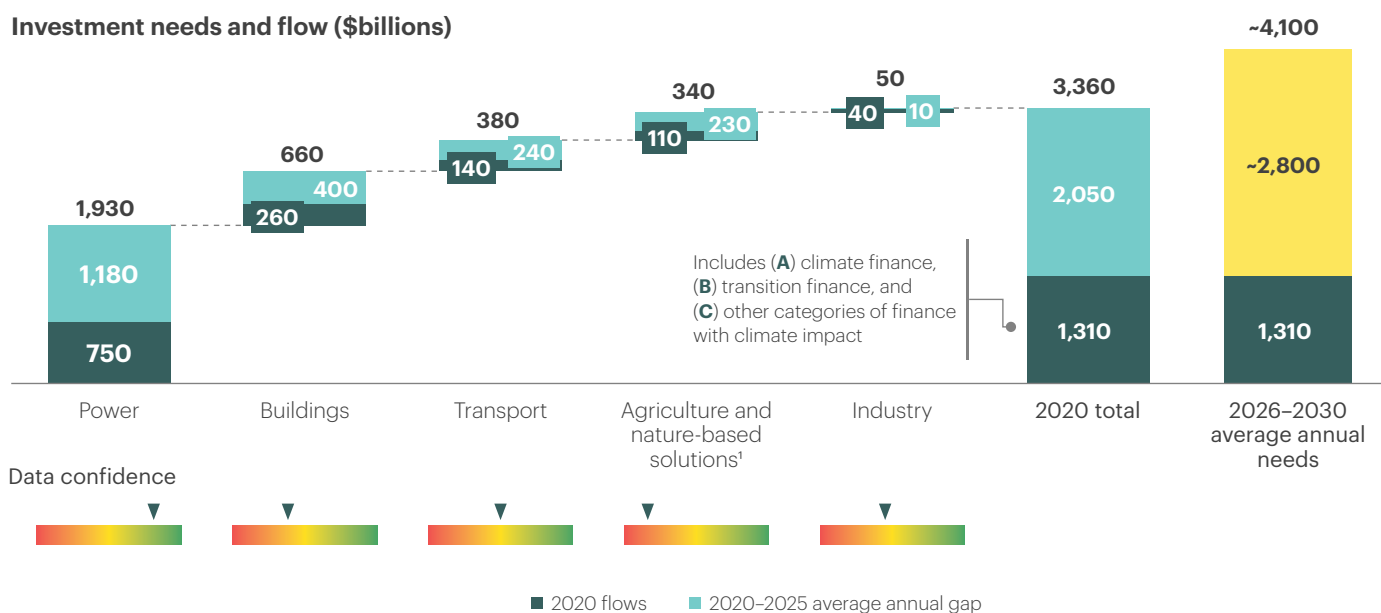
1. Comparison of Annual Financing Flows to Estimates of Financing Requirements for 2020. To compute current-state estimates, we compared actual capital flows in 2020 to average annual investment needs for the first half of the decade (2020 to 2025). We took a best-available view of the investments required for known technological interventions such as renewable energy, green hydrogen, and carbon capture, utilization, and storage to arrive at our figures, focusing on the highest-emitting sectors, which collectively produce over 70% of global emissions. We derived most of our assumptions about investment needs from IEA's Net Zero Emissions by 2050 (NZE) Roadmap.

2. Comparison of Current Gaps to Future Gaps Based on Forward-Looking Financing Commitments. In each sector—except industry and agriculture and nature-based solutions—we compared the current state of climate-financing gaps to projected gaps in the second half of the decade (2026 to 2030), with the assumption that all announced climate targets will be fulfilled. This comparison offers directional insight into the relative degree to which gaps may shrink or grow. For our 2026-to-2030 view, we compared investment estimates under the IEA's Announced Pledges Scenario (APS) to average annual investment needs for the same period. The APS indicates the amount of investment that would have to be generated to meet government and corporate commitments. This amount considers pledges only and should not be equated with actual financing flows. In the near term, real flows are unlikely to reach the level of APS estimates. Notably, APS commitments in this report include only those made as of October 2021. APS estimates therefore exclude some significant commitments made in the past year, including the US IRA and a number of pledged bans on ICE vehicle sales in the EU and elsewhere. Despite these limitations, the APS provides a window into the categories that are likely to receive the most attention from investors.

Our estimates have some limitations. First, by focusing on heavy-emitting sectors and direct emissions (Scope 1 and Scope 2), our analysis may be ignoring the investment needs of lower-emitting sectors (such as consumer goods, services, and technology). Second, we were unable to fully disaggregate investment needs and flows by geography. Third, we lack annual point estimates of investment needs before 2030; our half-decade views for the 2020s should therefore be treated as directional. Fourth, our estimates cannot fully disentangle climate finance from additional finance with climate impact, and they likely overstate financing flows. Despite these limitations, our estimates provide a view of the top global mitigation priorities by sector, technology, and decarbonization lever.

Exhibit 7 - Approximately \$3.4 Trillion in Mitigation Finance Will Be Needed Annually Across Sectors from 2020 to 2025

Investment needs and flow (\$billions)



Sources: IEA NZ by 2050; IEA World Energy Investment 2022; BCG analysis.

Note: The bolded letters A, B, and C in this exhibit refer to the categories identified in Exhibit 1.

¹Based on estimates that include operating expenses and dual-mandate projects with A&R benefits. Investment needs in agriculture and nature-based solutions use a 2020-2050 average rather than a 2020-2030 average, as other sectors do.

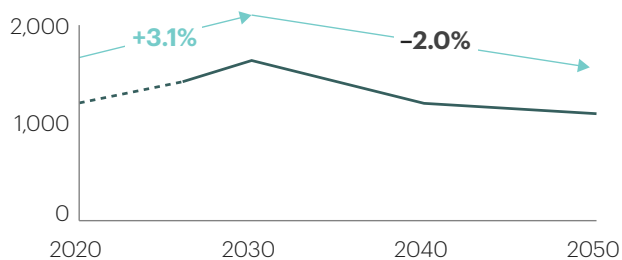
Investment needs in each sector will evolve differently over time during this decade and beyond. (See Exhibit 8.) The industry sector will experience the sharpest acceleration in investment need through 2030 as key emerging technologies such as CCUS and hydrogen move from early development stages to large-scale commercialization. Capital-intensive plant retrofits and new builds will drive investment need growth through 2050 in this sector. Investment need in the transport sector will continue to expand beyond 2030, too. The upfront cost of electric vehicles will drive most of this growth, particularly the transition to fuel cell electric vehicles (FCEVs), which will accelerate in earnest after 2030.

In contrast, investment needs in electricity generation and buildings will peak around 2030 and decline thereafter under the NZE scenario. In the power sector, the cost of renewable energy will decline over time and many capital-intensive capacity expansions will be relatively heavily frontloaded. In buildings, the number of retrofits to existing buildings will decline after 2030, on the assumption that most of this work will have taken place by then. After 2030, the emphasis will shift to new net-zero carbon buildings, and we expect the cost of energy-efficient technologies to decrease. We excluded agriculture and nature-based solutions from this analysis because time-based views of how investment needs evolve are not currently available for these sectors.

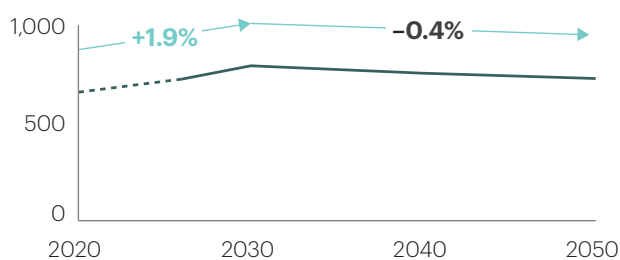
In the subsections that follow, we take a more granular view of financing gaps by sector and market.

Exhibit 8 - Investment Needs in Buildings and Electricity Generation Will Peak in 2030, While Those in Industry and Transport Will Grow Through 2050

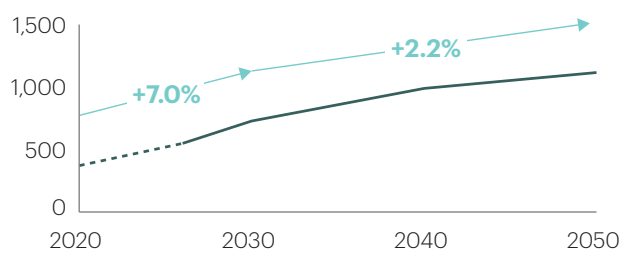
Average annual investment needs by sector, 2020–2050 (\$billions)¹



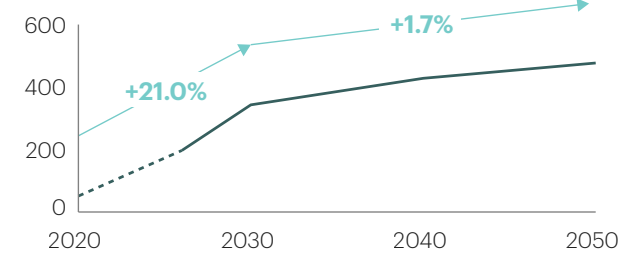
Power (electricity generation)



Buildings



Transport



Industry

--- Estimated — Reported in IEA

Sources: IEA NZE 2050; BCG analysis.

Note: Average annual investment needs for 2020–2025 are reported at the 2020 mark in each graph, and average annual investment needs for 2026–2030 are reported at the 2026 mark.

¹ Based on 2020 values.

4.1.1 Power

The power sector will require an average investment of \$1.9 trillion annually from 2020 to 2025 to meet net-zero targets—the most of any sector. (See Exhibit 9.) However, capital flows in 2020 totaled only \$750 billion. Cumulative need will grow in the second half of the decade, rising to just under \$2.3 trillion. Data from IEA's NZE scenario suggests that the mix of clean-energy sources (for example, wind and solar, hydro and other renewable energy sources, and nuclear and other technologies) will remain the same through to 2030.

Clean-energy generation accounts for the greatest share of financing need, and demand for renewable energy capacity expansion will drive the bulk of this amount. To meet net-zero targets, the installed gigawatt capacity of renewable energy must more than triple from 2020 to 2030. Financing clean energy generation will require around \$1.2 trillion in capital flows annually. Even mature technologies that are nearing cost parity with fossil fuels will require heavy investment in order to scale capacity.

Exhibit 9 - Energy Generation and Distribution Are Key to Decarbonizing Power



Investments flows in power are expected to increase, but at a pace insufficient to meet needs

Subsector	2020 flows (\$billions)	2020 gap remaining	Forecasted gap closure this decade	Commentary
Wind and solar	320			Wind and solar photovoltaic are most mature and driving high flows: But investment growth cannot match significant installed gigawatt capacity demand/need
Hydro and other renewable energy sources	100			Other renewables are often overlooked despite capacity need: Investments are expected to grow but pace has slowed 25% versus previous decades
Others (e.g., nuclear, CCUS, hydrogen/ammonia)	40			Technological and political hurdles limit investments in the subsector: Investment will accelerate considerably in the latter half of the decade as technology continues to mature
Networks and storage	290			Investment in grid and storage complements renewables: New networks and R&D to support viable generation (e.g., energy storage systems) are needed; however, teasing out the climate finance portion is difficult

Closing
 Stagnant
 Widening

Sources: IEA NZ by 2050; IEA World Energy Investment 2022; BCG analysis.

Beyond energy generation, developing a more efficient and flexible distribution and storage infrastructure will be critical to net-zero efforts. This infrastructure will require around \$725 billion in investment annually from 2020 to 2025. The amount going toward actual mitigation efforts is probably far less than the estimated \$290 billion invested in 2020. This value included all grid and storage investment, regardless of decarbonizing impact. Policy momentum is likely to prompt more concerted mitigation action. More governments are embracing performance-based regulations that encourage utility providers to develop higher-quality infrastructure, which we anticipate will spur investment in low-carbon solutions.

Mobilizing necessary investment will not be easy. High upfront capital demands and long energy asset life cycles can hamper power companies' efforts to secure project financing. Operational and supply constraints pose additional obstacles. For example, solar photovoltaic supply chains are threatened by challenges ranging from shortages of critical mineral to humanitarian concerns in regions that produce many solar panels. Government policies and subsidies supporting decarbonization will be key to incentivizing continued investment. Passage in the US of the IRA, which directs \$370 billion over ten years toward climate-change abatement measures, should accelerate the transition to clean energy. But this investment alone is unlikely to enable the US to reach clean-energy targets set under the Paris Climate Agreement.

Many technologies for clean-energy generation are relatively mature. However, other, less-mature-but-vital solutions face technological hurdles that limit investment. Financing for low-carbon hydrogen production, for example, totaled just \$500 million across sectors in 2020. Likewise, CCUS technologies that are essential to help the power sector curb carbon emissions until renewables can meet capacity demands have been seriously underfunded. However, we expect investment in these emerging technologies to accelerate considerably. Relatedly, annual APS investment in the “other” category, which includes CCUS and hydrogen, is projected to rise from \$40 billion in 2020 to \$105 billion in the second half of the decade—a much higher rate of increase than other sectors are likely to see.

In some regions, financing renewable project development remains a challenge. Borrowing costs and hurdle rates are much higher in many EMDEs than in advanced markets. This is particularly consequential given the capital-intensive nature of large-scale renewable energy projects. Many such projects make economic sense only when assessed on a 20- to 30-year time horizon. For power companies in EMDEs, finding long-term financing can be nearly impossible because of political instability and project costs. As a result, building an unsubsidized solar plant in Ghana, for example, would cost about 140% more than building the same plant in the US. Macroeconomics aside, factors such as limited local technical expertise also complicate project execution.

4.1.2 Buildings

The buildings sector has the second-largest mitigation finance need after the power sector, at just over \$660 billion per year from 2020 to 2025. (See Exhibit 10.) But as of 2020, flows stood at just \$260 billion.

Addressing Scope 1 and Scope 2 emissions in the buildings sector involves fewer technological hurdles than in other sectors, since many major decarbonization levers are relatively commercially viable. Even so, long payback periods and the different incentives offered to building owners and tenants have discouraged financing and investment in decarbonization. Continued policy support is essential to increasing investment—especially in light of the high upfront costs associated with many decarbonization levers such as full-building envelope retrofits.

Addressing Scope 3 emissions—downstream emissions from material inputs—is much more challenging. Keeping pace with net-zero targets will require all regions to implement zero-carbon-ready building energy codes by 2030. Some advanced economies, including Korea and Canada already have plans to do this, but most EMDEs do not. Broadening the use of green-certification programs such as LEED, Energy STAR, and BREEAM can provide structure and attract financing in places that lack comprehensive building codes.

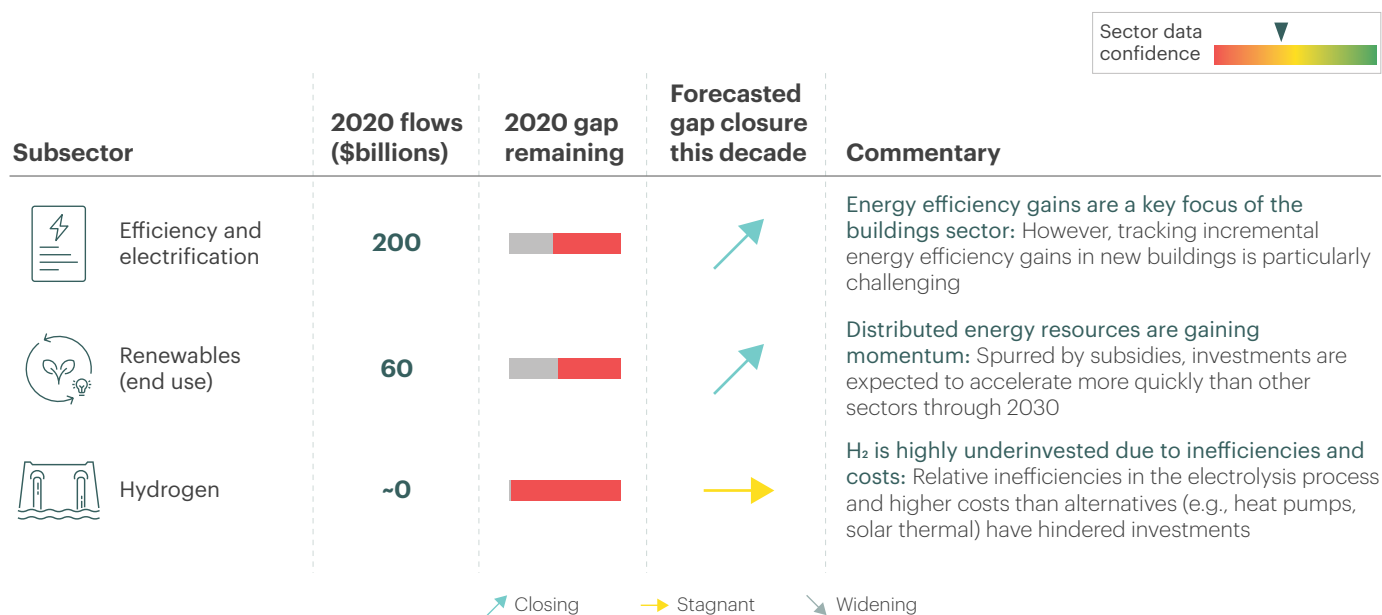
Efficiency and electrification improvements make up the largest share of absolute investment need from 2020 to 2025, accounting for \$520 billion of the \$660 billion total. Decarbonization levers within this category include everything from advanced building envelope construction and retrofits to high-efficiency appliances and lighting. This category also covers investments in high-efficiency heating and cooling systems—including heat pumps, which alone claimed about 10% (\$20 billion) of overall efficiency and electrification investment in 2020 (\$200 billion). Owing to limited data availability, however, tracking energy efficiency investments in the building sector is quite challenging, and the difficulty is compounded by uncertainty over whether such improvements will enable a timely path to net zero and warrant classification as climate finance.

