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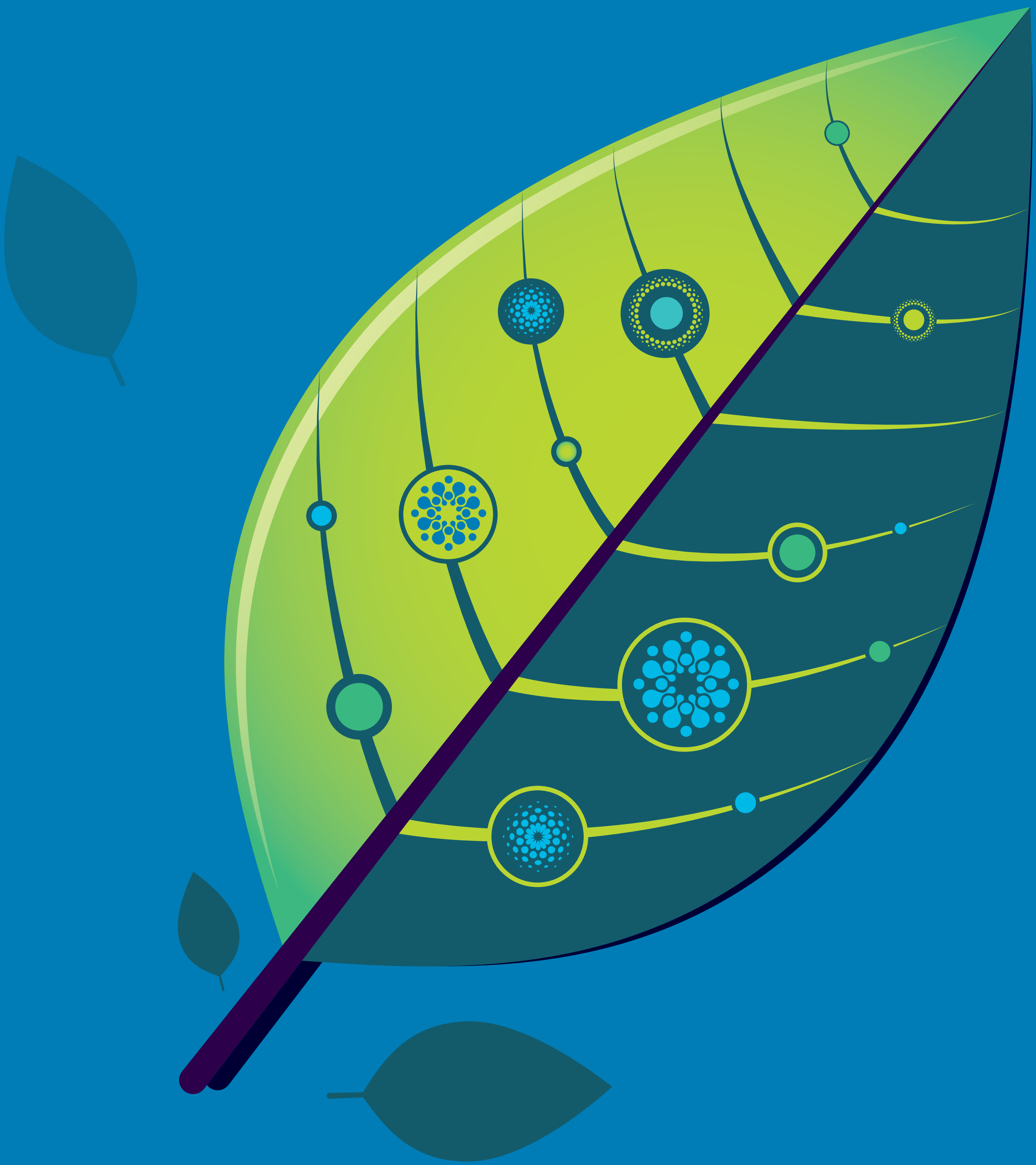


Climate AI

How artificial intelligence can power your climate action strategy

Executive summary

As the COVID-19 pandemic spread across the world, it also highlighted another major collective hazard we face – climate change. Extreme weather events are increasing, lives are being affected and placed in danger, and costs are mounting for governments and industry. Given the urgency of this issue, this report seeks to understand how AI can accelerate our response.

