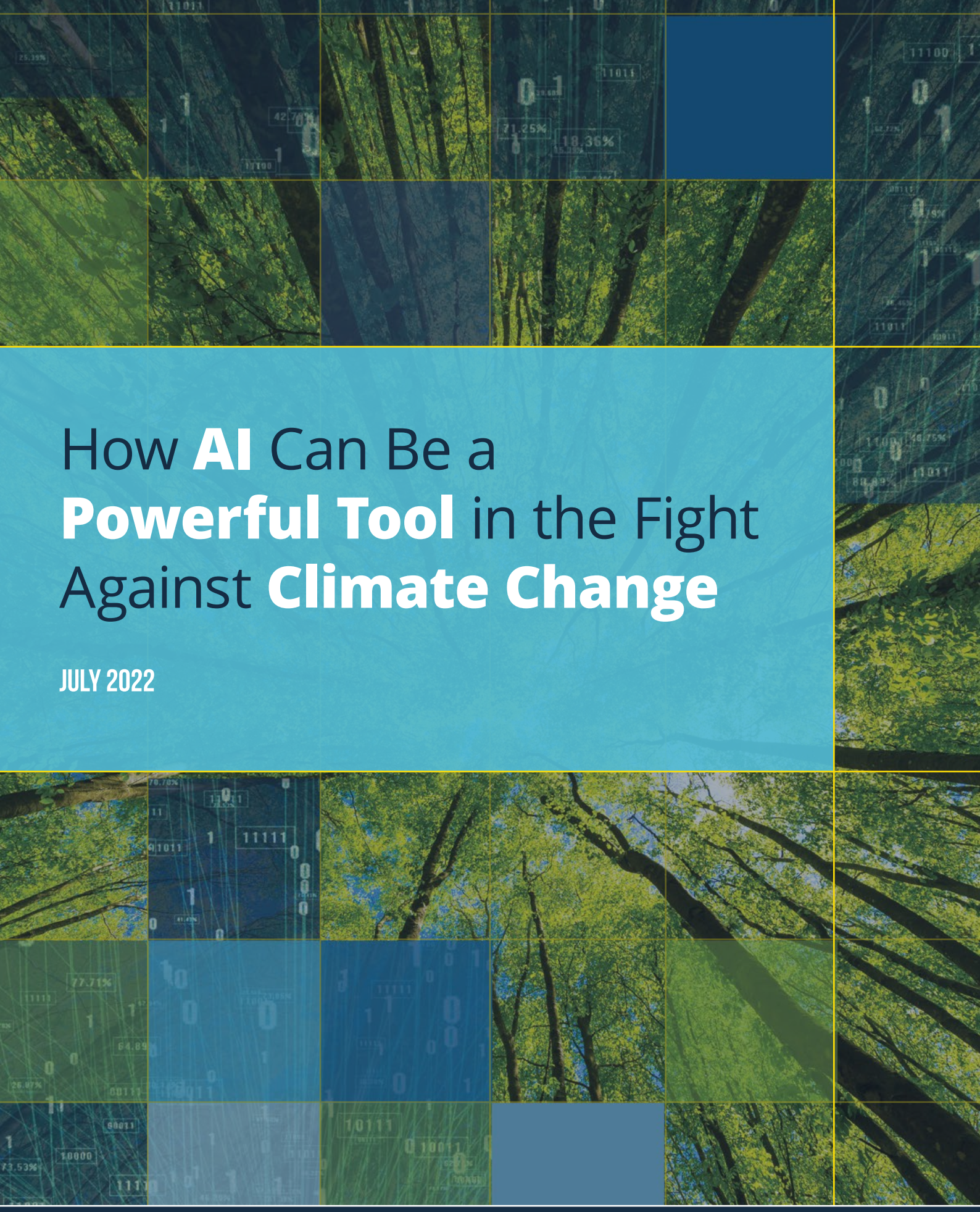

How **AI** Can Be a **Powerful Tool** in the Fight Against **Climate Change**

JULY 2022

BCG | BCG GAMMA

AI for the Planet

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AI FOR THE PLANET ALLIANCE

AN INTRODUCTION

AI for the Planet is an alliance created by Startup Inside, with Boston Consulting Group (BCG) and BCG GAMMA as knowledge partners, in collaboration with four other organizations: the AI for Good Foundation; the United Nations Development Programme (UNDP); the United Nations Educational, Scientific and Cultural Organization (UNESCO); and the UN Office of Information and Communications Technology (OICT).

This unique, multidisciplinary, and diverse coalition has several core objectives:

- **Promote innovation** in applying advanced analytics and artificial intelligence (AI) to climate challenges, supported by global experts from academia, startups, and the public and private sectors.
- **Act as a global platform** for identifying and prioritizing the leading tools and uses for AI in addressing the climate crisis.
- **Identify and champion the most promising solutions** to address climate change mitigation, as well as adaptation and resilience, especially in the Global South, giving the solutions visibility and recognition.
- **Ensure impact at scale** through concrete and measurable actions such as building access to funding and to practitioners on the ground.
- **Facilitate the development of networks** among project teams, investors, and experts in the field—including startups, corporations, and the public sector.

This alliance is looking for teams and ideas that have the power to disrupt the climate crisis and make a meaningful difference by using advanced analytics and AI. We encourage all interested parties to participate in our first call for solutions, including proposals at any stage of maturity if ready for a first pilot (at minimum) and from any sector, whether private, public, academic, or nonprofit. We will tailor support for each solution chosen to its specific needs, ranging from customized commercial or technical support to investor relationships and network development.

Throughout this report, we use the term “AI” to refer to artificial intelligence and advanced analytics, defined as the use of sophisticated data analysis techniques such as machine learning algorithms and data engineering.

EXECUTIVE SUMMARY

The changing climate will have a major impact on environmental, social, political, and economic systems around the globe. We are already experiencing many of its environmental effects, from more intense droughts to more destructive storms.

Mitigation of climate change—along with adaptation and resilience—is therefore critical, including efforts to achieve net-zero emissions by 2050 and to prepare for the consequences of climate change and minimize the resulting harm.

AI AS AN ESSENTIAL TOOL

Advanced analytics and artificial intelligence (a pairing that we will refer to in this report simply as "AI") are tools uniquely positioned to help manage these complex issues. A BCG survey conducted in May 2022 found that 87% of global public- and private-sector leaders who are responsible for climate or AI topics believe that AI is a useful tool in the fight against climate change, and 43% of these leaders say that their organizations can envision using AI to help achieve their climate goals. (See the sidebar "Survey Methodology.")

Three areas of application are particularly relevant:

- **Mitigation.** AI can be employed to help mitigate the climate crisis through the measurement of emissions at both the macro and micro levels, through the reduction of emissions and greenhouse gas (GHG) effects, and through the removal of existing emissions from the atmosphere. In BCG's experience, for example, AI can be used to help reduce GHG emissions by an amount equal to 5% to 10% of an organization's carbon footprint, or a total 2.6 to 5.3 gigatons of carbon dioxide equivalent (CO_2e) if scaled globally.
- **Adaptation and Resilience.** AI can be applied in boosting adaptation and resilience capacity, in part through improved hazard projections of regionalized long-term effects (such as sea-level rise) or extreme events (such as hurricanes or droughts). These efforts also include the management of vulnerability and exposure, by such means as developing infrastructure that minimizes the impact of climate hazards.
- **Fundamentals.** AI can also be used to bolster climate research and modeling; climate finance and analytics; and education, nudging, and behavior change (such as in the form of recommendations for environmentally friendly purchases).