Building sector investment in renewable energy sources such as solar home systems is expected to accelerate through 2030 at a faster rate than in other subsectors, spurred by subsidies, incentives, and the rise of zero-carbon-ready building standards. The state of Victoria in Australia, for example, is offering rebates and interest-free loans to support solar photovoltaic installations. In addition to expanding distributed-energy generation, scaling renewable heating will be critical to the building sector’s net-zero efforts. Government support will play a key role in increasing adoption rates of biomass, solar thermal, and geothermal heating systems. In most regions, lifetime costs for renewable heat systems are higher than for nonrenewable systems, and we expect this to remain true in the medium term.

In the building sector, hydrogen is primarily used in heating applications, and it can be integrated into existing natural-gas networks or used in onsite hydrogen boilers and fuel cells. Currently, however, it is highly underinvested, with less than 1% of finance needs met.⁴ Because hydrogen makes up just 3% of overall climate-related finance need within the buildings sector today, the implications of underinvestment are less consequential there than in sectors where hydrogen plays a more critical role in decarbonization efforts. In the longer term, we expect demand for hydrogen applications is likely to increase after 2030.

4. Hydrogen investment estimates in buildings cover such things as boiler costs and retrofits to enable integration into natural gas networks. These numbers do not include hydrogen fuel production costs.

Exhibit 10 - The Need to Retrofit and Upgrade Buildings Continues



Sources: IEA NZ by 2050; IEA World Energy Investment 2022; BCG analysis.

Note: IEA methodologies endeavor to avoid double-counting renewable end use and renewable electricity generation within the power sector.

4.1.3 Transport

This decade will be transformative for the transport sector. To keep pace with net-zero targets, transport must continue to shift from traditional internal combustion engine (ICE) vehicles to BEVs and must press forward with the development of FCEVs and sustainable aviation fuels (SAF). (See Exhibit 11.) The transport sector will need \$380 billion in mitigation finance annually through 2025 to support this transformation. As of 2020, however, funders were meeting only \$140 billion of this need.⁵

APS commitments toward BEVs have been particularly ambitious. If pledges in support of BEVs are met in full, capital flows will increase fivefold over 2020 levels in the second half of the decade. But even accounting for these commitments, our analysis suggests that the transport sector will need an additional \$170 billion per year to meet its mitigation-finance requirements. However, the APS report covers only pledges announced through October 2021, meaning that it does not take into account recent plans to impose bans on ICE vehicle sales in places like the EU and California, starting in the 2030s. These announcements will likely mobilize significant additional investment.

Investment is necessary across the wider electric vehicle ecosystem to expand public charging infrastructure and to expedite innovations in battery technologies to overcome supply constraints affecting lithium, nickel, and other critical minerals.

Capital flows directed toward road vehicle efficiency, primarily for ICE vehicles, meet almost all financing need. For example, flows in 2020 totaled just over \$90 billion compared to an annual need of \$100 billion through 2025. This gap is likely to vanish by the second half of the decade under the APS. ICE vehicle sales made up over 95% of automotive sales in 2020, and fuel efficiency remains important to consumers, but most financing avenues in ICE vehicle efficiency have plateaued.

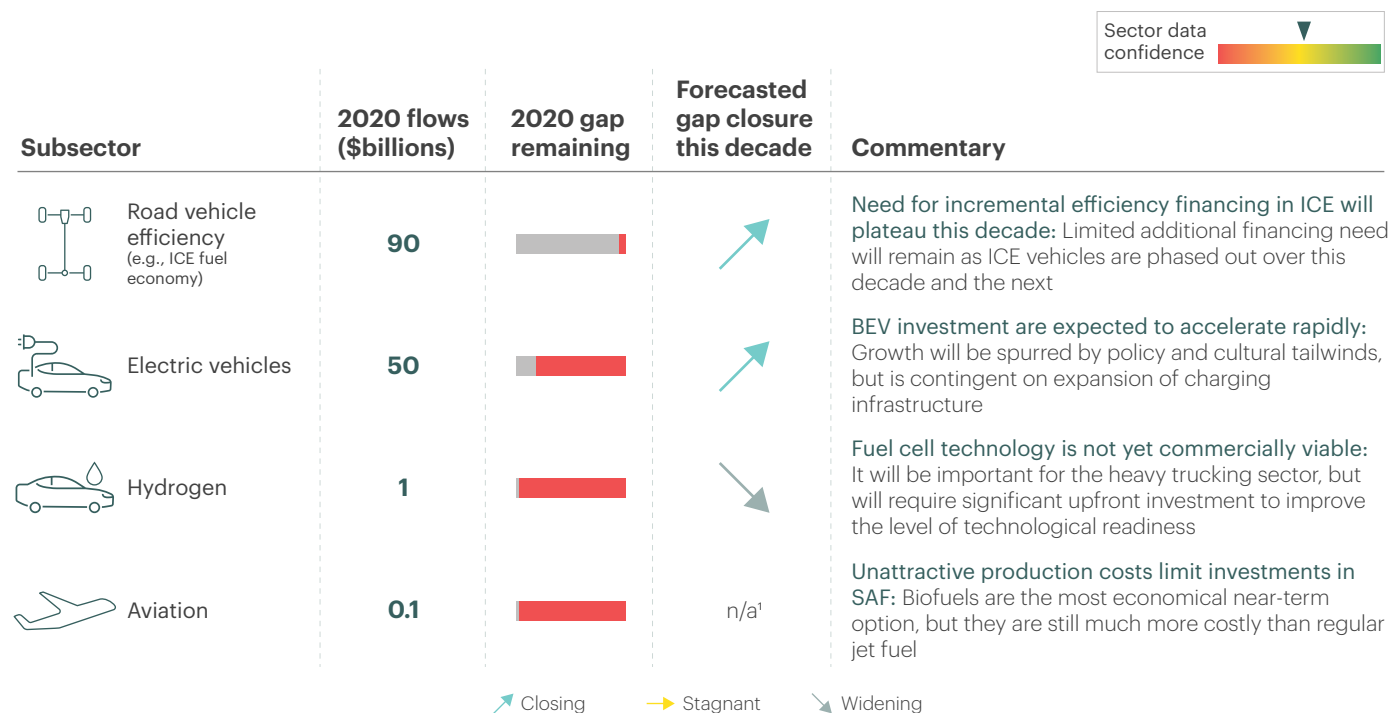
Emerging transport technologies have a much more daunting uphill climb than BEVs. Capital flows to FCEVs and SAF covered only 2% to 3% of mitigation finance need in 2020. Neither technology is cost competitive yet, and hurdles to commercialization at scale lie ahead. We expect roughly 70% of need in this category to remain unfinanced by 2030 because of challenges related to commercial maturity, despite an expected rise in absolute funding commitments.

5. To account for pandemic-related disruptions in 2020, we took the average of 2019 and 2021 investment flows to approximate investment during 2020. IEA's estimated investment in 2020 was much lower (\$83 billion).

Assuming that investment flows do not change from today's levels, our analysis points to a mitigation finance gap of \$2.8 trillion during the second half of the decade.



Exhibit 11 - The Transition to Low- or Zero-Carbon-Emitting Vehicles Is a Focal Point of Investment in Transport



Sources: : IEA NZ by 2050; IEA World Energy Investment 2022; BCG analysis.

Note: BEV = battery electric vehicles; ICE = internal combustion engine; SAF = sustainable aviation fuels.

¹ Insufficient data.

Multiple stages of the FCEV value chain must develop before large-scale commercialization will become feasible. Low-carbon hydrogen fuel production must gain scale. Hydrogen fuel cell purchase prices must become more affordable. And public hydrogen refueling infrastructure must expand substantially. FCEV development is crucial to enabling the heavy trucking sector to meet its net-zero targets. Adoption of these vehicles must reach 5% of sales by 2030 if projections for the technology are to stay on track, but it was essentially zero as of 2020. Significant upfront investment in tech development, fuel production, and fueling infrastructure will be needed to close this gap. Tokyo, New York, Los Angeles, London, and Copenhagen are among the cities that have launched hydrogen transport programs to support investment in this space. The UK's Hydrogen for Transport Programme is one example. It provides a total of £23 million to support growth of FCEV and hydrogen refueling stations.

With respect to SAF, although more airlines are committing to purchase contracts, sustainable fuels made up only 1% to 2% of total jet fuel demand in 2020, largely because SAF costs two to five times as much as regular jet fuel. Investment in SAF production totaled just \$140 million compared to an average need of around \$5 billion annually through 2025.⁶ Other advanced propulsion technologies such as open rotor systems, hybrid engines, and full-electric engines will eventually play important roles in decarbonizing aviation. Most of these technologies are emergent, however, and will not enter service until after 2030. Consequently, they do not account for a significant share of investment needs this decade.

As in aviation, decarbonization in shipping is relatively nascent. Investment needs and flows for sustainable shipping are not well documented, and 2020 capital flows seem to have been negligible. Greater investment in energy efficiency and in low- and zero-carbon fuels such as advanced biofuels and ammonia will be necessary as the decade advances, given the sluggish start to shipping's green transition.

6. We used 2019 numbers to avoid pandemic-related disruptions. These numbers include only biofuels; they exclude synthetic SAF, which is unlikely to play a significant role until after 2030.

Liquid biofuel is another important investment area for the transport sector. Biofuels will play an especially important role in heavy transport as an energy-dense, low-carbon fuel that can accommodate the intensive weight, power, and distance requirements of these vehicles in ways that full electrification cannot. Because SAF probably captures some of this need and because not all biofuel applications are transport related, we have omitted this estimate from our analysis to avoid double counting. Still, the IEA estimates that an annual biofuel investment of \$53 billion across sectors will be necessary during this decade.

4.1.4 Agriculture and nature-based solutions

Agriculture and nature-based solutions will need roughly \$330 billion annually through 2050 to achieve climate targets. In 2020, investment flows met \$100 billion of this need. Because of how UNEP tracks project financing, investment estimates include operating and capital expenses. The analysis shows that decarbonization levers are more operating-expense-intensive in agriculture than in other sectors.

Across subsectors, biodiversity protection efforts such as reforestation, afforestation, and biosphere conservation require the largest amount of mitigation finance in absolute terms—around \$70 billion. These protection measures also receive the most flows: roughly 40% of financing need is being met, according to 2020 data. Looking ahead, governments are likely to enforce stricter regulations on biodiversity conservation, making it more cost effective for agriculture companies to proactively pursue conservation rather than waiting to make remediations. The agriculture, forestry, and fishing subsector will need more mitigation finance support. Currently, only 25% of the \$120 billion in need is being met.

Some 35% of the cost-effective CO₂ mitigation required by 2030 depends on nature-based solutions. Deployed properly, such solutions can support agriculture production and resilience, mitigate climate change, and enhance biodiversity, delivering a triple benefit.

Functioning carbon markets are central to the economic viability of agriculture and nature-based solutions, allowing producers to sell credits generated from projects in afforestation or agroforestry to corporations and governments seeking emissions offsets. (See Exhibit 12.) But these markets have suffered from critical inefficiencies such as low transparency and slow accreditation that have prevented them from gaining traction. Moreover, the absence of a compliance market for carbon credits poses a significant challenge. Voluntary markets are small and lack enforceable standards. These growing pains haven't deterred financial institutions and insurance companies from taking a keen interest in nature-based solutions, however, given the long-term carbon offset potential they offer.

Regenerative agriculture includes but is not limited to nature-based solutions. Large food and beverage companies are committing to buy crops grown through regenerative practices across their supply chains. These practices have improved crop yields through low-till, no-till, cover cropping, and other techniques that enhance soil health and biodiversity. One early mover was General Mills, which announced in 2019 that it would adopt regenerative agricultural practices on 1 million acres of land by 2030. Whole Foods, PepsiCo, Cargill, and Walmart have followed suit with their own commitments.¹¹ But farm-level financing remains limited—a major shortcoming, given the small scale of individual initiatives and the fact that roughly three-quarters of farms worldwide are family owned.

Alternative proteins are another important component of decarbonization in agriculture. To meet net-zero targets by 2050, the sector must replace approximately 30% of meat with alternatives. Success in reaching this goal will hinge on changing consumer dietary habits—no simple matter. And although many technologies for producing alternative proteins are now commercially viable, over \$40 billion in annual investment will be needed to stimulate and sustain adoption. Funders are currently meeting only 7% (\$3 billion) of this need.

Exhibit 12 - Growing Activity in Carbon Markets Is Driving Investment in Agriculture and Nature-Based Solutions



Subsector	2020 flows (\$billions)	2020 gap remaining	Forecasted gap closure this decade	Commentary
Agriculture, forestry, and fishing	30		n/a ¹	Financing is challenged by split incentives: Landowners gain benefits in the long term, but investments are required from farmers (e.g., new machinery and regenerative agriculture practices)
Biodiversity protection	70		n/a ¹	This subsector receives the most flow, but also has the highest need: There is growing interest in the long-term carbon offset potential these solutions provide, but near-term issues with these markets (e.g., lack of transparency and slow accreditation) are challenging
Alternative proteins	3		n/a ¹	Product is commercially viable but requires a behavioral shift: Investment potential is contingent on consumer dietary behaviors and sustained adoption if it is to warrant investment in the space

Sources: UNEP; GFMA; GFI; BCG analysis.

Note: Operating expenses and capital expenses are included in this analysis.

¹Insufficient data.

4.1.5 Industry

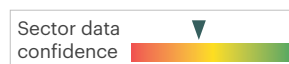
Industry is the second-heaviest-emitting sector after power. Most industrial CO₂ emissions come from three subsectors—iron and steel, chemicals, and cement—and funders direct the lion’s share of investment flows toward these categories. Light industries, which include most consumer goods, are not a focus of most climate finance literature. Given the way the relevant data is reported, some light-industry investments may have been rolled up in our analysis of heavy industry, but these amounts are unlikely to be material.







Investment need in industry is on a path to quadruple to nearly \$200 billion by the second half of the decade. (See Exhibit 13.) This increase stems in part from the investment required to develop and deploy key decarbonization technologies that are not currently market-ready, such as CCUS and hydrogen. Even if announced pledges are met in full, the relative financing gap will nearly double from 20% in 2020 to just over 40% during the second half of the decade. The problem will worsen further beyond 2030 as investment needs accelerate, reaching approximately \$430 billion in 2040.

Net-zero pathways for the iron and steel subsector and the chemicals subsector involve a significant share of improvements in commercially viable energy efficiency, such as the use of recycled scrap in steel production and heat recovery systems in chemical plants. Because the market for these solutions is relatively mature, these industries have found it easier to attract financing than CCUS-reliant cement has. To reach net zero, however, iron and steel and chemicals will eventually need to rely more heavily on CCUS and green hydrogen technologies, since they will have fully adopted most energy efficiency steps by the end of the decade.

To date, owing to their limited commercial viability, CCUS and hydrogen have struggled to attract financing. Low-carbon hydrogen has suffered from supply constraints and poor cost-competitiveness, and it attracted negligible investment in 2020. But prospects should improve. Technological innovation and at-scale production are advancing, which could enable low-carbon hydrogen to draw greater investment through 2030. Regulatory moves should also help. In the US, subsidies provided under the IRA may eliminate the price differential between gray and green hydrogen and dramatically expand the latter’s market. If APS commitments are met in full from 2026 to 2030, annual global investment will approach \$10 billion, meeting around 60% of total need. Attaining this goal would signal progress, even if a large gap were to remain.