Our research found that:

I. AI offers many climate action use cases

- We analyzed over 70 AI-enabled use cases for climate action and identified the ten most impactful ones. By that we mean they offer significant benefits for organizations in terms of reduced greenhouse gas (GHG) emissions, improved energy efficiency, and reduced waste.
  Examples include:
  - Tracking GHG emissions and tracing GHG leakages at industrial sites
  - Improving the energy efficiency of facilities and industrial processes
  - AI for designing new products that reduce waste and emissions during prototyping, production, and usage
  - AI for inventory management - improving demand planning and reducing wastage of food products and raw materials
  - Route optimization and fleet management for retail, automotive, and consumer products firms

II. AI-enabled use cases are already reducing GHG emissions and can accelerate climate action

- Across sectors, AI-enabled use cases have helped organizations reduce GHG emissions by 13% and improve power efficiency by 11% in the last two years. AI use cases have also helped reduce waste and deadweight assets by improving their utilization by 12%.
- Our modelling estimates that, by 2030, AI-enabled use cases have the potential to help organizations fulfil 11–45% of the 'Economic Emission Intensity' targets of the Paris Agreement, depending on the scale of AI adoption across sectors. For instance, for the automotive sector, AI-enabled use cases have the potential to deliver 8 percentage points of the 37% reduction (more than one-fifth) required by 2030.
- In the future, AI is expected to reduce GHG emissions by 16% and improve power efficiency by 15% in the next three to five years.

III. Even though climate action is a strategic priority, most organizations are struggling to support climate action with AI capabilities

- 67% have made long-term business decisions to tackle the consequences of climate change.
- However, few organizations are successfully combining their climate vision with AI capabilities and have driven solutions to scale. We call these high-performing organizations – Climate AI

Champions. They represent only 13% of the entire survey sample.

- A closer look at the challenges that organizations face in scaling AI for climate action reveals a range of issues: only 42% of the potential AI use cases are being experimented with and more than eight in ten organizations spend less than 5% of climate change investment on AI.

IV. How organizations can leverage AI's full climate action potential

We believe that six action areas are critical:

- Account for, and take measures to combat, the negative impact of AI on the climate.
- Educate sustainability teams on how AI can make a real difference and educate AI teams on the criticality of climate change.
- Lay down the technological foundations for AI-powered climate change action.
- Scale use cases on the basis of impact for your sector and emissions intensity of particular functions.
- Collaborate with the climate action ecosystem.
- Harness AI to bring greater focus in reducing scope 3 emissions.

The research approach draws on a range of tactics, from using climate models developed in partnership with 'right. based on science' – a climate startup – for estimating the impact of AI on greenhouse gas (GHG) emissions to a survey of over 400 sustainability executives and 400 business/tech executives from the automotive, industrial/process manufacturing, energy & utilities, and consumer products and retail industries. Additionally, we surveyed 300 experts, including regulators, academics, and non-governmental organizations working in the field of sustainability, and interviewed over 40 industry executives and experts. More details on the research methodology are in the Appendix.

Introduction

The climate crisis is urgent and the organizations need to act now

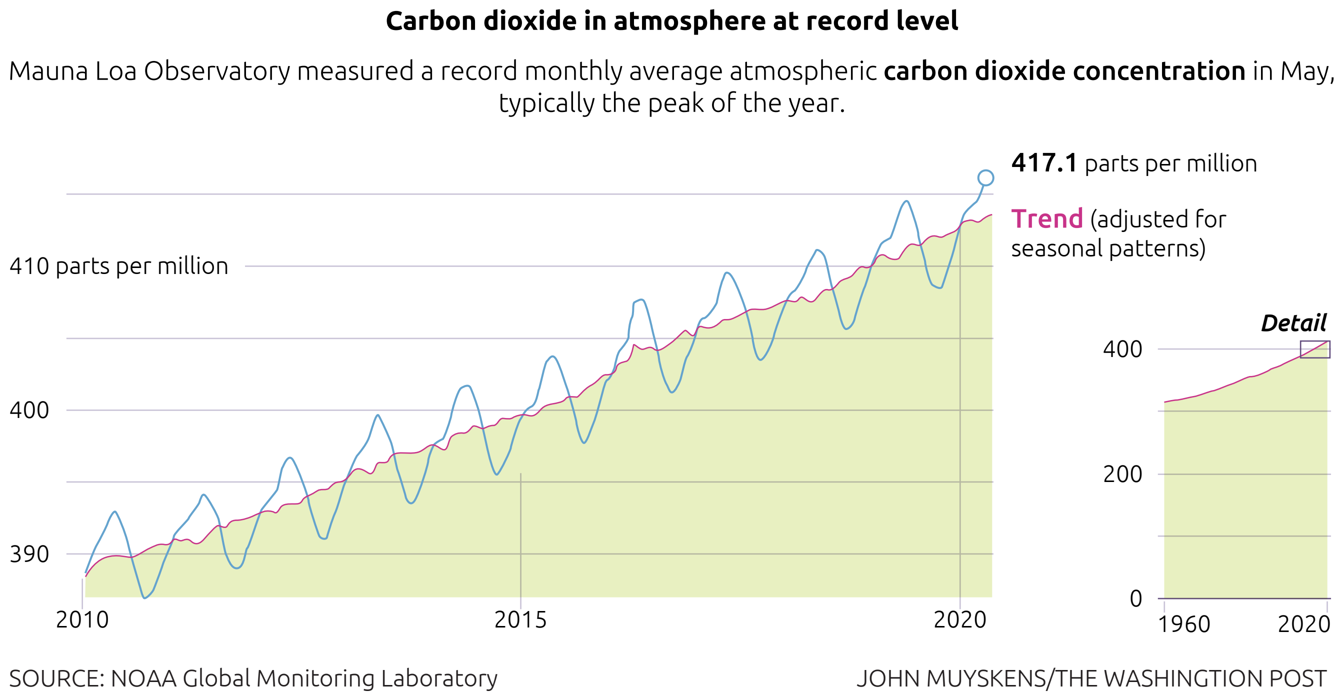
Today's global pandemic is not the only global threat we face that has wide-ranging impact on economies and society. The extent of climate crisis is laid bare by the changes we are seeing:

- The atmospheric levels of CO_2 are at the highest compared to any point in human history (see Figure 1).[1] This is despite the steep drop in global GHG emissions during the pandemic lockdown.[2]
- Average temperatures have been on the rise for decades now.[3]
- Average sea levels have risen about 8 inches (over 20 centimeters) since 1880 and 3 inches in the last 25 years alone.[4]
- 2019 was also the hottest year on record for the world's oceans.[5]

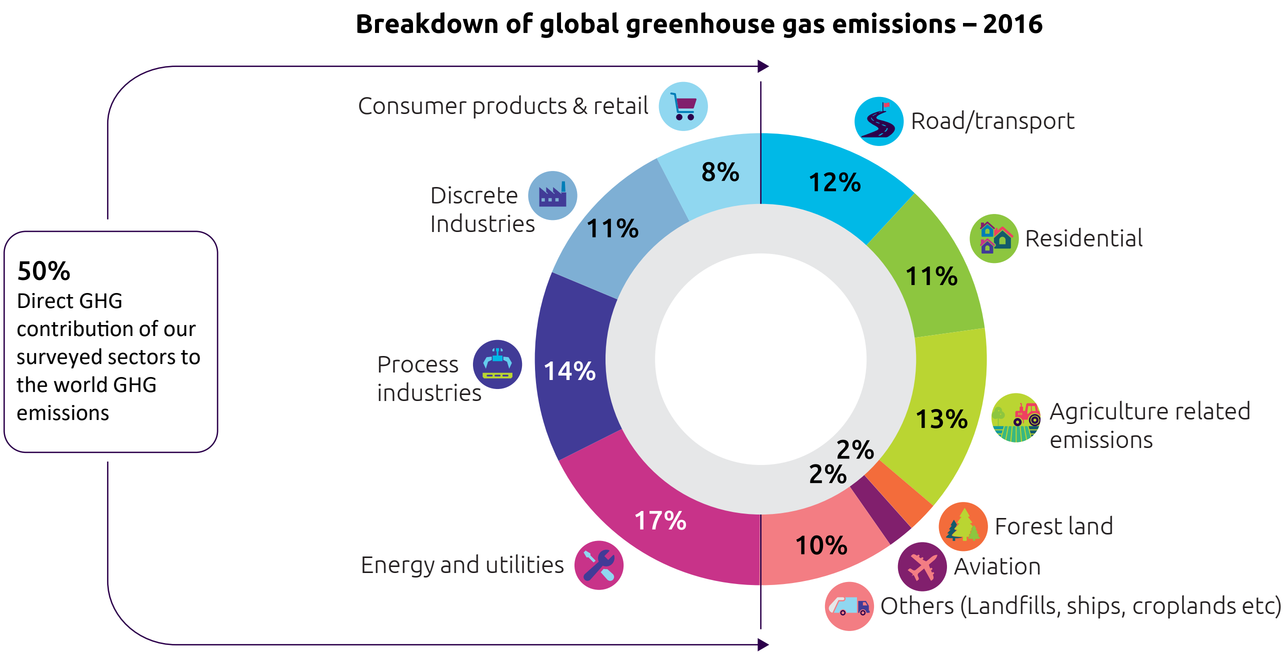
In recent years, we have witnessed a range of unprecedented natural disasters as a result of major changes in the earth's climate. A UN report released in October 2020 states that between 2000–2019, there were 7,348 major recorded disaster events claiming 1.23 million lives, affecting 4.2 billion people resulting in approximately USD2.97 trillion in global economic losses.[6]

Large organizations have a sizeable climate footprint and their operations are adding to GHG concentration, which is the prime reason behind global warming and climate change. If we look at four sectors that make up our research – automotive manufacturing, industrial manufacturing, energy & utilities, and consumer products and retail – they together contribute roughly 50% of the world's total GHG emissions (see Figure 1).

Figure 1. Rising CO_2 levels and sector distribution of GHG emissions



Source: The Washington Post, "Earth's carbon dioxide levels hit record high, despite coronavirus-related emissions drop," June 2020.