Within each of these uses, AI can be employed as part of five key tasks: to gather and complete complex data sets on emissions, climate impact, and future projections; to strengthen planning and decision making; to optimize processes; to support collaborative ecosystems; and to encourage climate-positive behaviors. In these ways, it can help stakeholders—from businesses and governments to NGOs and investors—pursue a more informed and data-driven course, while offering them opportunities to create meaningful change in this critical moment.

NEED FOR MEANINGFUL SUPPORT

User friendliness is critical if AI solutions are to gain widespread adoption, regardless of whether they are developed for corporations, governments, or the general public. They need to be readily accessible, offer tangible benefits to the user, and provide clear information to guide user action.

In some areas—such as emissions measurement and the monitoring of natural carbon sinks—AI solutions are well-established and ready for broad application, but most existing AI-related climate change solutions are scattered, difficult to access, and lack the resources to scale. Even among public- and private-sector leaders engaged in climate or AI topics, 78% say that a lack of AI expertise is a clear obstacle to their organization's efforts to use AI to combat climate change, 77% blame a lack of AI solutions, and 67% point to a lack of confidence in AI-related data and analysis.

AI solutions need much more meaningful support than they currently receive, including access to capital investments, informed decision makers, and trained practitioners. In addition, today's AI research—predominantly directed by research institutes and corporations in the Global North—risks neglecting the needs of the Global South, where climate change is likely to disproportionately affect many countries.

Survey Methodology

The original quantitative findings presented in this report are based on a BCG Climate AI survey conducted in May 2022, in which BCG reached out to 1,005 global private- and public-sector leaders with decision-making authority on AI or climate-change initiatives at their organizations. Most respondents had authority over both topics.

Respondents represented private- or public-sector organizations with at least 1,000 employees or at least $100 million in global annual revenues. The survey sample covered 14 countries: Argentina, Australia, Brazil, Chile, China, France, Germany, India, Japan, New Zealand, South Africa, Spain, the UK, and the US.

Survey questions asked respondents for their views on the use of advanced analytics and AI to fight climate change, as well as on organizational obstacles to such efforts.

Accomplishing these ends will require the following:

- **Capacity Building.** Training and reskilling can ensure that civil servants, private sector leaders, and other stakeholders use and interpret AI solutions effectively in critical contexts. A willingness to overcome vendor lock-in is also essential to ensure that users can deploy promising solutions at scale.
- **Resources and Networks.** Financial support can bridge the gap between academic research and at-scale deployment, and connections to policymakers and corporate leaders can help boost awareness and adoption. In addition, sharing knowledge on best practices and promising applications can help ensure that solutions are ready for government and corporate deployment at scale. All such resources and networks are especially valuable for solutions that address the needs of the Global South.
- **Confidence and Trust.** Given AI's complexity and the associated risks of bias or unethical behavior, whether intentional or unintentional, AI users must earn the confidence of leaders. To do so, they should focus on such key areas as the quality and granularity of the underlying data and the interpretability of the analysis conducted.

Despite its promise, AI cannot be used to solve the climate crisis in isolation. Rather, it is one of many essential tools for addressing this global challenge. Individuals, communities, and organizations engaged in combating the climate crisis—regardless of their formal role in AI or climate topics—should therefore consider how other established and emerging technologies can help and should assist in removing obstacles to scale for those technologies as well.

In this report, we provide an overview of the potential uses of AI in combating climate change, and we examine the key roadblocks that are preventing AI solutions from achieving impact at scale.

THE CHALLENGE AHEAD

Climate change is already having a major impact on environmental, social, and economic systems as global temperatures rise, droughts worsen, and storms become more severe. It is creating major shifts in physical risks—from chronic risks such as sea-level rise to acute risks such as wildfires—and affecting every area of the world. And it is engendering new and complex challenges for policymakers, corporate executives, and other leaders everywhere.

If we are to meet the Paris Agreement's goal of limiting the increase in average global temperature to less than 2°C above pre-industrial levels, we must achieve rapid, deep, and in most cases immediate emissions reductions in all sectors, according to a report from the Intergovernmental Panel on Climate Change (IPCC) titled *Climate Change 2022: Mitigation of Climate Change.* Such reductions call for substantial mitigation efforts, including the attainment of global net-zero emissions by 2050.

The more—and the sooner—we reduce and remove GHG emissions, the fewer challenges we will face over the coming decades as we deal with the risks and impact of climate change. But minimizing the harm resulting from climate change also entails increasing our efforts at adaptation and resilience across multiple time frames, from immediate crisis response to long-term planning. Furthermore, effective climate action in support of mitigation, as well as of adaptation and resilience, requires complementary efforts in research, finance, and education.

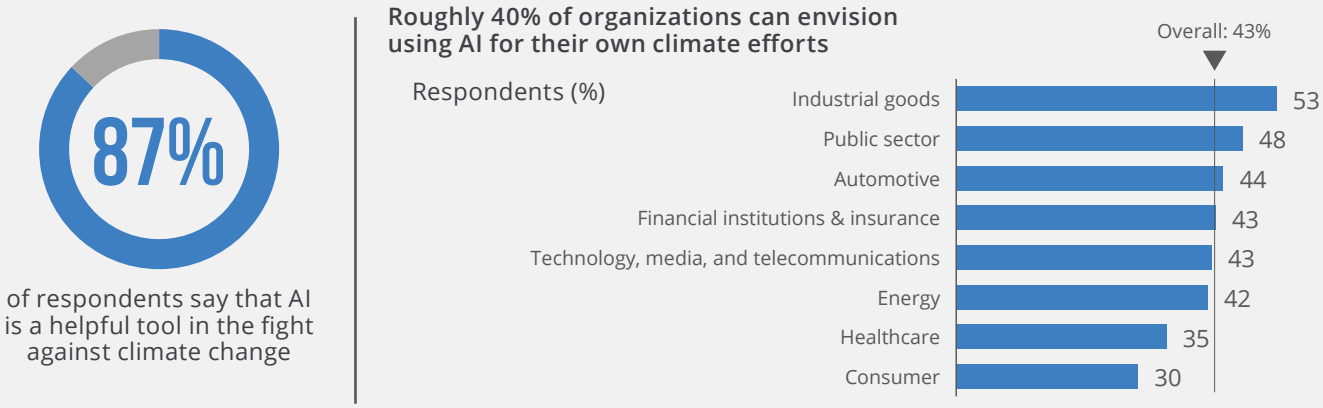
This report primarily focuses on the United Nations Sustainable Development Goal (SDG) 13 (Climate Action) and SDG 17 (Partnership for the Goals), as the AI for the Planet Alliance is expressly dedicated to promoting collaborative action to address the climate crisis. As with most other climate discussions, however, the themes touched on here allude to many other SDGs as well, including SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land). Wherever possible, AI for the Planet seeks to advance all SDGs through its activities.

The AI for the Planet Alliance is grateful for the leadership and momentum built in the climate-AI space by Climate Change AI (CCAI), Global Partnership on AI (GPAI), the Coalition for Digital Environmental Sustainability (CODES), and others. This report—like the alliance's work overall—draws on insights from these initiatives and attempts to advance these contributions further. In particular, the alliance is committed to the three strategic shifts outlined in the CODES action plan launched in June 2022: enable alignment, through networks and sharing of best practices; mitigate negative impacts, by promoting responsible AI; and accelerate innovation, by helping bring effective climate AI solutions to scale.