Exhibit 13 - Industry Investment Needs Will Accelerate Quickly in the Latter Half of the Decade



Subsector	2020 flows (\$billions) ¹	2020 gap remaining	Forecasted gap closure this decade	Commentary
 Iron and steel	20		n/a ²	Green steel is a focus of future investments, but remains nascent: Future investments will be driven by emergent technologies, including development of green H ₂ and a large-scale shift to electric arc furnaces
 Chemicals	20		n/a ²	Alternative, low-emission fuels will drive future needs: Future investment will be driven by the need for green H ₂ as well as R&D investment in less mature solutions (e.g., ethylene, propylene)
 Cement	10		n/a ²	Decarbonization will rely heavily on CCUS and biofuels: Such solutions and others, including alternative binding agents, are not yet commercially viable

Sources: IEA NZ by 2050; IEA World Energy Investment 2022; GFMA; BCG analysis.

Note: IEA methodologies endeavor to avoid double-counting renewable end-use and renewable electricity generation within the power sector. CCUS = carbon capture, utilization, and storage.

¹ Calculated by scaling overall sector estimate to total relative subsector industry market size. Estimate includes some negligible investment in light industry efficiency.

² Insufficient data.

Prospects are more dire for CCUS, even under the assumption that all APS commitments are fulfilled. Current CCUS commitments for industry will meet just 10% of anticipated need from 2026 to 2030, although this estimate does not capture the effects of the recently enacted IRA, which may accelerate funding of CCUS.

The cement industry has a lower absolute annual financing need (\$31 billion through 2030) than chemicals or iron and steel, but it depends more heavily on CCUS and biofuels. Because of underfunding in both areas, cement faces a significantly larger financing gap for mitigation. Just 23% of its need is being met, compared with around 35% in the other two subsectors.

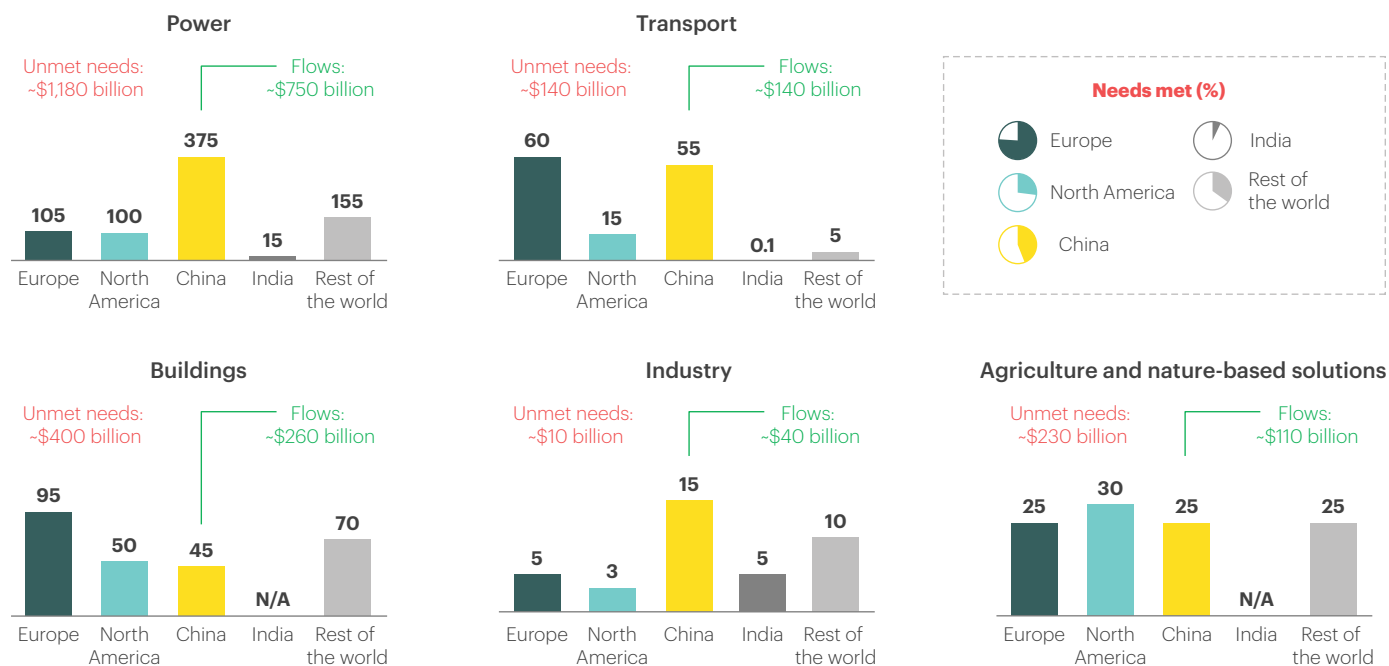
Government support in the form of tax credits, carbon pricing, or other interventions could make CCUS more attractive and generate greater investment interest. It is no accident that the world's first major carbon capture project for cement is underway in Norway, which has one of the highest carbon taxes in the world, at \$88 per metric ton. In the meantime, capital flows in the cement sector tend to target energy efficiency and renewable use, where solutions are more commercially viable. Examples include alternative binding agents to reduce ratios of clinkers (solids) in the cement mix, increasing the alternative fuel mix, and optimizing energy use with higher-quality equipment.

4.2 Mitigation finance by region

Climate finance gaps vary greatly by sector and geography. (See Exhibit 14.) But tracking mitigation finance flows by region has limitations. For example, IEA generally splits its geographical analysis into three broad categories—advanced economies, EMDEs, and China—likely owing to insufficient granularity and data confidence to disaggregate geographies more finely. CPI, on the other hand, splits its reporting across ten regions and publishes one sector-agnostic estimate per region.

One reason for the tracking challenges is that climate finance flows, especially domestic flows, are not well documented in markets that have few disclosure requirements. Another is that while some investment needs are linked to the location of the industries they abate—such as CCUS in steel production—others are location-agnostic, as in the case of R&D to electrify maritime or heavy road transport.

Exhibit 14 - Unmet Climate Financing Needs Vary by Sector and Geography



Source: BCG analysis.

Note: Estimates are based on 2020 values. Because of rounding, not all bar totals equal the approximate sum listed for the entire set of bars in a given sector.

Few estimates today identify the specific mitigation investments required in EMDEs geographically, and in many cases they group needs outside North America and Europe into a single large cluster. Most mitigation finance today is concentrated in China, Western Europe, and North America, which together accounted for about 80% of investment flows in 2020. Excluding China, EMDEs will require about \$1 trillion in climate finance per year, or about one-third of global need. But data suggests that they are receiving only 27% of needed flows. Their need is likely to rise steeply as growth in population, income, standard of living, and urbanization drive further resource consumption and, consequently, further mitigation investment. Our analysis indicates that spending \$800 million on early warning systems for floods, droughts, heatwaves, or storms in these countries could reduce climate-related disaster losses by \$3 billion to \$16 billion per year.ⁱⁱⁱ

Mobilizing investment for EMDEs will be a complex undertaking. Operational and supply chain obstacles pose serious challenges to scaling decarbonization, and macroeconomic factors such as high-cost debt and foreign exchange dynamics complicate project financing. Open and fair global systems that facilitate the flow of technology across borders will be critical. Overcoming the obstacles to investment will require more ambitious commitments and policy support from the public and private sectors.

One approach to helping EMDEs access needed technologies would be for organizations to scale them in developed markets first. This approach has found advocates in venture capital firms such as SOSV and has been adopted as a core theory of change by organizations such as Bill Gates's Breakthrough Energy. Widespread deployment would help reduce the green premiums that make these solutions unaffordable to poorer nations and would help shepherd new zero-emission technologies to EMDEs.



5

Adaptation Finance

Investors consider adaptation and resilience (A&R) a frontier space that is rapidly changing as we gain intelligence on where solutions are needed and how to quantify their benefits.

Definitions of key terms in this area vary. According to the UNFCCC, “adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts.”^{iv} IMF elaborates on these themes, stating that A&R “can take many forms beyond direct government financing of infrastructure; it involves encouraging the private sector to adapt, social protection after disasters, and a holistic strategy for budgeting and planning that factors in climate change.”^v Other organizations define A&R in yet other ways. Most cover only physical measures, but some extend their rubric to transition measures. (See Exhibit 15.)

Meanwhile, taxonomies aligned with the EU’s screening criteria are also being built. One example is an Adaptation Solutions Taxonomy that identifies small and mid-size companies that focus on addressing systemic barriers to A&R.^{vi} Other private entities, such as the Coalition for Climate Resilient Investments (CCRI), are working on developing a taxonomy for resilience bonds.

The way A&R measures are defined can have a significant bearing on their bankability. (See Exhibit 16.) Right now, many funders view A&R benefits as social goods with economically diffuse benefits that do not have a clear payee. Moreover, some A&R measures are challenging to make bankable because in many contexts, investors have not yet appropriately priced the physical risks related to climate change. The lack of clear and quantifiable benefits can be an obstacle to freeing up financing, since corporate and other investors may need to demonstrate measurable returns before they can make funding available.

Exhibit 15 - All Definitions of Adaption Finance Cover Physical A&R Measures, and Some Extend to Transition Measures

	Physical	Transition
Climate-resilient development and building the capacity to respond to the physical risks of climate change (CPI)	✓	
Costs of planning, preparing for, facilitating, and implementing adaptation measures, including transaction costs (UNEP)	✓	✓
Promote resilience of infrastructure and social and economic assets to climate change and its consequences (GFMA/BCG)	✓	✓
Examples	Flood and fire protection Coastal infrastructure Drought-resistant agriculture	Business operation redesign Reskilling displaced persons Managing cultural and lifestyle losses

Sources: CPI Global Landscape of Climate Finance 2021; GFMA Climate Finance Markets and the Real Economy 2020; UNEP Adaptation Gap Report 2021.

Another challenge is that in many instances A&R measures, especially in infrastructure, are defined on the basis of their additionality—for example, the incremental investment required to build a bridge higher than would otherwise be necessary, in order to protect it against flooding. The cost of building the core bridge is not treated as an A&R investment, but the distinction between core and incremental is often hard to make in practice. This challenge adds to the difficulty of assessing specific A&R investments and preparing the fact base needed to raise financing.

Increasingly, we see comparisons of A&R finance to the cost of inaction. Such comparisons can provide a helpful way to measure impact and to highlight areas of need for adaptation investment, but accurately forecasting the cost of inaction requires more sophisticated and robust modeling than is in use now.

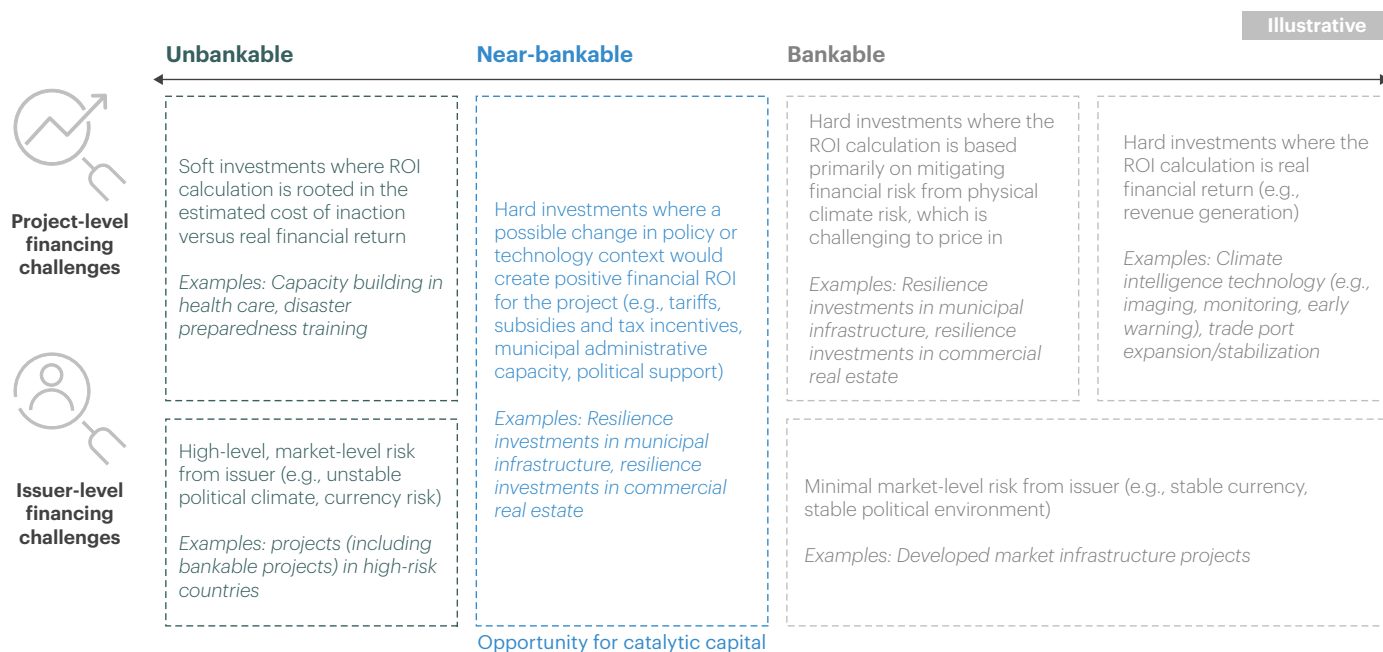
Evolving definitions should comprehensively address how A&R benefits accrue and should employ language and screening criteria with care. For example, while intent is important in assessing A&R, defining projects by this filter alone can be restrictive, since many investments may have an A&R benefit even if that is not their stated purpose. Likewise, taxonomies should consider not only the direct project, but also supporting activities, such as adaptation research, that can provide important indirect benefits.

5.1 Current state of adaptation finance

There are multiple estimates of annual A&R need, but the most widely cited figures come from UNEP’s 2016 “Adaptation Gap Report.” By synthesizing estimates from different bottom-up studies, including studies that use publicly available Nationally Determined Contributions (NDC) and National Adaptation Plan (NAP) data, UNEP determined that annual A&R finance needs in developing economies alone could reach \$140 billion to \$300 billion by 2030 and could climb to between \$280 billion and \$500 billion by 2050. (When adjusted for inflation, these numbers equate to \$155 billion to \$330 billion and \$310 billion to \$555 billion, respectively, in 2020 dollars.)

These figures likely understate the true level of A&R need. In addition to incorporating inconsistent definitions, most estimates focus on initiatives that are suitable for public financing but leave out private sector investments. Although some countries have begun trying to quantify A&R costs using disclosure documents set out under the Paris Agreement—such as nationally determined contributions (NDCs), which outline proposed climate actions, and national adaptation plans (NAPs), which detail a country’s roadmap to achieving these goals—few developed countries have done so. Instead, most developed countries opt to provide estimates in their federal budgets, an approach that limits forecasts to one-year increments and often fails to reflect state or municipal needs. Furthermore, since NDCs must be updated only every five years, they may not reflect the latest thoughts on and commitments to climate finance.

Exhibit 16 - Bankability Varies Across Sector and Region, and Near-Bankable Investments Require Catalytic Capital



Source: BCG analysis.

Estimates of A&R need vary. (See Exhibit 17.) To arrive at a more comprehensive estimate of A&R need across the public and private sectors, we used UNEP’s data as a baseline, together with government and private company data. Our analysis suggests that developing countries have an additional unmet annual A&R need of \$30 billion to \$130 billion, and that the private sector has an additional unmet annual A&R need of \$80 billion to \$150 billion, yielding a total annual need of at least \$410 to \$560 billion for the global economy as a whole.⁷ (See Exhibit 18.)

Actual A&R financing falls far short of this figure. According to CPI, data suggests that average annual A&R funding in 2020 reached only \$46 billion—well below the lower limit of UNEP’s need range (\$140 billion).

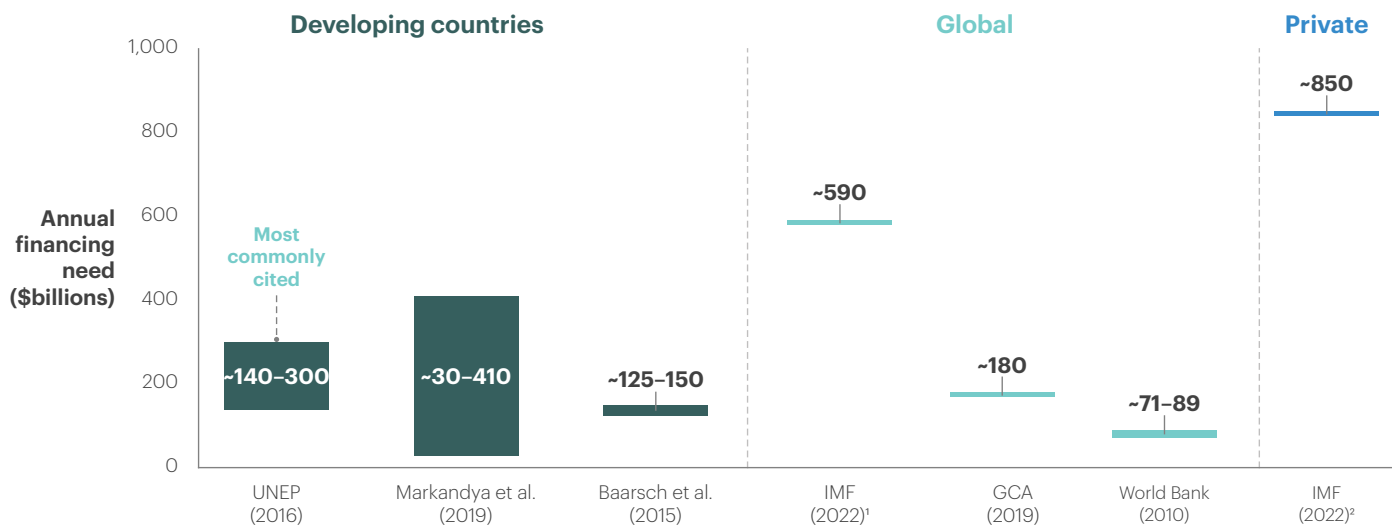
5.2 Public sector adaptation need

Although UNEP’s figure of \$300 billion is the most widely cited estimate of public sector A&R finance need, other sources have published different estimates based on different methodologies. Such estimates vary widely in what they include and exclude, with some estimates including development investments that would be needed even without consideration of climate change. Sources also differ on the extent of future warming and climate change impacts and on the degree to which adaptation policies may affect them.