Source: Capgemini Research Institute analysis. Data from CAIT Climate Data Explorer via. Climate Watch/Our World in Data, accessed October 2020.

"Our assessment shows that with digitalization, artificial intelligence, big data analysis, deep learning, we can realize a green economy much more easily with those technologies than without them,"

Dirk Messner,
President, German Environment Agency Board Member, Stockholm Energy Institute.

Not surprisingly, organizations are under pressure to act. The October 2018 special report from the IPCC (Intergovernmental Panel on Climate Change) stressed the need to avoid global warming reaching 1.5°C more than pre-industrial levels. Similarly, the Paris Agreement, which was adopted by 195 nations in December 2015, set that target at 2°C more than pre-industrial levels.[7]

Pressure from climate groups, regulators and shareholders is mounting too. Kelly Levin, senior associate at the World Resources Institute, says: *"There is a huge range of actions that are building pressure. For example, the movements that are taking to the streets and calling for different actors to increase their ambition towards reducing emissions, to shareholders and corporate boards. Some of the highest emitting companies don't have science-based targets; so while organizations are taking steps, it's certainly not at the pace that we need to be consistent with the science."*

Investors are now actively shunning companies with low ratings or performance on ESG metrics. One of the largest asset managers in the US, BlackRock, recently put 244 companies "on watch" for failing to take sufficient action on climate change. It also took voting action (holding directors accountable or supporting shareholder proposals) against 53 of these.[8] As a result, organizations across industries need to adopt radical methods, make adequate investments, and deploy appropriate tools, technologies, and strategies to achieve this goal.

These are challenging goals for the world economy and society, but technology offers an exciting opportunity for organizations to make a real difference. *"Our assessment shows that with digitalization, artificial intelligence, big data analysis, deep learning, we can realize a green economy much more easily with those technologies than without them,"* says Dirk Messner, president, German Environment Agency Board Member, Stockholm Energy Institute. *"However, despite the potential, during the last two decades, these technologies have not been used enough to really solve the climate and environmental and earth system challenges. We still have non-sustainable growth patterns in most economies and organizations around the world. We need to make the link proactively between climate politics, earth system stabilization strategies on the one hand side and these modern technologies on the other."*

If organizations and countries globally do not take decisive action, our planet is set to warm by almost 3^{0}C by the end of the century – double the rate needed to constrain the worst impacts of climate change.[9] Over the last few decades, organizations have been taking significant measures such as decommissioning coal plants and directing more funds to renewables and less to fossil fuels. However, using technology levers to contain the effects of climate change is rarely seen as the biggest enabler. Among the technology levers, while the spotlight often falls on point solutions that address a specific outcome – such as carbon capture technologies to remove CO_2 from the atmosphere, or renewable sources of energy – few technologies offer advantages that cut across sectors and value chains. Recent advances in Artificial intelligence (AI) for instance, in image recognition powered by deep-learning neural networks is one such fast-emerging field, and points to AI's significant potential that is yet untapped. We believe that AI solutions when deployed sustainably, complementing technological and various other levers to reduce carbon footprint, offer a sizeable and promising opportunity that is worth exploring.

AI offers unique opportunities to accelerate organizations' climate action

Our recent research shows that the adoption of AI across organizations has been on the rise with more than one in two organizations (53%) moving beyond pilots or proofs-of-concept in a few or more use cases.[10] Given that organizations are already beginning to deploy AI at scale, it is an opportunity for organizations to also explore AI-enabled use cases from a climate action perspective and how existing AI deployments or new innovations could also bring climate-positive outcomes (see section 1 on "AI offers many climate action use cases").

In recent years, several AI use cases have been identified that offer significant value in improving energy efficiency, reducing dependence on fossil fuels, and optimizing processes to aid productivity – all contributing significantly to climate action.[11] For instance, Air France uses Sky Breathe – an ML and AI platform to provide a series of recommended actions that can reduce the total fuel consumption by up to 5%. Various airlines have used the solution to save more than 590,000 tons of CO_2 in 2019.[12] Getting the focus right can have significant benefits in the long run. As we heard from James McCall, Senior Director Global Climate and Supply Chain Sustainability, Procter & Gamble *"AI has the potential unlock a lot of data capabilities that we don't have today, such as predictive energy analytics at the production line level. Are those going to change your global footprint overnight? No, they are going to typically be incremental, but changes to energy efficiency – such as driving a 4% to 5% energy reduction across our global manufacturing sites – is worth millions of dollars while helping significantly reduce our GHG emissions."*