THE AI OPPORTUNITY

AI is in a unique position as a tool to help manage these complex issues. In a global survey conducted by BCG in May 2022, 87% of public- and private-sector climate and AI leaders said they view AI as a helpful tool in the fight against climate change. Furthermore, 43% said they can envision using AI for their organization's own climate change efforts—confirming the high level of interest among such leaders in the technology's potential to generate positive change. (See Exhibit 1.)

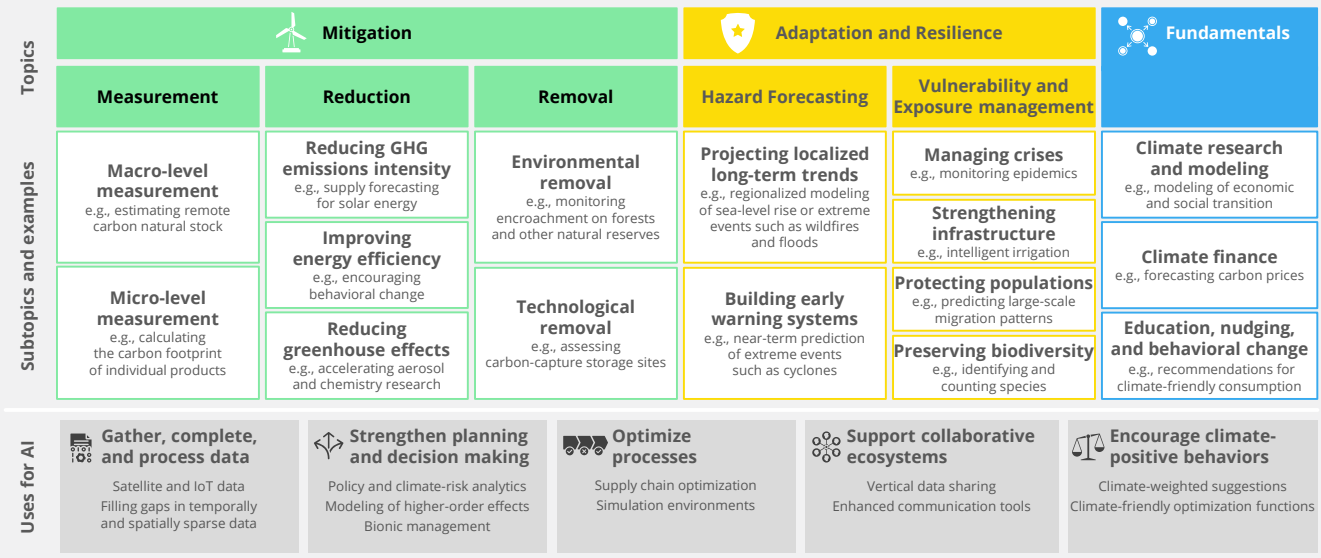
Exhibit 1 - Public- and Private-Sector Leaders Who Oversee Climate and AI Topics Support Using AI to Fight Climate Change



Source: BCG Climate AI survey, May 2022.
Note: All respondents have decision-making authority over climate or AI topics at their organizations. Respondents were asked if their organization has a "clear vision for how advanced analytics and AI can be used in climate change efforts." "Public sector" excludes academia.

Because of AI's unique capacity to gather, complete, and interpret large, complex data sets on emissions, climate impact, and more, the technology can be used to support all stakeholders in taking a more informed and data-driven approach to combating carbon emissions and building a greener society. It can also be employed to help reweight global climate efforts toward the most at-risk regions. (See the sidebar "Addressing the Needs of the Global South.") As such, the use of AI offers an opportunity to make meaningful change at this critical moment, whether through mitigation, through adaptation and resilience, or through the fundamentals underpinning all climate efforts. (See Exhibit 2.)

Exhibit 2 - Framework for Using AI in Combating Climate Change



Sources: BCG project experience; Climate Change AI, "Tackling Climate Change with Machine Learning"; Global Partnership on AI, "Climate Change and AI: Recommendations for Government Action."
Note: GHG = greenhouse gas; IoT = Internet of Things.

Addressing the Needs of the Global South

More than 3 billion people live in areas that are highly vulnerable to climate risk, such as in Small Island Developing States, South Asia, and much of Africa, according to the Intergovernmental Panel on Climate Change (IPCC). These regions are in danger of being hardest hit by extreme weather events, such as prolonged droughts or hurricanes, or by sea-level rise, according to the April 2022 S&P Global report *Weather Warning: Assessing Countries' Vulnerability to Economic Losses from Physical Climate Risks.* And yet these regions have historically contributed relatively few of the global emissions that lead to elevated climate risk.

Despite these realities, current climate change efforts tend to neglect the needs and priorities of vulnerable areas of the Global South. In part this reflects the lower concentration of wealth and resources there, such that the region lags the Global North in adaptation and resilience. Another factor is that research institutes and corporations in the Global North dominate AI research. Even among AI solutions that emphasize the UN Sustainable Development Goals, more than 80% are from the Global North, according to the International Research Centre on Artificial Intelligence.

The disproportionate focus on the Global North risks creating blind spots in AI research and development, and it prevents promising AI solutions from being applied in the contexts where they are most urgently needed. As Golestan (Sally) Radwan, former AI advisor to the Egyptian Ministry of Communications and Information Technology, explains, "Models designed and optimized for Global North countries do not necessarily apply well to specific conditions in other countries."

As a planet, we cannot afford to develop solutions that fail to address the needs of the Global South and do nothing to improve the lives of the billions of people living there. To the contrary, we must direct AI research and development toward solutions that address the priorities of public- and private-sector leaders and populations in the Global South.

In addition, we must ensure that these regions have access to relevant solutions, along with the capacity to train those who will use them, if we are to ensure adoption of those solutions. "The best approach is to build capacity in different regions," Radwan adds, "helping countries develop models that work in their local context and exchanging knowledge and learnings informed by local expertise." This may mean bridging gaps in data availability and making solutions designed for high-data-availability environments work in contexts with less data.

Finally, we need to make global resources available to ensure that AI projects developed in the Global South reach their full potential. Similarly, connecting projects developed in the Global North to practitioners and users in the Global South is a crucial step in ensuring that these solutions meet everyone's requirements.

MITIGATION

One of the most critical uses of AI is in the measurement, reduction, and removal of emissions and GHG effects. Increased efforts in these areas are crucial to ensuring that we meet the goals of the Paris Agreement. In BCG's experience, for example, AI can be used to help generate 5% to 10% reductions in GHG emissions, amounting to a total 2.6 to 5.3 gigatons of CO2e if applied globally.

Measurement

Understanding the size of the problem is critical to tackling it effectively. Measuring emissions, both in the overall environment and at the level of individual products and actions, allows us to take stock of our current situation and forecast future trends. It also allows us to prioritize the abatement efforts with the highest potential to reduce emissions, at both the macro level and the micro level:

- **Macro Level.** Measurements of overall environmental emissions are important inputs to models that simulate future climate scenarios. Solutions can use AI to support such models through more precise measurements, for example, or through the processing of remote-sensing data from satellites. They can also use it to monitor the impact of new and existing climate policies, thereby enabling teams to refine their climate models and mitigation strategies.
- **Micro Level.** Emissions measurements at the level of individual products or actions—including emissions created at any point in a supply chain—can help producers understand their products' carbon footprint; track their progress toward environmental, social, and governance (ESG) targets; or identify the leading ways to abate their scope 1, 2, and 3 emissions. They can also help consumers understand the emissions that their own purchases and actions generate, enabling them to live a carbon-conscious lifestyle and prioritize efforts to reduce their carbon footprint.