To quantify the order of magnitude by which public sector A&R needs are currently underestimated, we used data pulled from the 57 developing countries that submitted relatively comprehensive adaptation finance estimates to extrapolate estimates for the remaining 125 developing countries globally. (See Exhibit 19.) We took this approach because the greatest A&R needs exist in developing countries, where domestic finance is unavailable and where project development risks are higher.

7. This estimate pertains only to developing countries. It excludes developed countries, due to insufficient NDC data.

Exhibit 17 - Reports Have Varied in Their Estimates of A&R Investment Need

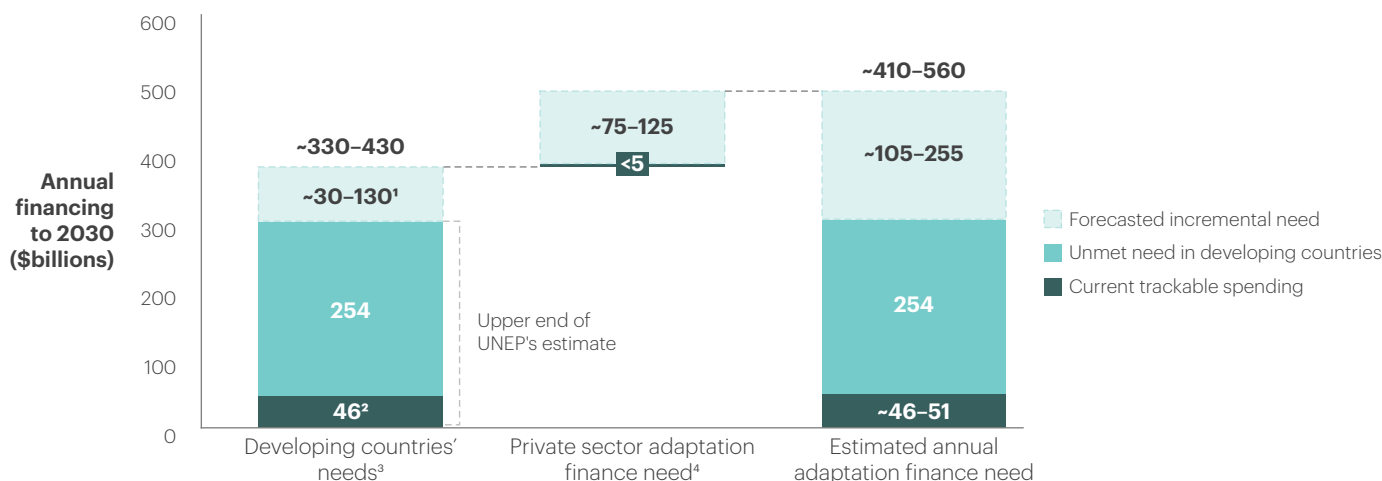


Sources: UNEP, Adaptation Gap Report (2016); Markandya & González-Eguino, “Integrated Assessment for Identifying Climate Finance Needs for Loss and Damage: A Critical Review,” *Loss and Damage from Climate Change* (2019); Baarsch et al., “Adaptation and Loss and Damage,” *Climate Analytics* (2015); IMF, “Macro-Fiscal Implications of Adaptation to Climate Change” (2022); GCA, “Adapt Now: A Global Call for Leadership on Climate Resilience” (2019); World Bank, “Economics of Adaptation to Climate Change” (2010).

¹ IMF’s public sector estimate comes from its estimate of public sector adaptation costs equaling 0.7% of GDP from 2020 to 2025; this percentage was multiplied with global GDP in 2020.

² IMF’s private sector estimate comes from its estimate of private sector adaptation costs equaling 1.0% of GDP from 2020 to 2025; this percentage was multiplied with global GDP in 2020.

Exhibit 18 - Annual A&R Finance Need Is Expected to Be at Least \$410 Billion to \$560 Billion



Sources: CDP questionnaire, question 2.3a; World Bank Databank World Development Indicators; UNICEF regional classifications; UNFCCC NDC Registry; UNFCCC Parties.

¹ Range was determined by grouping countries into four regions and extrapolating A&R need from well-defined NDCs on a per capita and per square kilometer basis.

² CPI estimate of adaptation finance in 2019/2020.

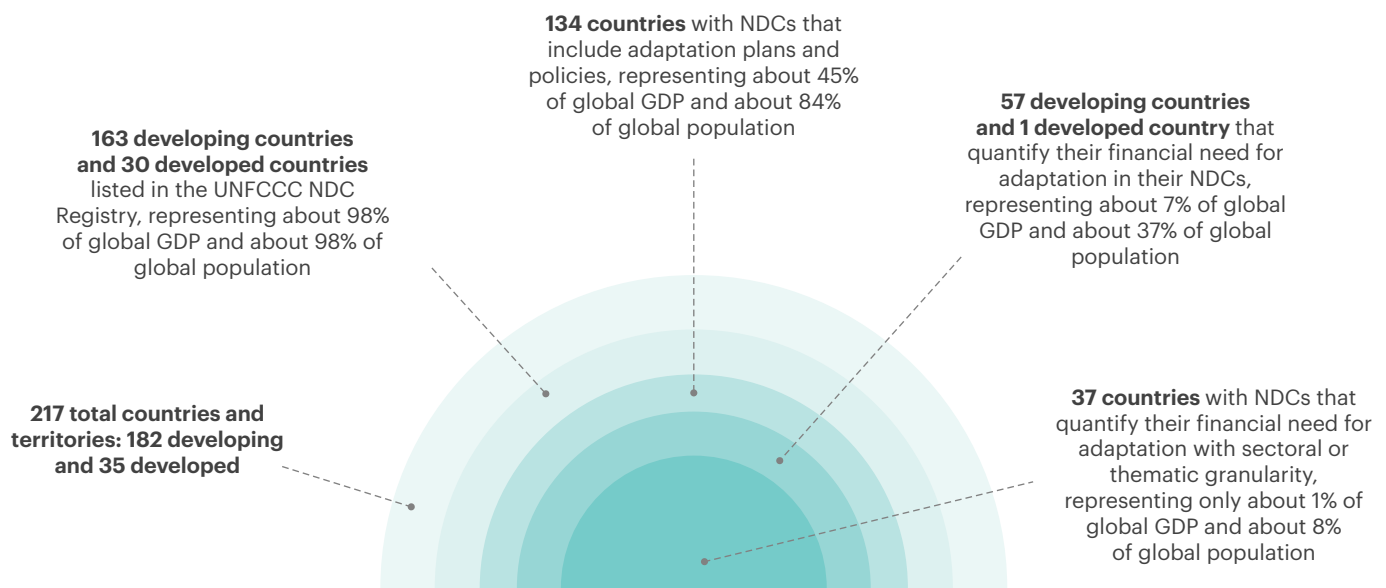
³ Refers to total public need for developing countries including the \$300 billion UNEP estimate and incremental extrapolated need.

⁴ Private sector finance need was determined by extrapolating the cost of responding to adaption risk disclosure to CDP across mid-cap and large-cap companies in each of 11 Global Industry Classification Standard sectors.

We estimate that developing countries need \$330 billion to \$430 billion of public sector A&R investment. This is 37% to 87% higher than UNEP's \$300 billion estimate and represents an investment shortfall of 86% to 89%, based on CPI's estimate of \$46 billion annual adaptation flows.



Exhibit 19 - Few Countries Include Quantified Adaptation Needs in Their NDCs



Sources: ClimateWatch; UNFCCC NDC Registry.

Note: NDC = nationally determined contribution.

¹ Developed and developing countries are categorized in accordance with IMF's taxonomy of "advanced" and "emerging" economies.

We categorized countries into four regions (Americas and Caribbean, Asia-Pacific, Europe and Central Asia, and Middle East and Africa). We then calculated the minimum and maximum A&R need for each region, using data from countries that disclosed their A&R needs and using extrapolated estimates for those that did not. We used the sum of these values to determine the range for the global total.

Working with this methodology, we estimate that developing countries need \$330 billion to \$430 billion of public sector A&R investment. This is 37% to 87% higher than UNEP's \$300 billion estimate and represents an investment shortfall of 86% to 89%, based on CPI's estimate of \$46 billion annual adaptation flows.

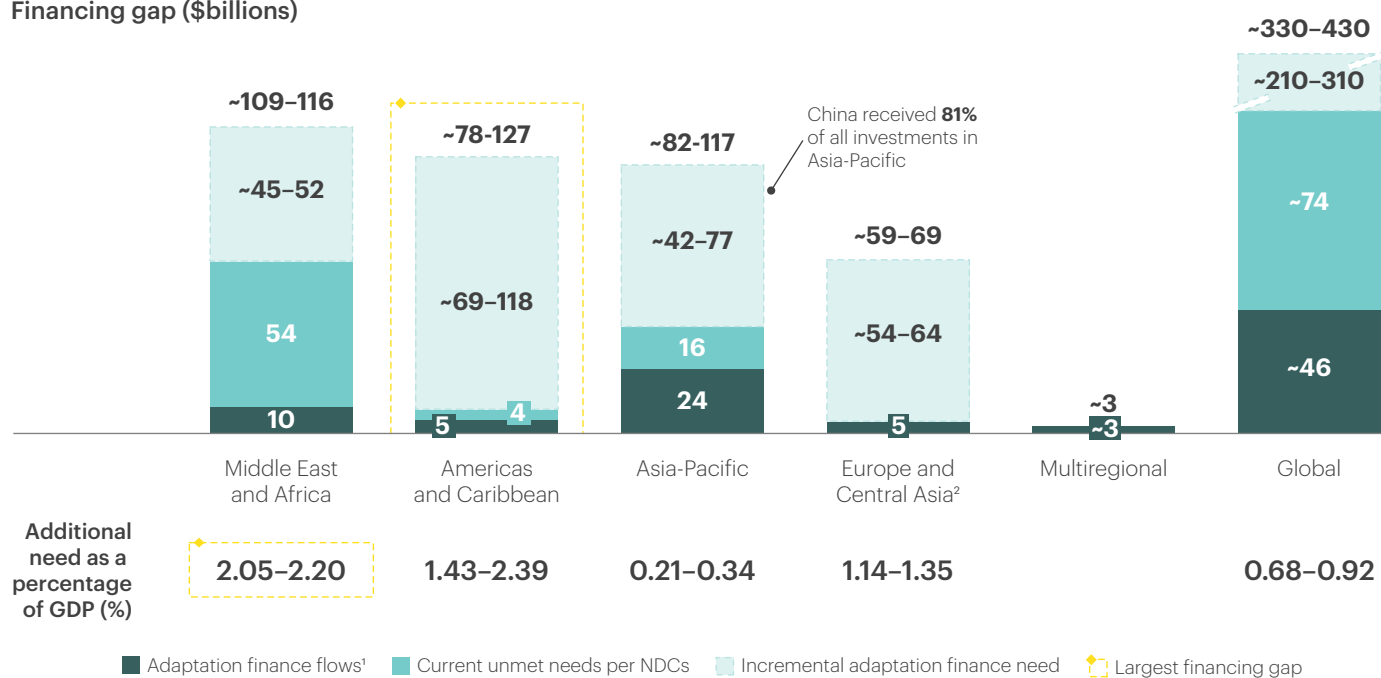
However, our estimate still probably underestimates the total need, since NDCs are oriented to specific public sector themes and do not consider all types of A&R. For example, IMF reported a public sector investment need of 0.7% of global GDP annually (or \$590 billion, based on the global GDP for 2020) across developing countries and developed countries.^{vii} This number presents a thematic view of A&R costs that focuses on three categories of need: upgrading investment projects to improve resilience (0.5% of global GDP), retrofitting existing assets such as exposed roads and railway assets (0.2% of global GDP), and building new coastal protection infrastructure (0.1% of global GDP).

IMF used bottom-up analysis to estimate the first two sets of costs. It overlaid road and railway assets that are exposed to natural hazards on climate-hazard maps and then calculated the share of assets at risk. It estimated the investment needed for coastal protection by determining the cost of the most economically optimal level of protection. Because IMF's analysis focuses on public infrastructure costs and assumes that the exposure of future assets to climate risks will be the same as the exposure of existing assets today, its estimates tend to be higher than those reported by other organizations—especially those that rely primarily on self-reported NDCs and NAPs.

Source and Direction of A&R Flows. Of the \$46 billion in global A&R financing provided in 2020, CPI estimates that 63% came from international sources and 37% from domestic sources. The majority (52%) of this financing went to the Asia-Pacific region, and most of that amount (81%) went to China. Our analyses suggest that developing countries in the Middle East and Africa and in the Americas and Caribbean have the largest financing gaps in absolute terms—in excess of \$100 billion. However, developing countries in the Middle East and Africa have the largest financing gap as a percentage of GDP (2.05% to 2.2%) and the largest unmet needs against those reported in NDCs, further highlighting the urgency and need in this region. (See Exhibit 20.)

Exhibit 20 - The Middle East and Africa and the Americas and Caribbean Face the Largest A&R Financing Gap

Financing gap (\$billions)



Sources: CPI Global Landscape of Climate Finance 2021; BCG analysis.

Note: Numbers are rounded to the nearest billion.

¹ Regional adaptation finance flows in 2019-2020 as reported by CPI.

² Adaptation finance flows to Europe and Central Asia were greater than estimated need based on NDCs.

Reporting from individual infrastructure project costs across Asia and Africa confirms the high level of investment required to protect against climate disaster in developing countries, which makes the underestimation of A&R needs even more concerning.

UN Secretary-General António Guterres has called for 50% of all climate finance to be spent on building resilience and adapting to climate change.^{viii} But while OECD countries have pledged \$100 billion per year to EMDEs, they actually provided less than \$80 billion in 2019.^{xi} And only 25% of that amount (\$20 billion) went toward A&R.

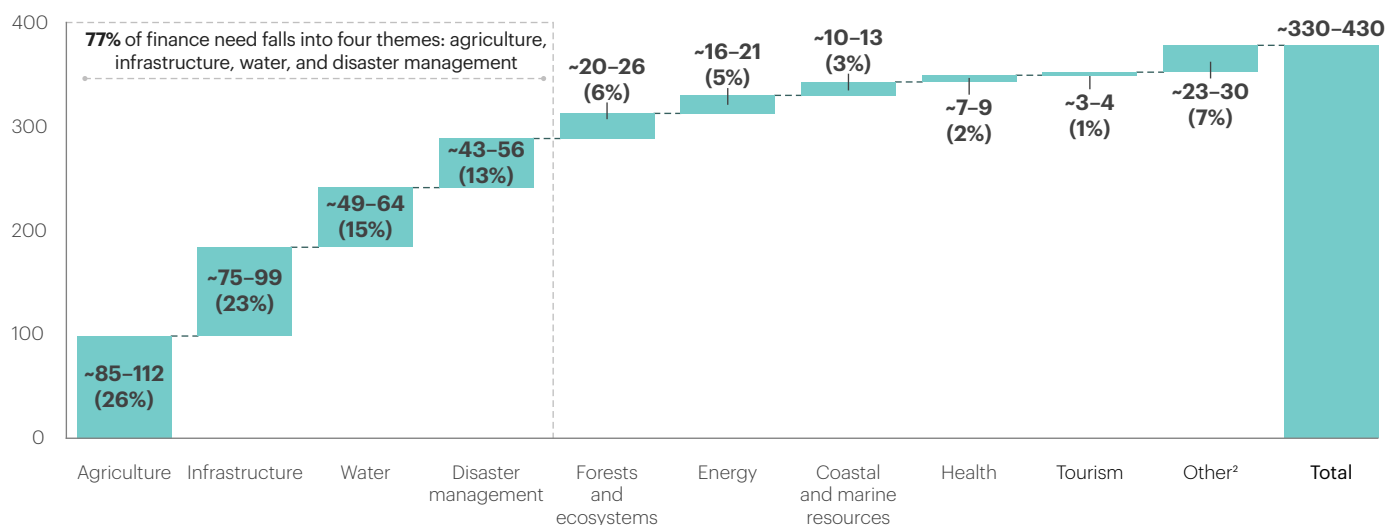
Sectoral Needs and Distribution. NDC and NAP data from 26 countries indicates that four sectors account for 77% of A&R financing need: agriculture, infrastructure, water, and disaster management and preparedness. (See Exhibit 21.) The biggest financing gap is in the agriculture sector, which represents 26% of all need, but average direct spending represented only about 8.6% of all A&R financing in 2020.