While AI offers an exciting new front in the fight against climate change, organizations have to be cognizant of AI's own climate footprint. Training AI models can contribute to significant emissions and AI could be used to further operations that accelerate climate change. In a move away from such outcomes, Google declared that it would no longer build AI tools for oil and gas extraction.[13] While it is important to acknowledge that AI applications have a GHG footprint, as some of the recent academic research has shown, it is also important to put it into the right perspective.[14] For most large businesses and public sector organizations, the footprint of individual AI applications is miniscule compared to their overall climate footprint. But, as the use of AI gains wider adoption, organizations do need to ask themselves how AI can be used sustainably and responsibly. On this front, we believe that optimizing AI training and execution can significantly limit its climate impact, when designed and deployed responsibly. For example, as an early adopter of AI for tackling climate change, Google was able to reduce the amount of energy it used in its data centers by 15% by using inputs from machine learning algorithms.[15] Using the wealth of data from usage of servers in data centers, Google was able to more efficiently regulate their cooling. Ultimately, this led to significant power savings. We explore more dimensions of this aspect in the final section of the report.

In terms of sectors, we focused on asset-heavy and product-based sectors in this research which have a sizeable emissions footprint, such as automotive, manufacturing, consumer products & retail, and energy & utilities sectors. Services sectors such as banking, insurance, and public services are beyond the scope of this research. We do acknowledge that these services sectors cut across the industrial landscape and do play a critical role from a financial, risk management, and regulatory standpoint, among others. Achieving international climate goals will require political, social, and economic willpower and action besides technological advances in many areas including AI – the core focus of this report.

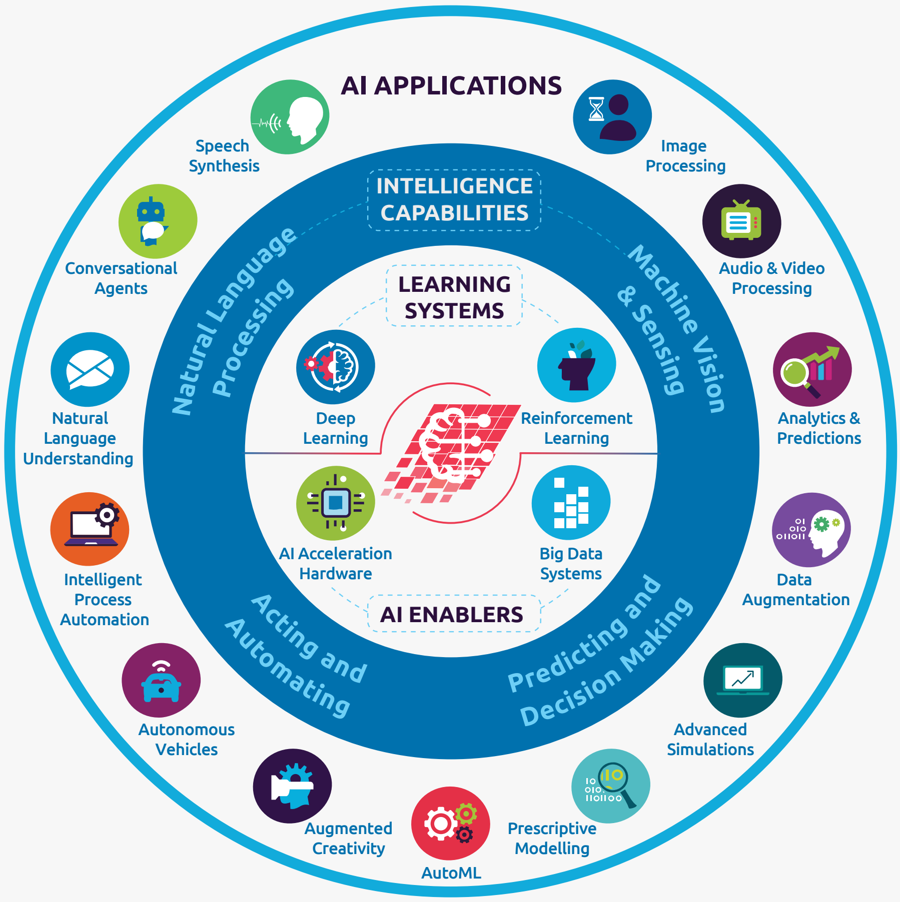
Based on our research and analysis, this report looks deeper into the following areas:

1. The most impactful AI use cases for climate action and where organizations stand in adopting them
2. The potential that AI offers for accelerating climate action and the benefits that have been achieved so far
3. What a group of high-performing organizations can teach us about how to align and leverage AI capabilities to execute on and achieve climate goals
4. How organizations can leverage the full potential of AI for climate action.

USD 2.97 trillion

Global economic losses due to climate change from 2000-2019 as per the UN

Artificial Intelligence



Source: Capgemini Technology, Innovation & Ventures.

Artificial Intelligence (AI) is a collective term for the capabilities shown by learning systems that are perceived by humans as representing intelligence.