According to the Carbon Disclosure Project's *Global Supply Chain 2021* report, only 38% of companies are engaging with their suppliers on climate change—even though supply chains cause on average 11.4 times as much emissions as companies' direct operations. Applying AI to automate parts of this measurement process will speed it up and make it accessible to more companies and consumers.

Reduction

Rapid efforts to cut the level of ongoing emissions and the consequent GHG effects—from optimizing transportation networks to supporting research on new technologies— are essential to change the fate of the climate. We see three critical opportunities in this area:.

- **Reducing Emissions Intensity.** Although some people are undoubtedly willing to shift to less emissions-intensive modes of transportation, we cannot reasonably expect them to stop heating their homes in the winter. Instead, we need to figure out ways to reduce the emissions intensity of these activities, such as by switching electricity generation away from fossil fuels. AI solutions can be used to support this switch by helping to solve some of the major outstanding challenges in the energy transition. For example, they might be employed to improve supply forecasts for intermittent renewable energy sources, which DeepMind has demonstrated can increase the economic value of wind energy by 20%. Such forecasts can help reduce reliance on battery storage and other sources of power held on standby. AI solutions might also be used to create more efficient, real-time, electric-grid balancing. They might even be put to work in support of R&D directed toward producing more efficient solar-panel and battery materials. On another front, some industries are large-scale direct emitters. Industrials generate 18% of today's emissions, for example, and much of that output comes directly from steel, cement, and similar processes. Teams could use AI to design more efficient processes for these industries or to support research into alternative chemical compositions.
- **Reducing Emissions-Generating Activities.** Solutions can employ AI to reduce emissions by optimizing supply chains, such as through improved demand forecasting (to reduce waste resulting from overproduction) or optimized transportation of goods (such as by selecting transportation methods and routes that minimize emissions and costs). The core objective of AI tools in these endeavors is to increase the efficiency of all activities—doing more with less.

- **Reducing the Greenhouse Effect.** Activities directed toward reducing the GHG effect, referred to as "solar geoengineering" or "solar radiation management," aim to shield the Earth from rising temperatures by modulating the amount of heat that enters the atmosphere before it is trapped by the greenhouse effect. If policymakers choose to pursue this type of activity, one approach might be to increase the Earth's ability to reflect light by deploying aerosols in the atmosphere. AI could be applied in this instance to advance the science of aerosols. (For the sake of simplicity, this framework categorizes geoengineering under "mitigation," but it differs from other mitigation activities, such as reducing emissions, because it does not focus on the concentration of greenhouse gases in the atmosphere.)

Removal

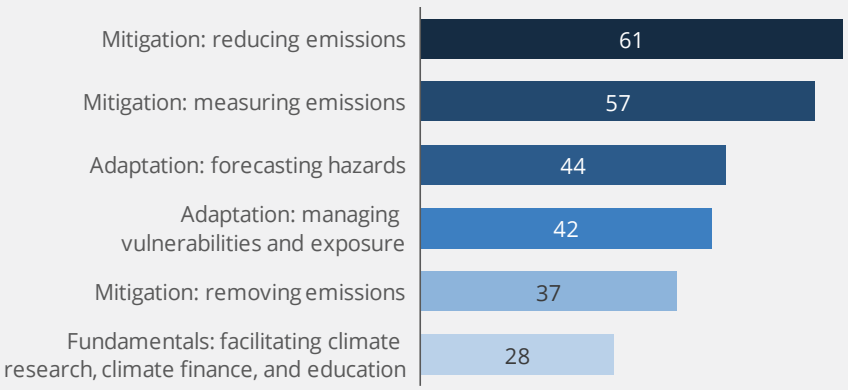
Removing emissions from the atmosphere is a crucial pillar of the effort to achieve a net-zero future, whether by monitoring natural carbon sinks, such as forests, or by supporting technological removal efforts, such as direct air capture (DAC). As the Intergovernmental Panel on Climate Change's *Sixth Assessment Report* on mitigation details, every scenario under which we succeed in keeping global warming below 1.5°C above pre-industrial levels relies to some extent on carbon removal. There are two basic carbon removal options:

- **Environmental Removal.** The Earth removes carbon from the atmosphere by sequestering it in natural sinks such as forests, algae, and wetlands. AI-based solutions can be used to support and more accurately quantify this natural process by analyzing satellite images to detect deforestation and estimate ecosystem carbon sequestration. Such estimates can help public- and private-sector leaders understand and guide the deployment of natural solutions, including land management and reforestation efforts.
- **Technological Removal.** Another way to remove carbon from the atmosphere is through scientific advances such DAC, which filters and captures CO2 from the air as it passes through a machine. The captured CO2 is either stored underground—in saline aquifers, for example—or prepared for industrial use. This technology currently faces questions regarding its energy efficiency, which may create barriers to scale, but further R&D may be able to resolve the issue. An alternative to DAC is bioenergy with carbon capture and storage (BECCS), which generates energy out of biomass, including wood and agricultural waste, and captures the resulting CO2 for storage underground or for industrial use. Solutions can apply AI to assess capture and storage locations, monitor leakage, and optimize the industrial processes and materials used for carbon capture.

Global private- and public-sector leaders in our survey see potential in all of these areas of climate-related AI. Reducing and measuring emissions seem to have the greatest potential business value; about 60% of leaders see value in such uses of AI. (See Exhibit 3.)

Exhibit 3 - Public- and Private-Sector Leaders See the Greatest Business Value in Reducing and Measuring Emissions

In which areas of climate-related advanced analytics and AI do you see the greatest business value for your organization? (%)



Source: BCG Climate AI survey, May 2022.
Note: All respondents have decision-making authority over climate or AI topics at their organizations. Respondents were permitted to give more than one answer.

ADAPTATION AND RESILIENCE

Adapting to climate change is a critical undertaking for policymakers and the public, as it boosts resilience to the effects of long-term climate trends and extreme events. Solutions can apply AI to promote adaptation and resilience, particularly in hazard forecasting and in vulnerability and risk-exposure management.