To close such gaps, the climate finance community needs more data detailing where proceeds are being deployed. CPI estimates that about \$22 billion of the total \$46 billion in A&R financing was directed toward cross-sectoral uses, illustrating the need for greater transparency into the sectors and initiatives that are being funded.

The good news is that A&R is receiving heightened attention. It is a key focus of COP27, and new initiatives such as the US government's Climate Mapping for Resilience and Adaptation (CMRA) portal have been launched in the past year.^x Benefits of A&R investment are becoming more quantifiable, too. Figures drawn from the Global Commission of Adaptation (GCA), for example, suggest that a \$1.8 trillion investment by 2030 in meeting public A&R needs could yield \$7.1 trillion in ROI. Those returns would come from reduced future losses, improved efficiency and innovation, and other social and environmental benefits. Still, while the scale of A&R finance is increasing, A&R costs are rising even faster.

Exhibit 21 - Agriculture, Infrastructure, Water, and Disaster Management Face the Highest A&R Financing Need

Annual financing to 2030, segmented by sector¹ (\$billions)



Sources: UNEP Adaptation Gap Report 2021; BCG analysis.

Note: Range figures contain extrapolation based on population and land area, respectively. Because of rounding, the bar chart segment percentages do not add up to 100%.

¹ Adaptation need per sector was calculated using the sector breakdown from UNEP Adaptation Gap Report 2021 and applying the percentages to the total annual extrapolated demand from BCG analysis.

² "Other" includes education and social services.

5.3 Private sector adaptation need

Adaptation finance flows today come almost entirely from the public sector. According to existing data, the private sector contributes only about 2% of total A&R capital, representing less than \$1 billion in annual capital flows. And most of this amount likely goes to public sector projects.^{xii} Furthermore, private A&R investments go primarily to higher-income countries and not to lower-income countries where climate change and the climate crisis are disproportionately affecting communities.^{xiii} The main reasons for underfunding in lower- and middle-income countries (LMIC) are unclear financial benefits and metrics, internal restrictions, and limited internal resources.

Still, IMF estimates that the private sector's own annual A&R need, derived by calculating the costs of strengthening private assets against storms and floods, may be around 1% of global GDP from 2020 to 2025, noting that these costs are "almost twice as large as in the public sector."^{vii} The private sector's investment in the A&R of its own operations, whether financed by its balance sheets or by its capital markets, generally goes unreported. We estimate that the private sector deploys, at a maximum, \$5 billion per year on A&R today on its own operations, compared with a total need of at least \$80 billion to \$130 billion annually.⁸ This discrepancy in numbers means that 93% to 96% of the investment need is going unmet. We derived these figures by examining CDP disclosures from a selection of midcap and large-cap companies in each Global Industry Classification Standard (GICS) sector and extrapolating need based on average cost of response to physical climate risk, companies' revenues, and sector size. We also took into account the time horizons that companies forecasted for their different A&R costs.

8. Estimate derived from the CDP disclosures of the 91 companies included in our extrapolation; each of their annual forecasted A&R needs was summed, with \$5 billion representing the potential maximum capital deployed by the private sector each year.

Our assessments are likely still conservative because they are extrapolated from voluntary disclosures to CDP and are not uniform in scope. More than 13,000 companies, encompassing over 64% of global market capitalization, reported data to CDP in 2021. Of these, 4,475 companies reported physical climate risks. And just over half (59%) of this group indicated that addressing the risks posed by extreme weather events was a priority, underscoring the importance of operational resilience. (See Exhibit 22.)

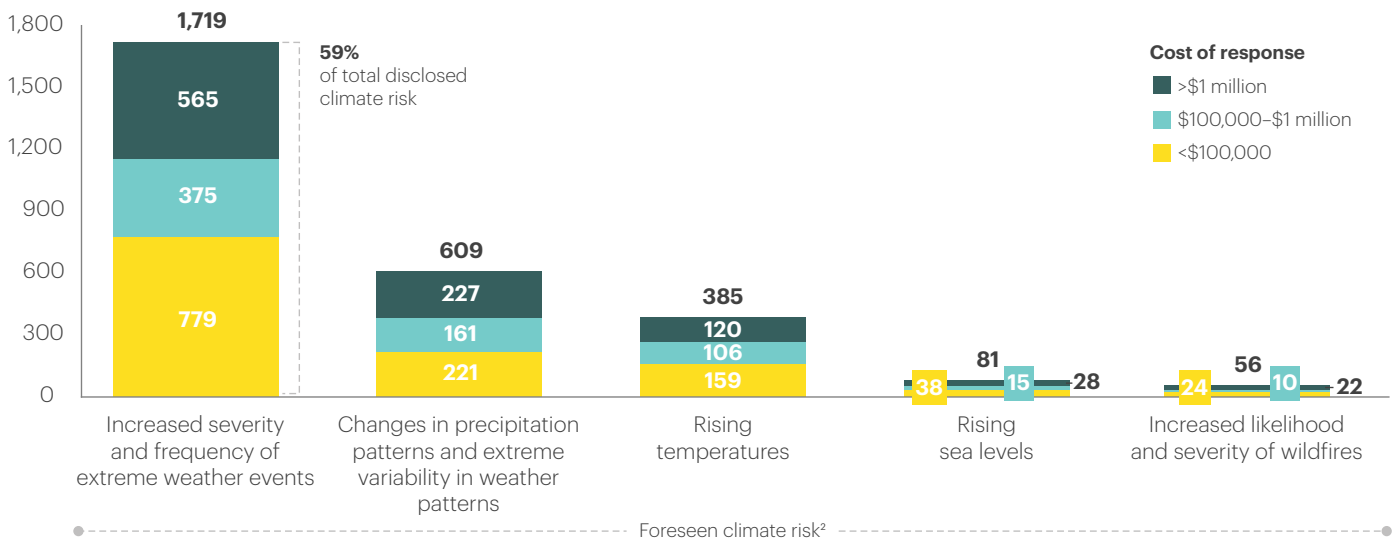
Unfortunately, there is little standardization in how companies report A&R costs in CDP disclosures. Companies vary in the types of activity they fund and in the time horizon within which they do so. Broadly, companies identify three categories of A&R need: offsetting losses through insurance; reducing exposure of real assets; and managing the costs of doing business and of gaining additional skills or data. Companies indicated whether these costs applied to short-, medium-, or long-term measures, but established parameters defining these time horizons do not exist. On average, short term indicates a period of 1 to 5 years, medium term 3 to 30 years, and long term 5 to 100 years. (See Exhibit 23.)

Given the difficulty of running A&R scenario analyses, the challenge of measuring and attributing benefits, and the risk of revealing competitively sensitive information, many companies decline to disclose their A&R costs or needs. As a result, they miss out on opportunities for collective action with other companies in their industry to strengthen supply chain resilience.

We see signs that more companies are embracing a culture of disclosure as regulatory and stakeholder pressure to do so grows. Available avenues include using the recommendations provided by the Task Force on Climate-Related Financial Disclosures (TCFD) and responding to CDP questionnaires. Regional mandates are emerging as well. In 2021, the EU introduced its Sustainable Finance Disclosure Regulation (SFDR) to increase transparency around reported ESG metrics. And in 2022, the US Securities and Exchange Commission (SEC) proposed rules to give investors greater transparency into corporate climate-related risks, such as through metrics that assess progress against climate finance pledges.

Exhibit 22 - Disaster Preparedness Leads Private Sector Investment, with 59% of Companies Prioritizing Response to Extreme Weather Events

Number of entries reporting this risk as a priority¹



Sources: CDP questionnaire, question 2.3a; BCG analysis.

Note: Climate risk types were classified as adaptation if they had a physical element (changes in precipitation patterns and extreme variability in weather patterns, increased likelihood and severity of wildfires, increased severity and frequency of extreme weather events, rising mean temperatures and rising sea levels).

¹ Sample size of 5,906 companies, with 4,361 reporting adaptation related climate risks and response need; from these companies, 2,850 entries for the costs of response to the five climate risks above were submitted with companies able to report on more than one risk.

² As specified by CDP.

Exhibit 23 - Adaptation Costs Span Time Horizons and Functions

Short term		Medium term		Long term	
PPL Corporation	Utilities	BNP Paribas	Financials	Amtrak	Industrials
●	Modernizing grid infrastructure \$2.2 billion	●	Climate change data acquisition, risk management staff \$85.9 million	●	New rail infrastructure, bridge and tunnel rehabilitation \$25.4 billion
BMW Group	Consumer discretionary	Coca-Cola	Consumer staples	AT&T	Communication services
● ●	Insurance premiums, additional personnel, resource efficiency \$99.9 million	● ●	Rainwater harvesting systems, check dams, sustainable supply chains \$41.5 million	● ●	Water management, network disaster recovery initiatives \$651.0 million
Simon Property	Real estate	Apple	Information technology	Schlumberger	Energy
● ● ●	Insurance costs, designing per FM Global standards, employee training \$47.0 million	●	Backup generators, micro-grids, onsite renewable energy \$38.6 million	● ●	Modification of facilities to reduce flood risk, climate-risk assessment \$17.0 million
Air Products	Materials	UnitedHealth	Health care		
●	Redesign of plants to minimize flooding \$22.0 million	● ●	Backup emergency generators, dedicated team \$11.0 million		

● Offsetting losses through insurance
 ● Reducing climate risk exposure of real assets
 ● Cost of doing business and gaining additional skills/data

Sources: CDP Questionnaire, Question 2.3a; BCG analysis.

Note: Climate risk types were classified as adaptation risks if they had a physical element (changes in precipitation patterns and extreme variability in weather patterns, increased likelihood and severity of wildfires, increased severity and frequency of extreme weather events, rising mean temperatures and rising sea levels). Figures reported to CDP in domestic currency and converted to US dollars using exchange rates as of August-September 2022. Companies classified risks as relevant over the short, medium, or long term, and each company submitted its own definition of these time horizons.

Although none of these changes is A&R-specific, mandating disclosures globally will make aggregating and assessing total private sector adaptation easier—a practice that is bound to improve over time as organizations systematize the processes necessary for data collection and reporting. Better tracking and disclosure in turn will encourage more private sector engagement in A&R.

Beyond private sector investment in the A&R of their own operations and value chains, increasing investment opportunities will emerge in cross-cutting measures that enhance adaptive capacity. The Lightsmith Group, the first private equity firm to establish an initiative focused on A&R, reports that the total addressable market for climate adaptation intelligence and other solutions could be worth as much as \$170 billion.^{xiii} Given the asset-light, venture-capital-like characteristics of climate intelligence, we are likely to see continued growth in financial flows into these efforts in the coming years. Meanwhile, asset-heavy emerging climate technologies that can deliver A&R benefits such as new materials will also emerge and demand sustained investment.

The private sector must also support A&R within its broader communities and regions, since infrastructure critical to private sector value chains is vulnerable to negative impacts of climate change. As the interdependency of public sector and private sector preparedness becomes clearer, we expect more companies to consider addressing a comprehensive set of A&R needs in their planning.



6

Drivers of Gaps in Climate Financing

A number of systemic and structural challenges contribute to the climate finance gap. Through interviews with senior executives from across the climate finance spectrum and our own analysis, we have attempted to break them down.

6.1 Project-based barriers

Four key variables impede the supply of climate finance.

Project Risk. Implementing even mature low-carbon solutions that carry minimal technology risks can introduce challenges that limit finance flow. Among the barriers that independent power producers face in securing risk-mitigation coverage for solar photovoltaic projects, according to the World Bank's Sustainable Renewables Risk Mitigation Initiative, were problems with the creditworthiness of off-takers (those who purchase the product or service being produced), inade-

quate legal and regulatory frameworks, weak procurement processes, grid integration constraints, and land ownership questions. These challenges are especially pronounced in EMDEs, where construction financing is less widely available and off-taker risk remains high. One global banker pointed to “[a] dearth of capital at the construction stage in emerging markets.”

Nature-based solutions projects also face acute off-taker risk. Investors in these initiatives require a mechanism to ensure the availability of carbon credits and a viable buyer for them. A venture-stage investor in new reforestation technologies said, “Measuring carbon for agriculture is a lot harder than for forestry because soil carbon levels can fluctuate from day to day even in the same field, and it’s costly to take lots of sample measurements ... A good soil carbon measurement technology tool would unlock a lot of carbon capture and sequestration opportunities in agriculture.”

Sovereign, Political and Macro Risk. Potential backers may shy away from investments in countries with high perceived political, regulatory, currency, or project-development risks. And commercial banks won't enter markets that they deem to have significant sovereign risk in the absence of high levels of political risk insurance. A banker working in sustainable finance said, "We need a foreign exchange hedge on currency for sustainable infrastructure projects, but will likely need involvement from the public sector to address this."

Challenging Return Profiles. Climate-related projects may struggle to conform to typical investor return profiles. Mitigation efforts involving emerging and subscale climate technologies often have a "green premium" that makes them more expensive to buy. Other sustainable practices such as no-till agriculture can be more expensive in the near term than the conventional ones they replace. Fossil-fuel subsidies, which are prevalent in many parts of the world, further distort incentives to invest in renewables. Policies that provide financial incentives for purchasing and using low-carbon solutions could make investment more attractive. (See "45Q shows the power of tax credits in driving CCUS adoption," section 8.2 in Chapter 8.) But significant policy barriers remain, especially in hard-to-abate sectors.

In A&R, the return challenge is especially acute, since many adaptation measures lack the concrete metrics and benefits needed to create bankable projects. A trade commissioner who works on climate finance in a developed country said, "I personally think in the short-to-medium term, adaptation is a social good rather than investible ... I don't think the private sector models exist to make this financeable yet."

For nature-based solutions, the investment economics are still in question. These projects are attracting attention from mainstream investors, but because the asset class is nascent, it doesn't have a track record of consistent returns. Building that track record will require a functioning carbon offset credit market. "Carbon pricing is the best tool... but we need other options to subsidize or incentivize," said a monetary policymaker. Absent carbon pricing, voluntary carbon markets can play an important role in creating financial return mechanisms. However, those markets remain immature, with low transparency, slow accreditation, long duration to revenue, and "charisma-based" pricing not linked to cost or value. The lack of pricing efficiency and transparency in carbon credits creates unpredictable revenue streams. "We do anticipate some hurdles regarding investor risk aversion and lack of understanding of carbon markets," one banker told us.

Lack of Project Supply. Many investors want to put more capital into sustainability sectors. But as one climate finance academic explained, the issue has more to do with a lack of investible projects than a lack of capital. In EMDEs, construction risk for infrastructure, off-taker risk for renewable energy projects, sovereign risk, and uncertainty over carbon offset accreditation for nature-based solutions projects are major factors in constricting project supply. In the developed world, regulatory challenges related to building new infrastructure often hinder project development. During Climate Week 2021, New York State announced a call for its NY-Sun program to achieve an expanded goal of at least 10 gigawatts of distributed solar installed by 2030. This initiative, which seeks to make solar energy more accessible to homes, businesses, and communities, is already falling behind. Issues include building codes that are not adapted to the requirements of rooftop solar capacity, credit and subsidy caps that prompt developers to halt work once limits are reached, and slow development of storage.

6.2 Investor-side barriers

Many investors have criteria that limit their willingness to provide capital for climate finance. There are four main obstacles in this area.

Lack of Scaled Investment Vehicles. Given the cost of diligence and management, most institutional and large-scale investors have high ticket minimums. But climate projects such as small-scale, off-grid energy systems typically involve small check sizes that fall below these thresholds, making it harder for them to secure capital. "Investors need to develop ways to deal with check-size friction," said a sustainable finance banker. "Many efforts in blended finance are too small for institutional investors to engage." A limited capacity for market aggregation across climate-related projects also serves to reduce the number of products and vehicles that meet large-scale investors' target check sizes. For EMDEs, a lack of pipeline-building investments, due to an immature venture capital ecosystem, further curtails the supply of investible opportunities at any scale, especially for domestic governments and domestic financial institutions. These challenges can hobble innovation in areas such as agriculture. A sustainable finance investor at a large US bank said, "There are no meaningful aggregators to solve scale challenges in investing in regenerative agriculture projects, so we're trying mezzanine investments in a few smaller impact funds."