These intelligent capabilities typically can be categorized into machine vision and sensing, natural language processing, predicting and decision-making, and acting and automating.

Various applications of AI include speech, image, audio and video processing, autonomous vehicles, natural language understanding and generation, conversational agents, prescriptive modelling, augmented creativity, intelligent process automation, advanced simulations, as well as complex analytics and predictions.

Technologies that enable these applications include big data systems, deep learning, reinforcement learning, and AI acceleration hardware.

1. AI offers many climate action use cases

AI offers a number of use cases that positively affect the climate, both in preventive measures such as reducing GHG emissions and remedial measures such as dealing with the effects of climate change more effectively. As we heard from David Rolnick, chair, Climate Change AI and assistant professor of Computer Science at McGill University, says: *"In both power generation and distribution, there are many ways in which machine learning can be used to increase efficiency, support low-carbon electricity generation and, in general, help reduce greenhouse gas emissions. Likewise, in traditional industry and manufacturing – both in the manufacturing component and in the distribution of goods – there is the capacity for vastly improved efficiency and lower energy use using machine learning."* The use cases include both AI systems that are designed to specifically address climate challenges (such as the fight against methane leakages) as well as those that can contribute to positive climate outcomes (such as AI for general energy efficiency). Figure 2 summarizes them.

In addition, large insurers and reinsurers are using AI for climate and environmental risk modeling and helping their clients with it. Munich RE, a provider of reinsurance, primary insurance and insurance-related risk solutions, is experimenting with AI in its risk solutions. As we heard from Christof Reinert, head of Risk Management Partners at Munich RE, *"We have a Risk Suite which is the umbrella for all our risk solutions we offer as a cloud-service. The comprehensive set of solutions cover location risk and data risk intelligence, in both of which we have the ability to use Munich Re's smart company matching algorithms which are trained on AI models."*

"In both power generation and distribution, there are many ways in which machine learning can be used to increase efficiency, support low-carbon electricity generation and, in general, help reduce greenhouse gas emissions. Likewise, in traditional industry and manufacturing – both in the manufacturing component and in the distribution of goods – there is the capacity for vastly improved efficiency and lower energy use using machine learning."

David Rolnick,
Chair, Climate Change AI and assistant professor of Computer Science at McGill University

Figure 2. Using AI for climate action across sectors and value chain

Energy production and distribution

Tracking emissions at industrial sites

Tracing leaks using smart leakage management to avoid GHG emissions

GHGSat uses machine learning to look for potential areas of methane leakages and autonomously monitors such areas from the satellite based methane detectors.[i]

ExxonMobil has teamed up with MIT to design and develop deep-sea AI robots to boost their oil seep detection capabilities. Oil seep could account for nearly half of the oil released into the ocean every year.[ii]

Energy efficiency

AI can help improve energy efficiency and use cleaner electricity sources when available

Google's Deepmind uses machine learning to predict wind patterns at their 700 MW wind farm upto 36 hours in advance leading to closer alignment with the grid.[iii]

Manufacturing operations

Route optimization and fleet management

AI for route and fleet management can help reduce fuel consumption and carbon emissions

Rio Tinto uses machine learning and sensors to track vital vehicle stats and asset efficiency, leading to increase in serviceable life.[vi]

Locus.sh uses AI for route optimization for last mile deliveries to achieve 25% efficiency gain and GHG reductions.[vii]

Maintenance

AI can help predict and avoid manufacturing disruptions due to mechanical failures

General Motors used image classification tool on nearly 7,000 robots to detect component failure leading to more efficient operations and lower energy costs.[viii]

Product usage, reuse, and recycling

Inventory management

AI for inventory management to improve store stock and to closely align demand and supply

PepsiCo is using big data and advanced analytics in Pep Worx to help identify potential households and avenues of sale, leading to more accurate demand forecasting and lower waste.[xi]

Morrisons uses AI to optimize demand and replenishment at a store and product level using internal datasets (e.g., sales data) and external data (e.g., weather forecast) leading to reduced wastage.[xii]

Wasteless, an Israeli startup, uses AI to dynamically price perishable products on retail shelves leading to wastage reduction of 39% in a 12 week pilot.[xiii]

Energy | Utilities | Automotive | Industrial manufacturing | Consumer products | Retail

Dynamic peak load adaptation

AI technologies can help manage peak demand planning and thus avoid energy wastage

EnPowered uses AI to adapt to demand response systems, thereby reducing peak load, leading to closer alignment of demand and supply and reduction in energy wastage.[iv]

Robert Bosch GmbH uses AI to predict future energy consumption, avoiding high peaking loads, and manage deviations in patterns of consumption resulting in emissions reduction by 10% in two years.[v]

Operational effectiveness

AI can help increase operational effectiveness to increase efficiency and better utilization of resources

Baker Hughes uses AI to provide operators and engineers insights into machine health and real time control of production processes leading to 12% better machine utilization.[ix]