Hazard Forecasting

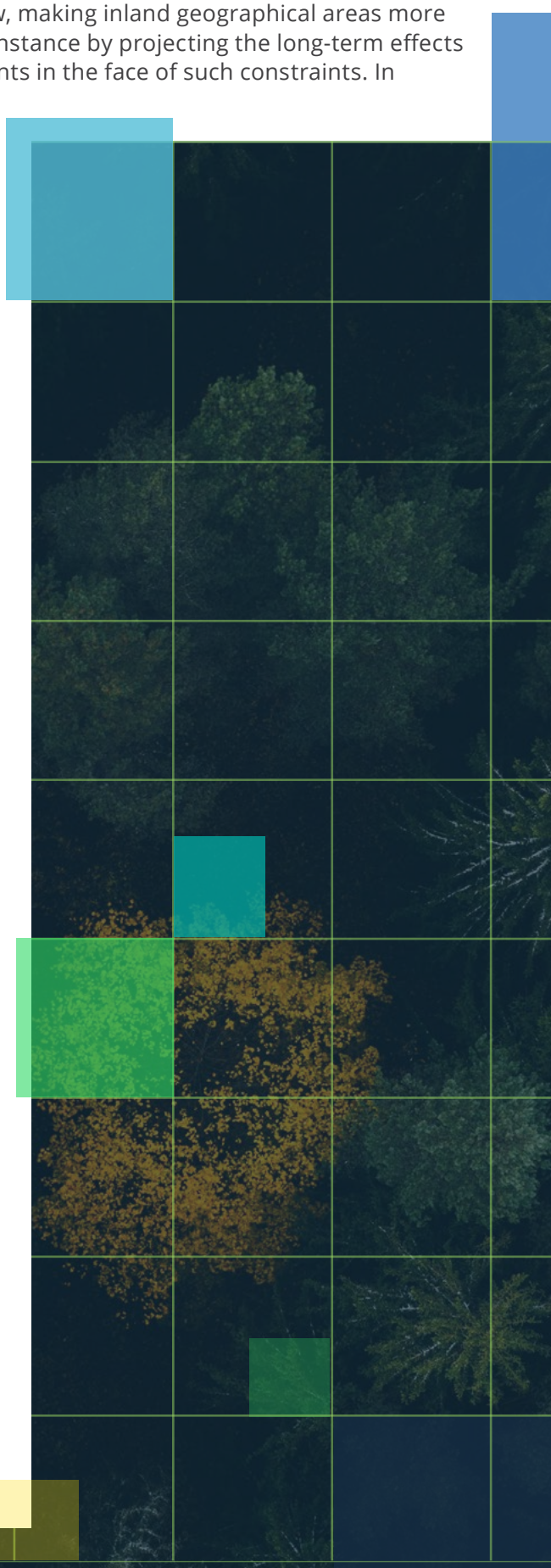
AI is well suited to help in forecasting and projecting climate-related hazards, whether in the form of improved long-term projections of regionalized events, such as sea-level rise, or in the form of early warning systems for extreme weather events:

- **Projecting Regionalized Long-Term Trends.** Accurate projections of regionalized events can support efforts by decision makers to adapt to climate change. Being able to plan ahead and know which areas are most likely to be affected can help planners devise long-term strategies to secure local livelihoods and support sustained economic growth. Solutions can use AI in this vein to create large-scale regional-level climate models, predict crop and fishing yields, or provide city-level climate indicators to local governments. Alternatively, decision makers can employ AI to guide investments into protective infrastructure or economic restructuring. Long-term projections can include assessments of the risk of extreme events, such as wildfires, cyclones, or floods—a critical input in infrastructure planning.
- **Building Early Warning Systems.** On a shorter time frame, forecasting individual extreme weather events can limit their devastating effects and thereby save lives. The use of AI in such forecasts has revolutionized forecasting accuracy and permitted real-time data processing and analysis—such as in reviewing satellite images to spot forest wildfires and even to predict their likelihood. For example, in 2019, UNESCO began partnering with local experts in West Africa to build early warning systems that will help eleven countries manage flooding risk in the Niger and Volta River Basins.

Vulnerability and Risk-Exposure Management

Another key component of adaptation and resilience efforts is the strategic management of vulnerability and risk exposure, such as by planning the development of infrastructure in threatened areas so as to minimize the impact of climate hazards. For example, sea-level rise may threaten the coastal infrastructure of an archipelago. Although access to waterways might traditionally have been an economic trade advantage, investing in coastal infrastructure might be riskier now, making inland geographical areas more attractive for development. Solutions could use AI to help in this instance by projecting the long-term effects of climate change and simulating optimal infrastructure investments in the face of such constraints. In addition, AI can be employed in each of the following ways:

- **Managing Crises.** Disaster response is a critical aspect of vulnerability management, enabling public- and private-sector leaders to make more informed decisions under circumstances where they might previously have had to operate with sparse or limited information. In such instances, AI can be used to efficiently combine natural-language processing with operations that involve gathering and combining information from multiple sources. Advanced analytics can also be deployed in conjunction with other emerging technologies, such as drones, as seen in a project implemented by UNESCO and other partners to reduce the impact of floods in The Gambia.
- **Strengthening Infrastructure.** The increasing frequency and intensity of natural disasters caused by climate change is putting existing infrastructure to the test. The resilience of health systems, transportation infrastructure, education, and information media is essential if we are to avoid the direst consequences of natural disasters. Solutions can use AI to strengthen infrastructure through predictive maintenance of structures such as roads, bridges, and electricity distribution systems; through monitoring of water quality and air pollution; and even through support for design projects and risk identification.
- **Protecting Populations.** On average, 20 million people every year must leave their homes and relocate to other areas within their countries as a result of extreme weather disasters, according to the UNHCR. Research by Oxfam shows that poor countries are especially at risk: 80% of those displaced by weather events live in Asia, home to more than a third of the world's poorest people. Solutions can include use of AI to boost the resilience of communities through the prediction of large-scale migration patterns, the identification and monitoring of food insecurity risk, and the handling of permit allocation schemes for social welfare.
- **Preserving Biodiversity.** Humans are part of a vast ecosystem. When a natural disaster strikes, that ecosystem's biodiversity is put at risk of imbalance and collapse. AI can be enlisted to control intelligent irrigation systems that minimize the adverse impact of weather events on agricultural production, to identify crop diseases early, or to promote the transfer of knowledge between biomes, for example.



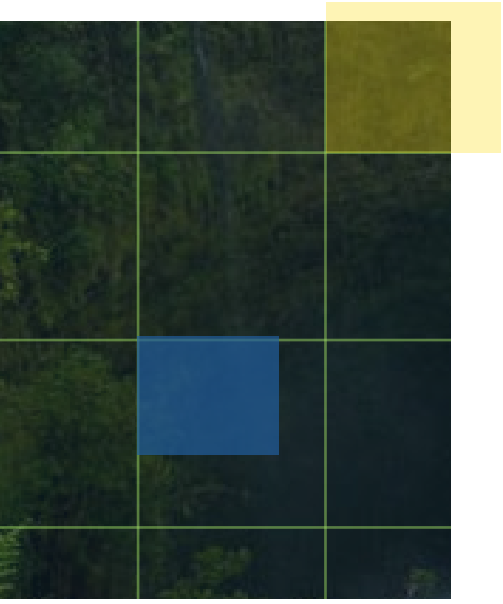
FUNDAMENTALS

AI can be used to support research and education efforts on climate change, helping stakeholders understand the risks and implications and share what they learn. All such efforts reinforce and magnify progress toward mitigation and toward adaptation and resilience.

Climate Research and Modeling

Modern climate research and modeling lie at the heart of all policy discussions about mitigation and about adaptation and resilience. They underpin our scientific understanding of the future consequences of climate change at the local, regional, and global levels. Without them, we would not be able to assess quantitatively either the scale of change in GHG emissions or the scale of the adaptation efforts needed.

AI can be used to enhance some aspects of climate-modeling research, in part because climate models rely on spatially and temporally sparse data sets—a major limitation. For example, AI can be employed to fill gaps in the data, improving the models' accuracy and increasing user confidence in their results. AI can also be used to strengthen connections in socioeconomic and climate models, such as by creating feedback loops within and between integrated assessment models and climate models for more accurate simulation and better design of mitigation strategies. Even more practically, AI can be employed to emulate computationally expensive submodels for higher-fidelity climate change simulations, thus accelerating the pace of climate research.