Difficult-to-Meet Risk-Return Targets. Many investors compete for positions in the same few qualifying deals because they share similar fiduciary mandates and capitalization requirements. DFIs that serve a de-risking role have AAA credit ratings that may be compromised by pursuing investments that have challenging risk-return profiles. One trade commissioner said, “All DFIs are looking for positions in the same solar generation investments in Sub-Saharan Africa.” Given the lack of projects that meet risk-return criteria, development finance that is notionally intended to provide soft capital often ends up channeled toward a small set of low-risk investments.

Costly and Slow Structuring. In addition to the complexity of blended-finance arrangements, such factors as impact measurement, verification, and the cost of technical assistance can slow down structuring. A development finance banker said, “Blended-finance investments have mostly been very bespoke, private deals. To get to the billions and trillions, we will need something programmatic and integrated into public transactions.” Catalytic capital could help. “A hundred thousand in grants can catalyze a billion-dollar transaction,” said one investor. A senior banker added, “We need structuring capabilities for new types of project finance. Catalytic capital could provide rebates on interest rates and fund a technical support facility. Multiple other structures could also be viable, whether an interest-rate rebate or a first-loss, de-risking layer in the capital stack.”

Lack of Slots for Key Areas of Climate Finance. Early-stage climate tech can be asset-heavy and lack the characteristics that commercial and concessionary investors require to deploy meaningful sums of capital. One venture capital investor said, “The greatest need for capital is in segments that are tech-enabled, but a little more asset-heavy than traditional VC characteristics. There is not enough equity capital to stand up innovation in machinery companies.”

Some investors are also hesitant to invest in “dirty” assets. In most cases, financing structures that enable the early phaseout of assets such as thermal coal are limited. Many investors have committed to a “no-coal” policy. To facilitate coal phaseout, funding requires either nuanced solutions such as changes in taxonomy or a carve-out in investment policy. A managed and financed phaseout is particularly important in EMDEs that rely on coal-powered utility companies in the near term. Securitization has been used to retire coal plants in a few places in North America, but this approach has not yet seen wider uptake. Increasingly, investors are acknowledging that they need to do more to support the brown-to-green transition and decarbonize assets. Some firms, such as Brookfield and General Atlantic, have launched decarbonization funds. Others are looking for signals to help them identify innovative companies that are ready to evolve. Blackrock found that companies with a higher rate of investment in low-carbon solutions, as indicated by the number of green tech patents filed, demonstrated greater resilience to commodity price cycles.^{xiv}

Conclusion

The clock is ticking. This is a pivotal decade for organizations and communities around the world to advance from pledging support for climate initiatives to deploying them, and it is a make-or-break period for companies to take concerted action on decarbonization and in building more-resilient value chains.

To spur greater action, all key participants in the climate finance ecosystem must improve the quality and consistency of their reporting. Governments should trace capital-finance needs, flows, and outcomes in order to promote availability of necessary structural interventions such as tax incentives and subsidies. Corporates should disaggregate climate finance initiatives, rather than rolling costs and allocations into business operations, in order to improve the accuracy of investment and performance assessments. And market-return-seeking investors should make the end use of their proceeds more transparent, so that others in the climate finance arena can better discern what gaps and needs remain. A strong disclosure framework based on a common set of taxonomies and reporting mandates—including provisions for proprietary data—will facilitate greater data transparency. Until these changes are in place, the climate-finance community has little choice but to rely on voluntary disclosures that reflect data of varying quality.

Just as collaboration in tracking and disclosure will benefit all participants, so will planning that encompasses the wider value chain. Climate finance is inherently interconnected. Many companies rely on infrastructure that others own and manage. Many municipalities rely on resources that their national governments provide. And products and commodities from one geography may be leveraged in another. Accurate disaggregation of investments by sector and by geography will be critical to understanding whether progress toward global climate goals is occurring at the necessary rate. Processes that encourage adoption of a wide-angle view for sizing climate-finance needs can optimize the use of available flows and create a more accurate picture of outstanding needs. Regularly updated, high-quality, freely accessible open-source data sets would give practitioners a much-needed tracking mechanism. Unfortunately, no such system exists today.

Improving the breadth and depth of climate finance data will not be easy. The collective action of policy-makers, voluntary action from investors in the public and private sectors, and funding to strengthen the remit of organizations that are already aggregating and analyzing data today will be essential to this endeavor.

Ultimately, more comprehensive data will drive greater climate action. To close the climate finance gap at the pace required, both the public sector and the private sector must move from commitments to concerted action. More than 90% of countries and 3,000 companies across industries have pledged investments in support of net zero. This is important work. But these pledges still leave a combined \$2.5 trillion shortfall in mitigation and A&R initiatives.

Every minute matters. If society is to meet its ambition of achieving net zero by 2050, the time to act is now.

Case Studies

8.1 Green-labeled financing is attracting investors and enabling accounting

Green bonds are one of the most well-known climate finance tools in the market today. Since 2008, when the World Bank launched the first of these fixed-income tools, green bonds have raised billions of dollars, and new issuances are commonly oversubscribed by a factor of 5 to 6. In 2021, the value of these instruments crossed the \$500 billion mark for the first time, and that value is likely to grow to between \$4.7 trillion and \$5.6 trillion by 2035. It is unclear, though, how much of this value is fully incremental and how much of it has simply been relabeled as green, especially given that green finance accounted for only around 4% of the total finance market in 2021.^{xv}

Green bonds are distinctive in that they can be issued at a higher price than standard bonds but offer a lower yield, a “greenium” that reduces borrowing costs for issuers. These tools perform well in the secondary market. Investors value their choice and range, they appreciate the opportunity to select bonds and issuers that align with their values, and they like the security that comes from instruments tied to specific underlying projects.

An important part of the appeal for issuers is that as green bonds gain volume, they can cover nearly all types of projects across different areas of climate-related activities. In 2018, for example, Seychelles released the world’s first sovereign “blue bond”—a green bond designed to support marine protection and the country’s fisheries sector. Other countries in the African region have since followed suit.

To address concerns about greenwashing, issuers are taking steps to improve standardization in reporting. These include increasing contractual protections, refining reporting metrics and transparency, and harmonizing guidelines and principles. Greater standardization has reduced the percentage of issuers that use internally calculated data in their reports, from 35% in 2020 to 13% in 2021.

The growing green-bond market has also led to development of international best practices through the Green Bond Principles and the Climate Bonds Standard. ISO 14030, launched in 2021, provides a framework for green-bond issuance and impact reporting, including requirements for designating an instrument as green. Governments are implementing national and regional guidance as well, with countries around the globe specifying in varying detail what constitutes a green-bond project. The EU's Taxonomy and Green Bond Standard, for example, provides a framework for project selection, use of proceeds, and tracking of proceeds.

8.2 45Q shows the power of tax credits in driving CCUS adoption

By enacting the Inflation Reduction Act (IRA), the US government has significantly enhanced its 45Q tax credit, a system designed to attract capital aimed at enabling CCUS to become a self-sustaining industry. (See Table 2.) Added to the federal tax code in 2008, the initial 45Q rollout imposed restrictions that resulted in low adoption: only the first 75 million metric tons of captured CO₂ were eligible for credits, and the program paid just \$20 per metric ton for CO₂ that was captured and stored and \$10 per metric ton for emissions that were captured and used for enhanced oil recovery (EOR). Moreover, to be eligible for the credit, claimants had to capture at least 500,000 metric tons of CO₂ annually. This high threshold impeded the development and funding of CCUS projects, since only the largest carbon-emitting projects could meet those requirements.

Table 2 - Summary of Major 45Q Amendments

		2008	2018	2022
Legislation		Energy Improvement and Extension Act	FUTURE Act, as part of the Bipartisan Budget Act	Inflation Reduction Act
Value of tax credit (\$ per metric ton)¹	Captured and used	10	30	60
	Captured and stored	20	50	85
Delivery of credit		Entity that captures CO ₂	Owner of carbon capture equipment; transfer allowed to related entities	Inclusion of direct pay/ tax refund provision; tax credit sales allowed
CCUS commencement requirement		After 2008	Before 2024	Before 2033
Credit generation		Credit capped—from a pool of 75 million metric tons until all credits have been claimed	Time capped—maximum 12 years from commencement	Time capped—maximum 12 years from commencement
Type of carbon		Carbon dioxide	All carbon oxides	All carbon oxides
Annual CO₂ capture requirements		>500,000 metric tons	Power plants: >500,000 metric tons Other capture facilities: >100,000 metric tons	Power plants: >18,750 metric tons Other capture facilities: >12,500 metric tons

Source: BCG analysis.

¹ Excludes price adjustments to account for inflation.

The credit was revamped in 2018 to provide higher credits (\$50 per metric ton for CO₂ captured and stored, and \$35 for CO₂ captured and used, with use cases expanding beyond EOR), remove the credit cap, and extend to all carbon oxides. The revised credit retained the minimum capture requirement of 500,000 metric tons per year for power plants, but it reduced capture thresholds for direct air capture and other capture facilities with lower land demands to 100,000 metric tons annually, and it lowered capture thresholds for facilities emitting less than 500,000 metric tons per year to 25,000 metric tons. These reforms triggered a wave of CCUS projects across the US.

The passage of the IRA in August 2022 is acting as a further catalyst. Enhancements to 45Q contained within the act increased government subsidies, simplified the tax credit process, and granted subsidies to smaller projects that previously did not meet requirements. The changes helped expand the CCUS market by increasing the value of the 45Q tax credit for capture of CO₂ from \$50 to \$85 per metric ton for facilities that capture and store CO₂, and from \$35 to \$60 per ton for facilities that use CO₂ in EOR or other industrial methods. These reforms make carbon capture a more cost-effective decarbonization option and will likely spur greater carbon capture efforts. In addition, the law extended the window to commence construction of carbon capture facilities by seven years to 2033, giving companies more time to develop projects. On top of this, the annual amount of CO₂ that a project must capture was dropped to 18,750 metric tons for power plants and 12,500 metric tons for others, allowing smaller facilities to monetize small pilots, pursue CCUS, and qualify for tax credits.

Together, these amendments to 45Q could increase the use of carbon capture 13-fold by 2030, making the IRA one of the most significant pieces of US legislation in the past decade for promoting decarbonization.^{xvi}

8.3 Risk-sharing structures can spur joint public-private funding

Risk-sharing instruments that anchor investments on clear outcomes can make climate finance more tenable for market-return-seeking capital. Three such instruments are attracting significant investment: blended-finance instruments, public-private partnerships (PPPs), and environmental impact bonds (EIBs).

Blended-finance instruments use philanthropic and public sector capital to de-risk commercial investments or to underwrite the transaction design and execution process. Offerers can also use these instruments to aggregate financing for small-scale projects into tradable products. Because they are structurally complex, blended-finance instruments require significant design time and diligence, making them difficult to scale for commercial investors. But once constructed, they can be extremely effective for raising finance, thanks to their risk-sharing nature. For example, the Land Degradation Neutrality Fund is a blended-investment fund created by the UNCCD's Global Mechanism and the French asset management company Mirova, with support from the governments of France, Norway, and Luxembourg and from The Rockefeller Foundation. The fund raised over \$200 million to achieve sustainable land management and land restoration, and it plans to spend a minimum of 80% of its money in developing countries. Blended finance continues to gain momentum as frameworks such as the OECD Blended Finance Principles emerge to guide blended-finance utilization and as platforms such as Convergence and the Tri Hita Karana Platform are created to put blended-finance principles into practice and offer interested commercial investors greater access to blended-finance project pipelines.

Public-private partnerships often rely on blended-finance vehicles to fund initiatives that generally last from 20 to 30 years and deliver a public good. PPPs have a reputation for on-time delivery, innovation, and high standards of execution. Typically, the private party bears the operational risk and management responsibility, with remuneration linked to performance. Private partners usually recoup their investment through payment from the public sector partner or by charging public users a fee. In the past two decades, PPPs have been particularly helpful in supporting A&R projects, and the number of PPPs in sub-Saharan Africa in particular has grown significantly. A successful example is the construction of the Bujagali Dam in Uganda. A collaboration between the Government of Uganda, World Bank, European Investment Bank, AfDB, and dam construction companies Industrial Promotions Services and Sithe Global Power, the 250-megawatt Bujagali project increased the country's supply of reliable electricity and improved water supply, education, and health services in nearby villages.

Environmental impact bonds are instruments in which the level of payment depends on measured outcomes, allowing issuers to hedge risk and protect taxpayer money and enabling investors to contribute to social and environmental initiatives with risk-adjusted returns. The first EIB structure was designed and introduced by Quantified Ventures, in collaboration with DC Water, a water and wastewater service in Washington, DC. Designed to manage stormwater runoff through green infrastructure, the EIB was purchased by Goldman Sachs Urban Investment Group and Calvert Impact Capital for \$25 million. Although the EIB offered traditional bond interest and principal payments, it allowed DC Water to use the capital from the EIB sale to construct necessary green infrastructure and share the performance risk with investors. A successful project was defined as one in which the measured outcome—in this case, stormwater runoff reduction—fell within the expected range. If the project underperformed, investors would make a contingent payment to DC Water; and if it overperformed, DC Water would make a contingent payment to them. The model was effective, and other US cities have since used EIBs to fund infrastructure projects of their own, with Atlanta offering the first public EIB.

8.4 Product innovation plays an enabling role in climate finance

Tackling climate change requires innovative products that stimulate public and private sector investments in areas that otherwise might find it difficult to attract capital. Examples range across a number of different fields of innovation.

Insurance product innovation. Insurance is a vital tool to help individuals and organizations recover and rebuild. To make climate-related risks insurable, however, some mitigation steps must be in place. A combination of public and private capital can help provide that balance and allow insurance schemes to operate in various ways.

In 2017, The Nature Conservancy (TNC) collaborated with Swiss Re and other local partners to launch the world's first nature-based insurance solution. The goal was to protect the Mexican state of Quintana Roo's coral reef against severe storms, thereby shielding businesses and community members that operated near the reef from severe financial strain. When Hurricane Delta hit the coast in October 2020, the insurance solution permitted speedy disbursement of around \$800,000 for restoration work, and it helped hotels and other local businesses resume operations more quickly. Based on the success of this solution, TNC and its partners are looking to scale up this model in other countries.

Nature-based insurance solutions must address certain challenges before they can become a mainstream tool in climate finance. One issue is the requirement that people pay an insurance premium for support that in the past was free, as a result of external or international aid. Another is that without more effective data and modeling, insurers may not always be able to measure the benefits of and risks to nature-based infrastructure and ascertain the value of the related insurance program. With better data and modeling, however, insurers could assist in a wider range of infrastructure projects.

Loan policy innovation. In developing countries, where insurance premiums may be less affordable, an alternative to nature-based insurance solutions takes the form of loans that include drawdown options, such as the World Bank's Catastrophe Deferred Drawdown Options (Cat DDO). In 2008, Costa Rica was the first country to receive a Development Policy Loan with a Cat DDO. The government directed the loan amount of \$65 million toward strengthening institutional frameworks and mainstreaming disaster risk management in the country. In January 2009, when a magnitude 6.1 earthquake struck north of Costa Rica's capital of San José, the government requested disbursement of the DPL with Cat DDO funds.

Business model innovation. The right structures can create a cycle that rewards actors for their work in addressing climate risks. For example, in the Philippines, Conservation International is implementing the pilot phase of a social enterprise model called RISCO that identifies mangrove sites appropriate for conservation activities and coordinates with local partner organizations and insurance companies to assess the potential risk-reduction benefits. RISCO receives fees from insurance companies and funds for mangrove forest restoration and protection from impact investors and blue-carbon credit buyers. Because mangroves protect people and coastal assets against flood damage, conservation work in such areas reduces flood and property risk, reducing insurance companies' necessary payouts and allowing insurers to extend coverage to coastal areas previously deemed too risky.^{xvii}

Asset class innovation. Intrinsic Exchange Group (IEG) and NYSE jointly developed a new asset class called natural asset companies (NACs). This asset class encompasses not just a natural asset such as a forest, wetland, or lake, but also any underlying ecosystem services (naturally occurring benefits) that the asset provides, such as carbon sequestration, increased biodiversity, or water purification. NACs can be formed, structured, and publicly traded on the market similarly to any other corporation, and NAC investors may include family offices, sovereign wealth funds, DFIs, and the public. The capital raised through the sale of NAC shares is then used for such purposes as restoration, conservation, and other sustainable practices, depending on what the asset requires, creating a cycle of investment into ecosystem services that benefit the environment.