New product design

AI for designing new products to build more environment-friendly products and reduce wastage in design

General Motors used machine learning to build a new seatbelt bracket design that is 40% lighter and 20% stronger with reduced resource wastage during design.[x]

Consumer behaviour analytics

AI for consumer behaviour analytics to reduce wastage

Bidgely uses machine learning algorithms and database of more than 50 billion meter readings to identify down to the appliance level the most energy consuming devices and usage patterns in households giving deeper visibility of decarbonization opportunities.[xiv]

Waste management & segregation

AI for effective waste management, segregation and recycling to reduce need of resources & avoid wastage

Stuffstr uses AI algorithms for pricing and discovering the value of reused items. They also use machine learning to ensure proper classification of all re-sale products.[xv]

ZenRobotics uses AI to assess waste stream in real time and separate waste quickly and with high precision resulting in effective recycling.[xvi]

Energy production and distribution

Manufacturing operations

Product usage, reuse, and recycling

Sources for Figure 2:

i. PRNewswire, "Meet Iris: GHGSat to Launch a Second Emissions-Monitoring Satellite This Summer," April 2019.
ii. SparkCognition, "Top 4 Real-World Ai Applications In The Oil And Gas Industry", March 2020
iii. Deepmind, "Machine learning can boost the value of wind energy," February 2019.
iv. Startup Toronto, "EnPowered Secures Stake in Ontario's Demand Response Electricity Program, Aiming to Improve Customer Revenue," December 2019
v. Bosch press release, "CO_2 advisory service: Bosch assists manufacturing companies as they work toward climate neutrality," July 2019.
vi. IoTforall, "Go Big on IoT Value with Preventive Maintenance," July 2017
vii. Locus.sh, "How the World's Best Route Optimization Engine Works," January 2018.
viii. iFlexion, "Industries to Be Transformed by Machine Learning for Image Classification", October 2018
ix. Capgemini, Artificial Intelligence (AI)-Driven Smart Factory solution provides operators and engineers with a new level of insight and the ability to adjust production at a moment's notice, June 2019
x. Autodesk, "Automotive Lightweighting with Generative Design."
xi. Forbes, "The Fascinating Ways PepsiCo Uses Artificial Intelligence and Machine Learning to Deliver Success," April 2019
xii. Retail week, "How machine learning is enabling Morrisons to innovate around its customers," March 2017
xiii. Singularity hub, "Food Waste Is a Serious Problem. AI Is Trying to Solve It," November 2020
xiv. Businesswire, "Bidgely Surpasses 10 Million Homes Under Contract With Utilities for Energy Disaggregation", December 2017.
xv. StuffStr website, accessed September 2020
xvi. Recycling Product News, "ZenRobotics' AI-based robotic waste sorting technologies help Remeo to build next-generation MRF," September 2020.

A range of organizations have already made innovative use of AI to address the adverse impact of GHG emissions, drawing on different data, such as satellite images, drone footages, and weather information:

- **Tracing methane leaks and emissions.** Methane is one of the most potent greenhouse gases – 84 times more potent than carbon dioxide, it constitutes around a quarter of manmade global warming.[16] Tracking and plugging methane leaks from oil & gas facilities, landfill sites, mines, and agriculture has been a daunting task for public and private enterprises. GHGSat – a startup focused on using satellites to detect greenhouse gas leaks that would be highly difficult by other means on land – uses AI to offer insights into emissions, potential areas of leakage, and then autonomously monitors and alerts on any irregular activity.[17] In January 2019, GHGSat helped locate a leak that is estimated to have released 142,000 tons of methane in 12 months prior to discovery.[18] In the US, the British multinational oil and gas company, BP, has used drones to track 1,500 well sites to monitor and trace methane emissions. Using AI-powered augmented reality, field technicians are quickly able to link with remote technical support and narrow down the emission sites.[19] As we heard from Patrizia Radice, CHRO, SARAS Group, a large player in the European refining industry, *"We started digitalization of the refinery three years back. It was a large program with a significant investment. As part of this, AI was one of the drivers to make better use of historical data to understand what is going on and support predictive maintenance of machines so that they offer greater energy efficiency and reduce GHG emissions."* AI-powered data analytics platforms are also helping monitor vital climate parameters such as atmospheric concentration of CO_2 to better understand its impact on climate.[20]
- **Optimizing renewable energy generation.** Greensmith Energy, a global energy storage company, uses machine learning to manage energy storage systems and balance multiple energy assets such as wind, solar, and diesel generation. The new, AI-powered "Graciosa Hybrid

Renewable Power Plant," automatically optimizes energy generation based on energy demand and weather patterns (that affect wind and solar power generation). It improves reliability of the energy grid while aiding larger adoption of renewable power from 15% to 65% and reducing the need for 17,000 liters of diesel per month.[21]