Climate Finance

The broad field of climate finance includes investing in and financing climate-change initiatives—funding that is essential if these initiatives are to achieve the scale necessary to have a meaningful impact. Another angle of climate finance involves carbon markets, which create monetary incentives for climate-friendly behavior by allowing firms to trade carbon offsets—instruments that represent the reduction, avoidance, or sequestration of CO2e in metric ton units.

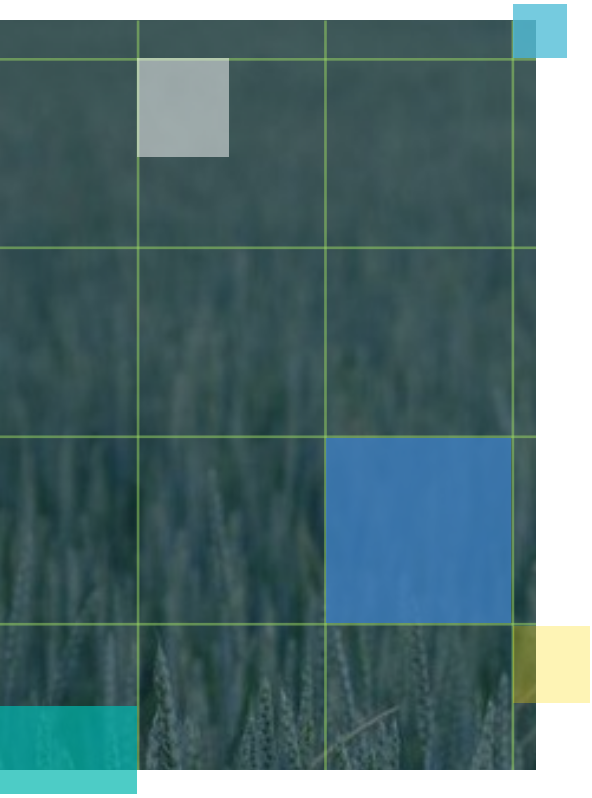
Climate finance can benefit from AI's ability to improve carbon price forecasts, the dynamic pricing of electricity, and other key financial and economic data used in investment and financing decisions. Further, AI can be employed to improve estimates of the cost of climate inaction, enabling policymakers, central bankers, and private-sector leaders to better quantify the risks associated with moving too slowly.

Education, Nudging, and Behavior Change

Educating the public about the practical realities and threats of global warming can foster change from the ground up, reshaping individuals' behavior. AI can be used in this vein to help power personalized tools for estimating carbon footprints and for making individual recommendations for online learning courses or climate-friendly purchases. AI is already ubiquitous in the domain of generating algorithmic recommendations for videos to watch or products to buy; similar algorithms can be applied to understanding behaviors and nudging citizens toward climate-friendly activities.

FIVE KEY AI APPLICATIONS

Across all of these critical uses, AI can be directed toward five leading applications in which its technical capabilities intersect with the needs of public- and private-sector decision makers. In each case, AI is not the solution itself but a tool to help leaders and citizens make informed judgments about how to tackle climate challenges. (See the sidebar "AI for Short-Lived Climate Pollutants" for an illustration of using AI for a specific climate challenge)



1 Gather, Complete, and Process Data

AI-powered data approaches, such as the Internet of Things (physical objects with embedded technology that exchange data with devices or systems over the internet), give rise to novel data on consumer behaviors and preferences, industrial processes, and supply chains. This data can be used to train algorithms that uncover behavioral patterns and preferences at scale. Moreover, AI allows the use of new types and combinations of data for analysis, including images, text, and sounds.

For example, the UNESCO World Water Quality Portal for Lake Chad applies machine learning algorithms to satellite imagery to detect and analyze water quality, generating new data that researchers can use to analyze the effects of climate change on water resources, among other benefits.

AI can also be used to impute missing data points in climate-related data sets—a critical capability, given that all climate-related decisions rely on such data sets. It is much harder to run analyses that support good decision making when key data sets are incomplete or fragmented.

2 Strengthen Planning and Decision Making

AI can be used to analyze and compare complex, multilayered problems—for example, when civil servants need to design an optimal agricultural policy to deal with more frequent droughts or more severe flooding. The impact of such policies is manifold and interlinked, making this application an ideal use of AI.

For their part, business leaders often encounter challenges to informed decision making because methodologies, tools, data sources, and expertise are not available in a timely manner. As a result, they may not be able to calculate the financial, operational, and socioeconomic impact of a particular action or assess the true costs of inaction—essential steps in prioritizing potential responses and allocating resources efficiently. Businesses can employ AI in these instances to help quantify baselines, simulate operational choices, and gauge outcomes.

When used in this capacity, AI should be applied in conjunction with human decision making to form a bionic process in which human and AI-powered capabilities go hand-in-hand, maximizing the effectiveness of both. For example, an AI system might be used to produce a number of policy scenarios, after which human experts could select the best alternative based on their domain expertise.

Optimize Processes

AI has long been used to solve optimization problems in various domains across the private and public sectors. For example, it may be employed to optimize a supply chain by lowering the carbon footprint of individual products or to optimize the coordination of crisis response teams in the wake of extreme weather events.

Support Collaborative Ecosystems

Global cooperation is essential if we are to respond effectively to the challenges posed by climate change, and AI-powered language tools can be used to support global communications and coordination on climate goals. Further, vertical data sharing between entities can be made faster and more secure through AI. For example, sharing data on GHG emissions between firms can contribute to a comprehensive view of the carbon footprint of entire value chains—a critical monitoring step for companies and individuals. And using AI can help automate this reporting, impute missing values based on similar production processes, and analyze the information on a wide scale.

Encourage Climate-Positive Behaviors

As discussed earlier, AI can be applied in recommendation systems to automatically weight suggestions toward climate-friendly options. Similarly, AI-powered optimizations can encourage climate-friendly processes by imposing penalties for alternatives that have a larger carbon footprint.

AI for Short-Lived Climate Pollutants

Contributed by Zerin Osho of the International Solar Alliance

Recent research from the Proceedings of the National Academy of Sciences has demonstrated that decarbonization alone is unlikely to achieve international climate goals. In contrast, rapid reduction of short-lived climate pollutants (SLCPs) such as black carbon, methane, tropospheric ozone, and hydrofluorocarbon stands out as a promising strategy for reducing near-term global warming, according to the Intergovernmental Panel on Climate Change (IPCC). The IPCC notes that methane is responsible for 0.51°C of the 1.06°C of total observed global warming over the past decade and is almost inextricably linked to modern life, in forms ranging from electricity generation to waste, food, clothing, and transportation.