NACs operate on the idea that nature produces goods and services equal to the value of our economy and that creating a financial instrument priced to an asset's ecosystem service allows investors to capitalize on this value. Properly maintained, these natural assets will be productive far longer than industrial assets, and they will increase in value as gauged both by natural asset metrics and by traditional ones, thus driving the demand for investment in NACs. Currently, IEG is in the final stages of approval from the SEC to trade NACs on the public market.

8.5 Hard policy mandates can strengthen finance data and enable financial flows

In recent years, companies have been taking action to improve the quantity and quality of their publicly available disclosures. As more stakeholders call for greater data transparency, more companies are using the Task Force on Climate-related Disclosures (TCFD) framework to voluntarily report climate-related risks and opportunities. In January 2022, the number of TCFD supporters exceeded 3,000 in over 90 jurisdictions. At the company level, the increase in disclosures has prompted boards to expand their ESG oversight, with ESG and audit committees coordinating with management on topics such as adherence to disclosure frameworks.

When implemented, hard policy mandates can improve climate governance. One effort that is gaining traction involves mandating banks, institutional investors, and companies to use the TCFD framework to make data and reporting more consistent and complete. In 2021, New Zealand became the first country to announce mandatory TCFD-aligned disclosures by 2022. Switzerland, the UK, China, and others quickly followed with similar declarations, and most look to have mandates in place by 2025.

Some countries that have not yet mandated TCFD-aligned disclosures are nonetheless launching initiatives to encourage such disclosures. The Canadian government established the Large Employer Emergency Financing Facility (LEEFF) in 2020, a bridge financing initiative that requires recipient companies to publish annual climate-related disclosures. In 2022, the SEC proposed requirements for increased standardization in climate-related disclosures, making climate-related financial data and GHG emissions data publicly available. With these changes underway, greater market transparency is on the horizon, leading to better allocation of capital.

As climate change accelerates, governments can move beyond mandating just disclosures to more concretely influencing the flow of finance. One analogy to this is the Community Reinvestment Act, a US federal law introduced in 1977 to reduce racial discrimination in banking and to overcome the practice of redlining, which prejudicially excluded ethnic minorities in urban neighborhoods from accessing credit. Studies have found that the CRA had a positive influence, encouraging banks to shift their lending activities in CRA-eligible neighborhoods. Indeed, one study estimated that the CRA was responsible for generating up to 20% of the growth in low- and middle-income lending among CRA banks, as well as for increasing home ownership rates despite continuing racial inequality. In light of research showing that climate effects disproportionately impact vulnerable communities, a hard policy mandate applicable to climate finance could be helpful.^{xviii} The success of any such initiative, however, depends on the availability of high-quality data and disclosures.

8.6 Soft policy in the form of industry action can drive transparency and impact

Climate alignment finance agreements are mechanisms designed to bring real-economy GHG emissions in line with 1.5°C climate change targets through industry commitments and accountability. This is important because climate alignment in high-emitting sectors will push companies to make decisions that are in line with their planned net-zero emissions transformation strategy, increasing both transparency and action. Launched in 2019, the Poseidon Principles for Financial Institutions were the first of their kind, creating a framework for sustainable maritime shipping finance. Pioneered by major banks involved in shipping finance, these principles aim to create global baselines that take social, environmental, and economic goals into account to ensure that banks' portfolios align with positive environmental impact, with the goal of reducing shipping's annual GHG emissions by 2050 by at least 50% from 2008 values. The four Poseidon Principles involve assessing climate alignment in shipping portfolios, using standardized taxonomy in assessments, adhering to the principles in all new business activities, and publicly publishing assessment scores to maintain transparency.

Following the establishment of the Poseidon Principles, 15 of the 16 signatories successfully reported their scores that same year. In 2021, the number increased to 23 of the 25 signatories reporting their score, and signatories now represent around 50% of the global ship finance portfolio. With changes made to the assessment methodology and with the continued havoc of the COVID-19 pandemic, however, 2021 disclosures revealed that the average annual alignment score was significantly worse than the previous year's (7.0% versus 1.2%), indicating that the industry may not be as far along the decarbonization pathway as they had previously thought. Nevertheless, the increased transparency into signatories' portfolios and future strategies represents an important achievement. The Poseidon Principles improved disclosures and data availability and furthered industry discussion of what steps should be taken next, with the hope that the impact of COVID-19 on the industry's decarbonization goals was only temporary.

The Poseidon Principles are just one of many examples of industry action. Their success spurred additional climate alignment agreements in the marine industry among ship chartering companies (with the Sea Cargo Charter, established in 2020) and marine insurers (with the Poseidon Principles for Marine Insurance, coming into effect this year), creating a trio of complementary frameworks for the marine industry and demonstrating the success of the original principles.

Other industries are forming agreements of their own. Inspired by the Poseidon Principles, six major banks representing \$23 billion in steel loans, came together in 2021 to establish a climate alignment agreement. Together, they signed the Sustainable STEEL Principles (SSP) and formed the Steel Climate-Aligned Finance Working Group, facilitated by the Center for Climate-Aligned Finance at the Rocky Mountain Institute. The group's goal was to create a foundation for measuring progress against climate targets and for decarbonizing the steel sector. Using a framework similar to that of the Poseidon Principles, the SSP aims to assess the emissions intensiveness of steel loans relative to the needed decarbonization trajectory.

With these successes serving as examples, industries can adopt additional sector-specific climate alignment agreements to improve transparency and reporting standards while driving change in industry activities toward net-zero goals.

Methodology and Technical Appendix

9.1 Introduction to the appendix and key sources consulted

We consulted various sources to form the estimates used in this report. This section summarizes the estimates we chose and the rationale for our source selections. We also describe the methodologies we used in deriving estimates for categories that had gaps in third-party reporting. Because this reporting is new and involves assumptions, there is potential for double counting in some cases—a risk we hope to reduce over time as we build a more robust and expansive view of the market.

In mitigation, we relied on the following primary reports:

- **IEA World Energy Investment 2022.** Provides a historical view of global investment in the energy industry; includes 2020 capital flow estimates in all sectors except agriculture and nature-based solutions.
- **CPI Global Landscape of Climate Finance 2021.** Provides a historical view of global investment in climate finance; includes 2020 capital flow estimates in all sectors.
- **BloombergNEF Energy Transition Investment Trends (2021).** Tracks global investment in the low-carbon energy transition; leveraged in this report for investments in emerging technologies (e.g., carbon capture, hydrogen).
- **IEA Net Zero by 2050 Roadmap (2021): Presents a roadmap to net zero for the global energy sector, including sector-level investment needs through 2050.**
- **GFMA and BCG Climate Finance Markets and the Real Economy (2020).** Presents a roadmap to mobilize global capital investment that is essential to reaching net-zero targets; includes sector- and subsector-level investment needs (cumulatively from 2020 to 2050).
- **UNEP State of Finance for Nature (2021).** Tracks existing investment and projected investment needs specifically for nature-based solutions.
- **Good Food Institute (2021).** Tracks annual investment in alternative proteins.

In adaptation, we relied on the following primary reports:

- **UNEP Adaptation Gap Report (2014, 2016, and 2020).** Examines progress in adaptation financing and identification of gaps that need to be addressed.
- **CPI Global Landscape of Climate Finance 2021.** Provides a historical view of global investment in climate finance; includes 2020 capital flow estimates in all sectors.
- **IMF Staff Climate Notes 2022 - Macro-Fiscal Implications of Adaptation to Climate Change.** Looks at fiscal policies for climate change adaptation.
- **Carbon Disclosure Project (CDP) Questionnaire.** Details company responses to CDP's Climate Change questionnaire—specifically those that focus on climate risk and respective adaptation costs.
- **McKinsey Net-Zero Transition (2022).** Examines capital spending on physical assets for energy and land-use systems as part of the transition to net zero; broader definitions used, resulting in a much higher estimate of \$4.7 trillion investment flow and \$9.2 trillion total investment need, annually.
- **UNEP Africa's Adaptation Gap Report.** Analyzes climate-change impacts and challenges in Africa.
- **Reports from various research teams: Chapagain et al., "Climate Change Adaptation Costs in Developing Countries," *Climate and Development* (2020); Baarsch et al., "Adaptation and Loss and Damage," *Climate Analytics* (2015); Markandya & González-Eguino, "Integrated Assessment for Identifying Climate Finance Needs for Loss and Damage: A Critical Review," *Loss and Damage from Climate Change* (2019).** Analyze different approaches and methodologies for estimating climate change adaptation costs in developing countries.

We also reviewed the following key reports, although we did not leverage them in our analysis:

- **IPCC AR6 (2022).** Examines physical effects of climate change, quantifies the time horizon available to address emissions, and the investment gap in funding interventions.

9.2 Appendix - Data confidence rubric for third-party financial flow estimates

Dimension	Low	Medium	High
Capital source coverage and clarity	<p>Unknown sources of capital (e.g., sector estimate only)</p> <p>Tracking mechanisms are likely to cover limited investment flow in the segment</p>	<p>Capital sources are provided but are generalized (e.g., public vs. private capital)</p> <p>Tracking mechanisms are likely to cover some investment flow in the segment</p>	<p>Primary and/or intermediary sources of capital are clearly defined</p> <p>Tracking mechanisms are likely to cover substantive/majority of investment flow in the segment</p>
Data granularity	<p>Leverages secondary data estimates from other sources and may adjust them without clear articulation of inclusion/exclusion criteria</p> <p>Does not specify financing data input into estimates</p>	<p>Builds estimate based on top-line disclosures from organizations that deploy capital (including intermediaries) based on a top-down approach</p> <p>May include a mix of primary and secondary transactions, risking double counting¹</p>	<p>Builds estimate from aggregation of primary-transaction-level or project-level data into investment flow estimates</p> <p>Excludes secondary transactions in cases where they might pose a risk of double counting¹</p>
Source quality	<p>Data sources are cited generally but not linked to specific estimates</p> <p>Does not specify data sources leveraged for estimates</p>	<p>Primary and secondary data sources and methodology are explicitly stated (e.g., in cases of extrapolation)</p> <p>Linkage between source data and estimates cannot be replicated by third party</p>	<p>Primary and secondary data sources are well-defined, and methodology is explicitly stated (e.g., in cases of extrapolation)</p> <p>Source data can be linked to estimate</p>
Clarity of end use	<p>Limited disaggregation or definition of end use of proceeds (e.g., no subsectors identified)</p>	<p>Definitions of end use of proceeds are defined in the basic hierarchy, but exactly what is included (e.g., how cross-cutting areas are disaggregated by sector) is an open question</p>	<p>Definitions of end use of proceeds (i.e., project vs. company, sectors) are clearly defined (e.g., subsectors included)</p>

Source: BCG analysis.

¹ Can include commitments.

9.3 Appendix - Intermediary actors involved in the deployment of capital

		Source of capital				
		Government	Institutional investor	Corporate (balance sheet)	Commercial banks (balance sheet)	Other privates
	Development finance					
	Government-backed entity					
	Corporate					
	Commercial banks					
	Funds					
	No intermediary—direct financing					

Source: BCG analysis.

9.4 Appendix - Literature review for 2020 climate mitigation investment flow estimates

2020 flows (\$billions)

Sector	Subsector	IEA WEI 2022	CPI	BloombergNEF 2021	Difference/source selection
Power	Renewables (generation)	418	324	N/A	Both estimates include the same renewable energy sources (e.g., solar, wind, hydropower). IEA considers investments to upgrade existing renewable energy infrastructure, while CPI includes only retrofits with clear energy efficiency gains. CPI's estimate comes from bottom-up analysis of financing data from large-scale renewable projects—mostly from BloombergNEF. IEA's estimate uses a wide range of industry surveys (including from BloombergNEF) to estimate capacity additions and corresponding investment costs.
	CCUS	1.8 ¹	N/A	0.94 ²	Both estimates leverage bottom-up aggregation of individual projects and financial commitments. BloombergNEF counts financing all in the year when a final investment decision (FID) is made, while IEA averages spending from the year of the FID until project end. BloombergNEF shares project-level granularity sufficient to split carbon capture investments between different sectors (power and infrastructure).
	Networks and storage	291.6	8	N/A	CPI leverages bottom-up analysis of individual projects and financial commitments supporting new grids or retrofits with clear decarbonizing advantages (e.g., energy efficiency gains, integration of renewable power capacity). IEA includes all investments in transmission and distribution regardless of their decarbonizing impact, which is a broader classification than we use in this report. IEA also counts public electric vehicle charging within its "electricity grid" category.

2020 flows (\$billions)

Sector	Subsector	IEA WEI 2022	CPI	BloombergNEF 2021	Difference/source selection
Transport	BEVs Vehicle efficiency Aviation	83 ³	174	N/A	CPI's transport estimate counts total electric vehicle purchase cost, less government incentives, leveraging the IEA dataset of electric vehicles purchased from 2019 to 2020 as the basis for its estimate. The main reason that the IEA's estimate is lower than CPI's is because it uses the price premium of efficient vehicles sold compared to the average price of a comparable, less-fuel-efficient vehicle (that is, a price-based versus cost-based approach). IEA's estimate also includes internal combustion engine fuel efficiency investments while CPI's does not. Finally, CPI's estimate includes electric vehicle chargers in the transport sector whereas IEA groups them in the "Electricity Grids" category, driving a higher estimate for CPI in this sector than appears elsewhere.
	Hydrogen	0		1.3	BloombergNEF estimates fuel cell electric vehicle investment (bus, passenger, and commercial) through total sales, which is a notably different methodology than it uses to calculate battery electric vehicle investment. Refueling infrastructure investment is calculated at the project level. Note that refueling stations do not necessarily supply clean hydrogen, and that vehicles do not necessarily use clean hydrogen.
Buildings	Energy efficiency Renewables Hydrogen	262.3	29	N/A	IEA uses a top-down approach to estimate the share of energy efficiency investments within larger building projects, using commercial databases to aggregate building projects. CPI's estimate is comparatively conservative, counting only verifiable, project-level investments in energy efficiency. As a result, CPI does not track public domestic or private financing.

2020 flows (\$billions)

Sector	Subsector	IEA WEI 2022	CPI	BloombergNEF 2021	Difference/source selection
Industry	Total	38	7	N/A	IEA uses a top-down approach to calculate the incremental costs of the average level of technology efficiency relative to the most likely alternative investment option in a recent base year. It also includes published data on investments in industrial energy management systems. CPI's estimate is more conservative because it focuses its estimates on verifiable, project-level investments in energy efficiency, resulting in limited tracking of private and public domestic financing.
	CCUS	1.8 ¹	N/A	2.06 ²	Both reports leverage bottom-up analysis of individual projects and financial commitments. BloombergNEF counts financing in the year a FID is made, while IEA averages spending from the year of the FID until a project's end. BloombergNEF shares project-level granularity sufficient to split carbon capture investments between different sectors (power and infrastructure).

Sources: IEA World Energy Investment (2022); CPI Global Landscape of Climate Finance (2021); BloombergNEF; BCG analysis.

¹ Figure from 2021.

² Estimated share of total BloombergNEF CCUS investment flows in given sector (power & industry).

³ \$83 billion is IEA's real 2020 figure for transport. Report uses average of 2019 and 2021 to approximate investment absent pandemic-related disruption.

9.5 Appendix - Literature review for annual climate mitigation capital needs

		IEA NZE (\$billions)		GFMA (\$billions)		
Sector	Subsector	Original: 2026–2030 annual average	Adjusted: 2020–2025 annual average	Original: 2020–2050 cumulative	Adjusted: 2020–2050 annual average ¹	Difference/source selection
Power	Electricity generation	1,421	1,204	39,000	1300	GFMA’s estimate is based on average annual investment need data from the International Renewable Energy Agency (IRENA, “Global Renewables Outlook,” 2019) scaled to reflect 30-year needs. The IEA model permits a more specific time-based view. It also includes nuclear energy generation, whereas GFMA’s does not.
	Networks and storage	857	726	17,000	567	IEA and GFMA should in principle have similar categorical definitions. The IEA estimate may cover slightly more (for example, electric vehicle charging networks, which GFMA counts within transport). The IEA model also supports a more specific time-based view.
Transport	All	489	372	46,000 ²	1,500	The GFMA future-need estimate counts total estimated electric vehicle purchase costs, while the IEA counts the estimated price premium of efficient vehicles compared to the price of a comparable, less fuel-efficient vehicle. This difference in accounting treatment is the main reason for the discrepancy between the two estimates, although other differences in scenario assumptions (e.g., higher estimates for fuel cell electric vehicle adoption in GFMA than in IEA) may contribute slightly.