In response, AI-driven technology is already being used to help predict, identify, and reduce these emissions, notes the Climate Change AI blog. Some powerful examples have emerged:

- Projects such as Cownter, undertaken by Picterra, and Plainsight in the agricultural sector have helped teach computers to count sheep and cattle so that farmers can quantify emissions and potentially avoid wasting millions of dollars as a result of inaccurate livestock tallies. Similarly, adoption of chemPEGS sensors has helped optimize fertilizer use and reduce nitrous oxide emissions, according to an article published in *Nature Food*.
- In oil and gas operations, methane leaks are harmful economically and environmentally. Machine learning algorithms deployed by projects such as VideoGasNet enable systems to scan continuously for invisible, odorless emissions, and to quantify leaks, per an article in Energy. Researchers have used AI to model flaring from oil and gas wells and even to predict leaks before they occur.
- An international team of researchers that includes the Laboratoire des Sciences du Climat et de l'Environnement, the nonprofit organization Carbon Mapper, and the analytics firm Kayrros has applied machine learning to satellite imagery, using artificial neural networks to identify point-of-source emissions from space-based data.
- By streamlining energy-intensive processes, AI-based technology can be used to reduce their costs and lessen any associated greenhouse emissions.

As illustrated by each of these projects, AI and machine learning are likely to play a significant role in the battle against SLCP emissions.

CRITERIA FOR SUCCESSFUL SOLUTIONS

Although there are a multitude of critical AI applications in the climate change arena, any successful AI solution must be as user-friendly, valuable, and effective as a standard online weather forecast. It should be designed, scaled, and marketed in ways that make it readily available to practitioners. It should offer enough value that its benefits can be immediately perceived, potentially changing the way users think or behave. And it should provide clear information that the user can act on. (See Exhibit 4.)

Exhibit 4. Effective AI Solutions Must Meet Three Criteria

Source: BCG analysis.

> To be truly user-friendly, a new AI tool needs to solve a tangible, immediate problem for the user. Even if tools have clear theoretical value, the most effective will help stakeholders take action on a problem that they directly control
>
> Vivienne Ming, co-founder and executive chair at Socos Labs

Some AI uses, such as for measuring emissions and monitoring natural carbon sinks, are already firmly established and ready for large-scale application.

Measuring Emissions

AI-based measurement of carbon emissions—both at the macro level and at the level of individual organizations—has made clear progress. Examples include the following:

- **Climate TRACE** (Tracking Real-Time Atmospheric Carbon Emissions), a coalition backed by Al Gore, uses satellite imagery and AI to measure global GHG emissions.
- **BCG's CO2 AI Platform** helps corporations measure, simulate, track, and optimize their emissions at scale.

Monitoring Natural Carbon Sinks

Various organizations are monitoring carbon sinks by using AI to analyze satellite imagery—often in combination with other data sets—and estimate GHG emissions, sequestration, and removal. Examples include the following:

- **Pachama** employs satellite imagery and AI to measure and monitor the carbon stored in forests over time, identifying high-quality carbon credits for its marketplace.
- **Blue Sky Analytics**, a member of Climate TRACE, estimates GHG emissions from fires, among other solutions that it offers.

OVERCOMING ROADBLOCKS

Unfortunately, most existing AI-related climate solutions are scattered, difficult to access, and underresourced for scaling, as highlighted by leading academic experts in both the CCAI report *Tackling Climate Change with Machine Learning* and the GPAI report *Climate Change and AI.*

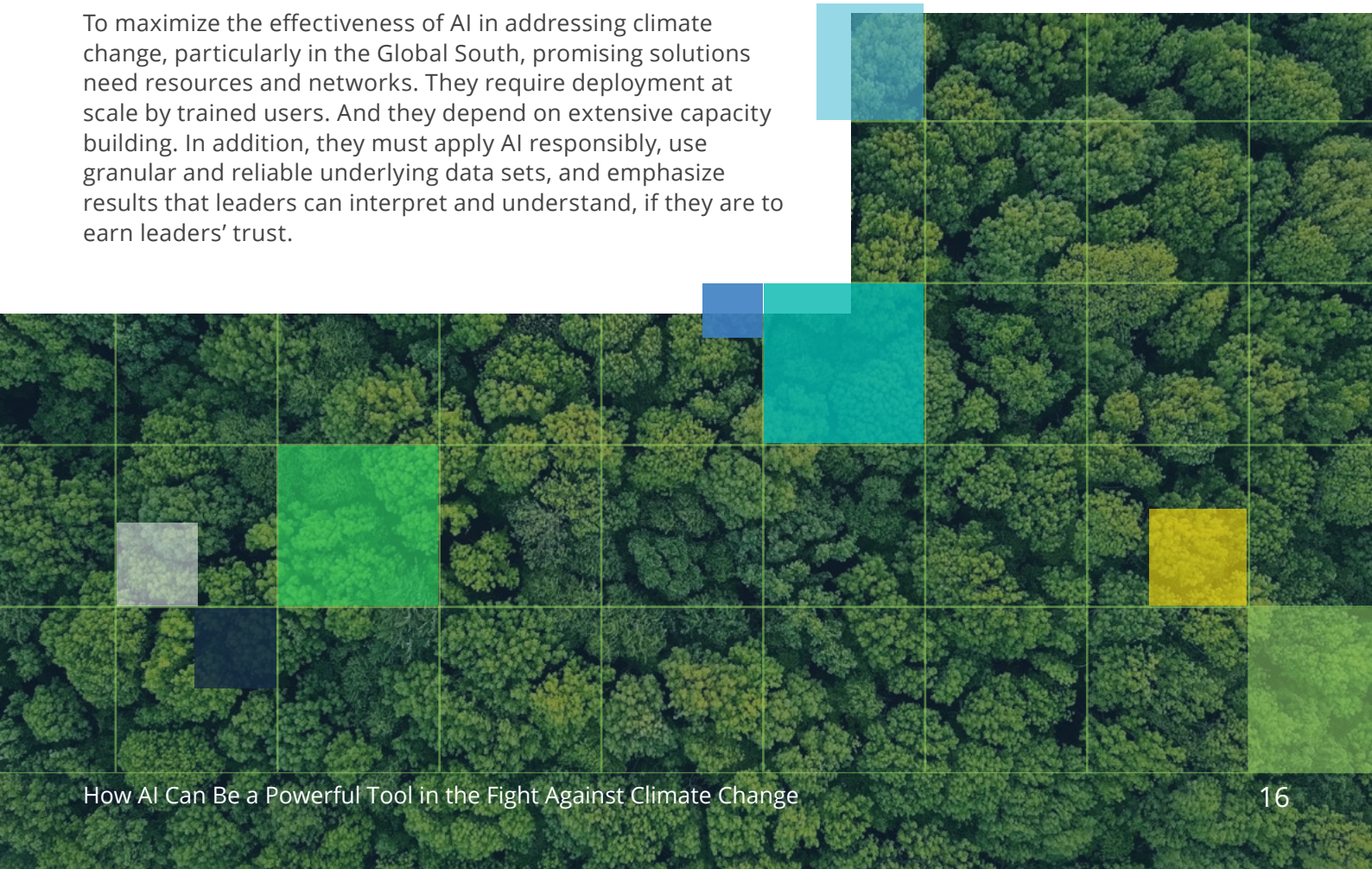
In addition, some organizations are not actively engaged in climate and AI topics, and even those that are face significant roadblocks. For example, when we asked global public- and private-sector leaders about the biggest challenges their organizations face in using AI to fight the climate crisis, 78% cited a lack of AI expertise inside or outside their organization, 77% pointed to a lack of available AI solutions, and 67% expressed a lack of confidence in AI data and analysis. (See Exhibit 5.)

Exhibit 5 - Leaders Cite Insufficient Expertise, Availability, and Confidence as Obstacles to Using AI in Their Climate Change Efforts

Respondents listed the following as obstacles (%)

Source: BCG Climate AI survey, May 2022.
Note: All respondents have decision-making authority over climate or AI topics at their organizations. Respondents were permitted to give more than one answer.