		IEA NZE (\$billions)		GFMA (\$billions)		
Sector	Subsector	Original: 2026– 2030 annual average	Adjusted: 2020– 2025 annual average	Original: 2020– 2050 cumula- tive	Adjusted: 2020– 2050 annual average ¹	Difference/source selection
Buildings	All	724	658	10,700	357	The GFMA estimate is based on scaling up investment needs outlined in IEA's more conservative Sustainable Development Scenario (SDS) to estimate a pathway to net zero by 2050. IEA Net Zero by 2050 is a more recent, primary view estimate. Methodologies to calculate energy efficiency investments also changed between the two.
Industry	Energy efficiency and renewables	144	37.6	2,500	83	GFMA methodologies vary by industry (iron and steel, chemicals, cement). Investment need estimates in the iron and steel and cement industries are based on scaling up investment needs outlined in more conservative IEA climate scenarios (SDS, Cement Technology Roadmap) to estimate a pathway to net zero by 2050. IEA Net Zero by 2050 offers a more primary, updated view and calculates industry investment need by decarbonization lever (efficiency; electrification; renewables; hydrogen; and carbon capture, utilization, and storage).
	Hydrogen	12.8	3.3	800	27	Estimates in hydrogen and carbon capture, utilization, and storage are more impacted than others by IEA's more precise time-based view.
	CCUS	40.3	10.5	2,700	90	

Sources: IEA Net Zero by 2050; GFMA; BCG analysis.

¹ Linear annual average of need from 2020-2050 (i.e. divided raw number by 30).

² An additional \$58 trillion is required for private battery electric vehicles and slow charging investment (roughly \$2 trillion annually).

9.6 Appendix - Literature review for capital needs and flows in agriculture and nature-based solutions

2020 flows (\$billions)

Subsector	UNEP	CPI	GFI	Difference/source selection
Nature-based solutions projects and private investment	67	N/A	N/A	CPI does not count these categories discretely. Some are grouped by financing source, rather than by subsector, to capture a greater share of private investment in nature-based solutions overall.
Regenerative agriculture and water/waste management	66	41	N/A	UNEP employed a top-down approach, using expert-reviewed scaling factors to estimate the share of nature-based solution investment in relevant categories. UNEP counts both public and private investment. Most of the private investment it tracks is counted by source (such as impact investment) rather than by subsector, and is categorized separately. UNEP uses CPI Landscape (2019) as a source and triangulation point for some sectors of public financing in its estimates. CPI's estimate is comparatively conservative because it focuses its estimates on bottom-up, verifiable, project-level investments. Data meeting these standards is scarce in these sectors. As a result, CPI is not able to track any private or public domestic financing in land use.
Alternative proteins	N/A	N/A	3.1	Fairly consensus, limited other sources available

2020-2050 investment needs (\$billions)

Subsector	GFMA	UNEP	Difference/source selection
Sustainable farming	1,900	N/A	Limited alternative sources available. There are calls for a consensus industry roadmap to net zero for agriculture, but no such roadmap exists as yet.
Nature-based solutions projects	N/A	8,130	UNEP's methodology and resulting estimates go significantly beyond estimating the capital expenses required in nature-based solutions to get to net zero. The model considers investment required to reach biodiversity targets as well as decarbonization targets, and includes operating expenses and downstream consumer costs associated with scenario policy actions. Broadly speaking, the agriculture and nature-based solutions sector includes more dual-benefit finance, with applications for mitigation and A&R.

Sources: UNEP, "State of Finance for Nature" (2021); CPI, "Global Landscape of Climate Finance" (2021); Good Food Institute; GFMA; BCG analysis.

9.7 Appendix - Literature review for flows and investment needs in adaptation and resilience

Adaptation spending

Geographies	Source	Year published	Estimate (\$billions)	Timing	Methodology
Global	CPI	2020	46	2019/2020	Very few sources track adaptation spending globally. CPI's estimate likely underestimates such spending, as it does not differentiate between public and private investments in A&R.

Adaptation need

Geographies	Source	Year published	Estimate (\$billions)	Timing	Methodology type	Methodology
Developing countries	UNEP	2016	140–300	2020–2030	Literature review and extrapolation	In conducting a synthesis of available bottom-up studies and comparing estimates from different sources such as the OECD and UNFCCC, UNEP predicted that actual need was higher than currently available estimates suggested. UNEP calculated the actual range as probably being several times greater than those predominantly cited at the time. We believe that these ranges are likely still understated.
			280–500	2030–2050		
			Baarsch et al., "Adaptation and Loss and Damage," <i>Climate Analytics</i>	2015		
			320–530	By 2050		An AD-RICE model, an integrated assessment model, was used to derive estimates. The model assessed GDP impacts due to temperature changes across 12 regions as a percentage decrease in production per region. The model then found the optimal balance of mitigation and adaptation investments to minimize GDP lost. ¹

Geographies	Source	Year published	Estimate (\$billions)	Timing	Methodology type	Methodology
Developing countries	Markandya & González-Eguino, "Integrated Assessment for Identifying Climate Finance Needs for Loss and Damage: A Critical Review," <i>Loss and Damage from Climate Change</i>	2019	30–410	By 2030	Integrated modeling	A WITCH model, also a type of integrated assessment model, was used to identify optimal adaptation expenditure, incorporating interactions between the economy, technology, and climate change. Optimal adaptation expenditure was defined as the point at which increasing/decreasing expenditure would not lead to a proportional change in damage avoided or benefits gained. The model assesses two scenarios: (1) low damage (2.5°C temperature change)/high discount rate, and (2) high damage (3.4°C temperature change)/low discount rate across 12 world regions. ⁱⁱ
			70–1090	By 2050		
Global	Global Commission on Adaptation	2019	1800 ⁱ	By 2030	N/A	GCA calculated total needs by 2030 as \$1.8 trillion, based on five adaptation areas (early warning systems, resilient infrastructure, dry land crop production, mangrove protection, and water resource management). ⁱⁱⁱ GCA states that these areas are mainly illustrative and are based on available data on financial returns; no further information is published on the origin of the estimate, and the data used to derive the estimates is not well documented.

Geographies	Source	Year published	Estimate (\$billions)	Timing	Methodology type	Methodology
Global	IMF	2022	~590	2020-2025	Infrastructure reinforcement cost analysis	IMF's estimate is calculated using the costs of upgrading and retrofitting exposed assets globally, as well as coastal protection. Exposed assets were identified by aligning locations of natural hazards with global road and railway assets. ^{iv} These costs were estimated to amount to about 0.7% of global GDP, which in 2020 was about \$590 billion.
	World Bank	2010	71-89	2020-2030	Scenario modeling of adaptation cost	World Bank followed a sectoral aggregation approach by covering infrastructure, coastal zones, water supply, agriculture, health, and extreme weather events in its global assessment. For each sector, it created development baselines in the absence of climate change, and it used two climate scenarios (from extreme wet to extreme dry) to create a large set of model predictions. World Bank used baselines to predict what would happen under these climate scenarios, with an emphasis on economic, human, and environmental impact. It analyzed A&R actions designed to offset the predicted impacts in each sector, extrapolating and estimating the associated costs. ^v
			95-106	2040-2050		
Sub-Saharan Africa	Narain, Margulis & Essam, "Estimating Costs of Adaptation to Climate Change," <i>Climate Policy</i>	2011	30-50 ^{vi}	2020-2030	N/A	N/A

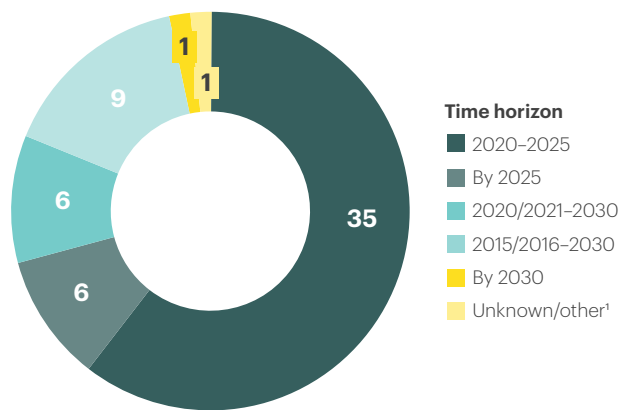
Geographies	Source	Year published	Estimate (\$billions)	Timing	Methodology type	Methodology
Sub-Saharan Africa	African Development Bank (AfDB)	2011	20–30 ^{vii}	By 2030	Literature review	Available estimates in literature were reviewed and compared against each other. The full range of estimates extended from \$2 billion to \$60 billion, but generally aligned on a range from \$20 billion to 30 billion, making this the go-forward estimate for the AfDB to use.
Private sector (global)	IMF	2022	~850	2020–2025	Infrastructure reinforcement cost analysis	IMF’s estimate is calculated using the costs of strengthening exposed existing and future private real assets against storm and flood risks globally. The methodology for identifying exposed assets was similar to that used for the public sector. IMF estimated that these costs equaled approximately 1% of global GDP, which in 2020 was around \$850 billion.

Source: BCG analysis.

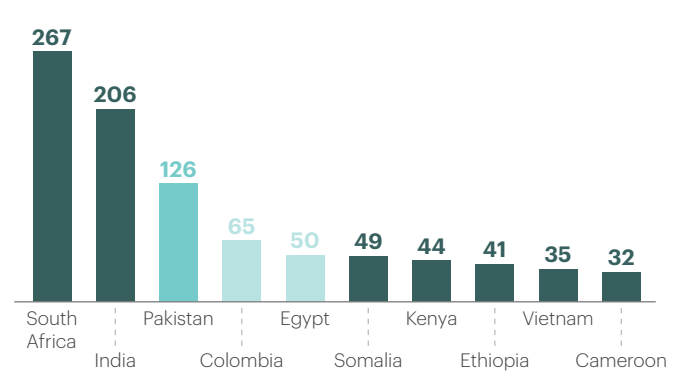
¹ Cumulative (not annual) need by 2030.

9.8 Appendix - Overview of NDC data and reported adaptation needs

Most of a total of 58 NDC quantified adaptation needs focus on needs over the next decade



Top 10 countries with the highest adaptation needs (\$ billions)



Source: Countries' NDCs.

Note: NDC = nationally determined contributions.

¹ Category includes entries where time horizons were not specified or were set to historical dates (e.g., by 2010).

9.9 Appendix - Reference infrastructure project costs in Asia and Africa demonstrate the underestimation of adaptation need

Asia		Africa	
	Example	Total cost	Non-exhaustive examples
Seawall	Jakarta, Indonesia: Great Garuda Seawall Project	\$40 billion	Seawall: Keta, Ghana: Keta Sea Defence Project (\$90 million)
Revetment, dams	Semarang, Indonesia: Central Java Flood Control	\$140 billion	Mangrove restoration: Senegal: Saloum Delta Project (\$8 million)
Storm surge barrier	Semarang, Indonesia	\$0.7 million to 160 million ¹	Freshwater systems: Lagos, Nigeria (\$1 billion)
Beach nourishment	Thailand coastlines	\$3 billion to 11.4 billion ²	Roadways: Tanzania: Himo-Arusha Road Rehab Project (\$48 million)
Range: \$0.7 million to \$40 billion		Range: \$8 million to \$1 billion	

Source: BCG analysis.

¹ Large range due to project complexity and technology; includes costs for both a movable barrier and a closed dam.

² From a study conducted to approximate costs of beach nourishment across all of Thailand's coastal zones.

9.10 Appendix - Methodology for climate mitigation capital needs and flows

Capital flows in 2020 for all sectors except agriculture and nature-based solutions came primarily from the IEA's World Energy Investment report (2022). We based our estimates of annual average needs for all sectors except agriculture and nature-based solutions on IEA's average annual need estimates for 2026 to 2030 and for 2030 individually, using the IEA's Net Zero Emission (NZE) roadmap. Assuming a linear relationship between those figures, we estimated investment needs for the first half of the decade. In some categories, additional subsector granularity was available for only one of the

time ranges (for example, for 2026 to 2030 but not for 2030). In those instances, we assumed that subsector shares would remain constant. We calculated investment needs in agriculture and nature-based solutions on the basis of cumulative figures for 2020 to 2050. Absent a more precise time-based approach, we assumed that an even distribution of spending across time to calculate annual average needs. Additional sector-specific approaches beyond the above are summarized below. Categories marked as N/A were not altered further.

Sector	Subsector	Flows added in 2020 (\$B)	Methodology notes	Needs added (\$B)	Methodology notes
Power	Carbon capture, utilization, and storage	0.9	Estimated the share of total 2020 investment in carbon capture (\$3 billion, BloombergNEF) directed toward the power sector based on known large projects.	N/A	N/A
Buildings	N/A	N/A	N/A	N/A	N/A
	Hydrogen	1.3	The share of the total \$1.5 billion hydrogen investment from BloombergNEF is the share exclusively applicable to transport (i.e., vehicles and refueling infrastructure).	N/A	N/A
Transport	Aviation	0.14	Estimated sustainable aviation fuel (SAF) production investment by multiplying 2019 production volume (IEA Bioenergy Technology Collaboration Programme) by average production cost per liter (IEA Renewables 2021). We used 2019 data due to a lack of available data for 2020 and due to likely pandemic-related distortions during that year.	4.5	Calculated SAF investment need by taking the estimated share of bioenergy investment need for 2020 to 2030, based on the share of biojet fuel in primary bioenergy production.

Sector	Subsector	Flows added in 2020 (\$B)	Methodology notes	Needs added (\$B)	Methodology notes
Industry	Division by heavy industry categories (i.e., iron and steel, chemicals, cement)	N/A	Scaled total investment to relative global market size shares for each of the three heaviest-emitting industries, approximating relative capital on hand for decarbonization investments.	N/A	Scaled the total IEA NZE industry investment need to the sectoral investment need ratios in GFMA's net-zero report.
	Carbon capture, utilization, and storage	2.1	Estimated the share of total 2020 investment in carbon capture (\$3 billion, BloombergNEF) directed toward the industry sector on the basis of data for known large projects.	N/A	N/A
Agriculture and nature-based solutions	'Agriculture, forestry, and fishing' and 'Bio-diversity protection'	N/A	Grouped relevant UNEP investment categories together to form broader sectors to match need categories. Investment without a specific end use was distributed proportionally across other sectors.	N/A	Grouped relevant UNEP and GFMA investment categories together to form these broader sectors. Categories were mostly discrete from one another, though some limited double counting is possible.

Source: BCG analysis.

Note: \$B = \$billions.

9.11 Appendix - Methodology for estimating public and private sector A&R need numbers

Public sector

Step	Approach
1. Creation of archetypes	<p>Our analysis focused on 182 developing countries, territories, and small island developing states (SIDS), of which 57 had quantified adaptation needs in their NDCs. We used these estimates to extrapolate values for other developing countries where NDCs were not submitted or need was not quantified within submitted NDCs. High-income/developed countries rarely quantify adaptation needs in NDCs; we therefore excluded from this analysis due to sampling bias.</p> <p>Developing countries were categorized into four regions:</p> <ul style="list-style-type: none"> • Americas and Caribbean • Middle East and Africa • Europe and Central Asia • Asia-Pacific
2. Calculation of investment need per capita and per square kilometer	<p>To calculate unit investment need for the region, we used the weighted average of investment needs from countries that submitted NDCs with a quantified need. We then used the calculated weighted average to fill data gaps where countries did not report a quantified need.</p>
3. Calculation of total investment need per region	<p>We multiplied unit investment need for each country (if it was one of the countries with a quantified need) or region (if it was one of the countries without a quantified need) by population and land area to get an extrapolated adaptation need minimum and maximum. We then summed these numbers across the countries in each region.</p>
4. Global adaptation need	<p>We summed the ranges from each region to get the global range.</p>

Private sector

Step	Approach
1. Identification of sectors for analysis	We used the GICS classification system for this analysis, categorizing each company into one of 11 GICS sectors to ensure that the entire private sector was accounted for.
2. Identification of companies to categorize into each GICS sector	To confirm that we had included major market players in the analysis, we cross-checked a list of the largest market-cap companies in each of the 11 GICS sectors and verified that those with available CDP data and quantified adaptation costs were incorporated. We then identified global mid-cap companies with available CDP data and quantified adaptation costs, and added them to our data set to ensure a global and complete view of the private sector.
3. Calculation of adaptation costs for each company	<p>We tagged cost of response to physical risk as an A&R cost. We recorded companies that we identified as having disclosed such costs in their CDP questionnaire, and we calculated their revenue multiplier (sector size divided by 2021 fiscal revenue). We annualized disclosed costs according to the time horizon that the company had provided (short, medium, and long term), as each company had different definitions of these horizons.</p> <p>We excluded outliers (companies with extremely high or low predicted costs compared to average) from further analysis.</p>
4. Calculation of total adaptation need per sector	<p>Using the adaptation needs of each company included in the analysis, we implemented two approaches to extrapolate a range for each sector:</p> <p>(1) Multiply the sector average of adaptation cost for each company by the multiplier for each company.</p> <p>(2) Then, for each company in a sector, multiply the weighted average of adaptation cost per dollar revenue by sector size.</p>
5. Calculation of total private sector range	We summed the minimums and maximums of all the sectors' ranges to derive the total private-sector range.

Source: BCG analysis.

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