To maximize the effectiveness of AI in addressing climate change, particularly in the Global South, promising solutions need resources and networks. They require deployment at scale by trained users. And they depend on extensive capacity building. In addition, they must apply AI responsibly, use granular and reliable underlying data sets, and emphasize results that leaders can interpret and understand, if they are to earn leaders' trust.



Capacity Building

Training and reskilling can help stakeholders across the spectrum—including civil servants, private-sector leaders, and others—use and interpret AI solutions effectively and in areas of most critical need. Many government leaders in the Global South, in particular, have expressed an interest in capacity building. This effort encompasses a number of essential elements:

- **Technologically Minded Leaders.** Leaders must understand the benefits of AI and be willing to advocate adopting AI solutions.
- **Trained Users.** Practitioners need to understand when to employ AI solutions and how to independently implement, manage, and troubleshoot them; but the necessary training often requires a technical background, such as a tertiary education in computer science and data science—a prerequisite that prevents many organizations from deploying such solutions at scale.
- **Agile Approaches to Business Cases.** Public- and private-sector leaders who want to solve climate challenges—and investors who want to support promising AI solutions—expect to see clear business value from any solutions deployed. Demonstrating this value can be a challenge, but it is a critical step in scaling any emerging technology. As Mehdi Ghissassi, director and head of product at DeepMind, observes, "Leaders, investors, and entrepreneurs alike must be willing to test and adapt their product vision and business cases as new information comes to light, as an AI solution may prove more valuable when used in a different way than originally conceived, or for a different set of stakeholders."
- **Public-Private Partnerships.** Public-sector support for emerging technologies such as AI can greatly spur their development. For example, national and international research laboratories can provide access to data, supercomputers, and other resources, enabling entrepreneurs and climate leaders to accelerate their use of AI in developing innovative solutions and insights.
- **Prioritization of Interoperability.** Long-term contracts and established solutions tend to create a lock-in effect that makes it difficult for users to switch to new technologies, thus reducing demand for promising AI approaches. Companies and governments should therefore be willing to build flexibility into their negotiations with vendors—such as by emphasizing data-sharing protocols to ensure that new AI solutions can be integrated more easily into current technologies—even if it means compromising on price.

Resources and Networks

Promising AI solutions need resources and networks if they are to reach scale and to be designed for users worldwide, whatever their economic standing. Access to capital, networks and mentorship, decision makers, and best practices is critical to success:

- **Capital Investment.** Financial support is essential to bridge the gap between academic research and deployment at scale. Investment and grants will support promising AI solutions to scale beyond the startup and small-pilot phases to reach industrial or national levels.
- **Strong Networks and Mentorship**. Matchmaking between climate AI practitioners (particularly researchers and startups) and potential supporters or users (including civil servants, investors, corporates, and international development agencies) will facilitate development and implementation. Engagement between such groups will help practitioners develop solutions that fulfill the needs of users. Nicolai Wadstrom, founder, CEO, and General Partner at BootstrapLabs, remarks, "As a VC firm, we've found that building the right mentorship and networks to support entrepreneurs is often our most important activity—sometimes beyond the capital investments we make."
- **Access to Decision Makers.** Because of AI's highly technical nature, public- and private-sector leaders do not always apply it effectively, since they are not familiar with the technology's potential benefits and limitations. To close this gap, practitioners need access to policymakers and corporate leaders so they can create awareness and increase adoption. Further, data and computing power are not always readily available for use by emerging solutions, and access to decision makers can help unlock these resources.

- **Sharing Best Practices.** Practitioners need to share knowledge about best practices and promising uses of AI if they are to prepare solutions for wide-scale government and corporate deployment. Shared learning, such as through use-case libraries, can help promising solutions achieve their full potential and avoid pitfalls as they transition from the research, pilot, and proof-of-concept phases to implementation. Best-practice sharing is critical to adoption across both the Global North and Global South.

Confidence and Trust

AI practitioners must earn the confidence of leaders, given the risks of bias or unethical behavior when AI is used inappropriately and without human monitoring. Consequently, practitioners must commit themselves wholeheartedly to Responsible AI—an approach that encompasses appropriate governance, thoughtful processes, and transparency about AI's role in decision making. (See the sidebar "Responsible AI.")

In addition, practitioners should focus on producing and using reliable, granular data so that they can explain and justify the results of any analysis. Doing this will ensure that topic experts see the AI tool as a valuable addition to their decision-making process. Testing the application in real-life circumstances through small pilots, as well as constantly verifying the data and analyses, will help build a track record of accurate, credible results.

Responsible AI

To ensure responsible use of the technology, AI teams and their algorithms should undergo regular compliance audits. In addition, AI teams should gather input from domain experts and potentially affected groups, and they should adhere to best practices regarding privacy, fairness, human control, and more. To learn more about Responsible AI, users can refer to the guidelines co-developed by Microsoft and BCG.

Even if an algorithm's primary purpose is not to address climate topics, it should be trained on data sets that include examples of low-emission processes, and it should favor options that produce lower emissions. If we train AI models on high-emission processes and use those models without considering the GHG impact of their suggestions, we may eventually undermine climate progress by replicating high-carbon processes in the future. For a systematic overview of AI's potential impact on climate change—both positive and negative—we encourage readers to refer to *Aligning artificial intelligence with climate change mitigation,* published in *Nature Climate Change.*

More information on Responsible AI approaches to climate change is available from the joint report from Global Partnership on AI, Climate Change AI, and the Centre for AI & Climate titled *Climate Change and AI: Recommendations for Government Action.* We also encourage readers refer to *Steering AI and Advanced ICTs for Knowledge Societies: A Rights, Openness, Access, and Multi-stakeholder Perspective*, which assesses AI through UNESCO's Internet Universality ROAM framework, and *Tackling Climate Change with Machine Learning.*

BEYOND AI

Although AI shows great promise as a way to address climate change, it is just one of many tools available to meet this global challenge. Like any technology, it has limitations and requires effective deployment if it is to achieve the desired results. Further, solving the crisis requires not just technological innovation, but also the will of decision makers to take action and make the necessary changes—supported in part by AI and other emerging technologies.

JOIN OUR CALL FOR SOLUTIONS

As climate change continues to present new and complex challenges to leaders around the globe, innovative AI solutions can help measure, reduce, and remove emissions more effectively; support communities and economies as they adapt to the changing environment and become more resilient; and support overall climate action through research, climate finance, and education.

Although there are still numerous roadblocks to implementation—from inadequate funding and training to lack of access to decision makers and best practices—we are excited to help push new solutions past those roadblocks and achieve their potential at scale. We again encourage all interested parties to participate in our first call for solutions, including those at any stage of maturity, given a working prototype, and from any sector.

Recognizing that all individuals, communities, and organizations have a role to play, regardless of their formal position in AI or climate topics, we further invite readers to consider how other emerging technologies can help in the fight against climate change and remove obstacles to scale for those as well.

We also encourage readers who are engaged in the climate or AI communities to share information on the roadblocks, frictions, and pain points they face in engaging with climate analytics, AI solutions for the climate crisis, and other issues. This vital support will inform future publications and, more importantly, help us prioritize our efforts to address these challenges.

For more information about this survey and additional findings from it, see the recent BCG article “AI is Essential for Solving the Climate Crisis”.

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