- **Reducing wildfire risk and adapting operations to changing weather.** Utilities in California are exploring the use of drones, along with computer vision, to regularly monitor transmission and distribution equipment for faults. This is part of efforts to reduce their risk of starting fires. Apart from being a threat to lives and livelihood, wildfires also contribute heavily to carbon emissions. The California wildfires this year have already generated 91 million metric tons of carbon dioxide as of September, 25% more than the state's annual fossil fuel emissions.[22] PG&E – a utility in California – has been using drones with computer vision for remote aerial inspection, and analytics and machine learning to predict how its transmission equipment will handle high-wind events. This allows the organization to prioritize maintenance work on vulnerable parts of the transmission chain.[23]

– Air France uses Sky Breathe – an ML and AI platform to suggest a series of recommended actions that can reduce the total fuel consumption by up to 5%. Various airlines have used the solution to save more than 590,000 tons of CO_2 in 2019.[24]

– Alibaba uses real time data such as GPS, traffic conditions, and AI to make routing decisions for its last-mile delivery fleet. These systems were able to reduce distance travelled for the fleet by 30% and reduce vehicles needed by 10% in a pilot run.[25]

– Ocado – the British online grocery retailer – has deployed machine learning-powered forecasting and optimization to reduce food waste. Ocado has been able to slash food wastage rates to just 1 in 6,000 items by using data analytics, machine learning and artificial intelligence to manage its produce.[26] Reducing food waste helps avoid methane build-up – a greenhouse gas much more potent than CO_2.

"We started digitalization of the refinery three years back. It was a large program with a significant investment. As part of this, AI was one of the drivers to make better use of historical data to understand what is going on and support predictive maintenance of machines so that they offer greater energy efficiency and reduce GHG emissions."

Patrizia Radice,
CHRO, SARAS Group

2. AI-enabled use cases are already reducing GHG emissions and have the potential to accelerate climate action

AI-enabled use cases have helped reduce GHG emissions by 13% since 2017

AI has been helping organizations around the world as they tackle the impact of climate change on their business operations and achieve their sustainability goals:

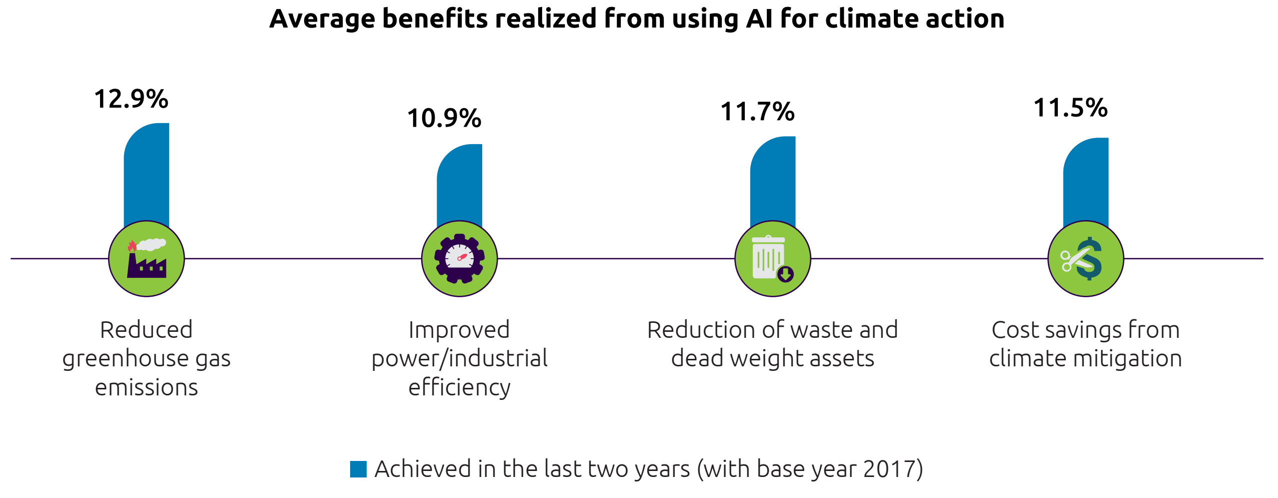
- Nearly half of the organizations (48%) we surveyed have used AI for climate action.
- As a result of AI, organizations have also reduced GHG emissions by 12.9%, improved power efficiency by 10.9%, and reduced waste by 11.7% since 2017 (see Figure 3).

This is a significant boost to organizations' climate actions and goals to achieve carbon neutrality and net-zero emissions.

Our survey found that, in the last two years, organizations have been able to reduce their GHG footprint by 13% using AI-enabled use cases.

We analyzed the average benefits yielded by AI use cases for climate action when deployed at partial scale or full scale (see Figure 3). Overall, these projects were able to deliver 11–13% gain across various KPIs in the last two years.

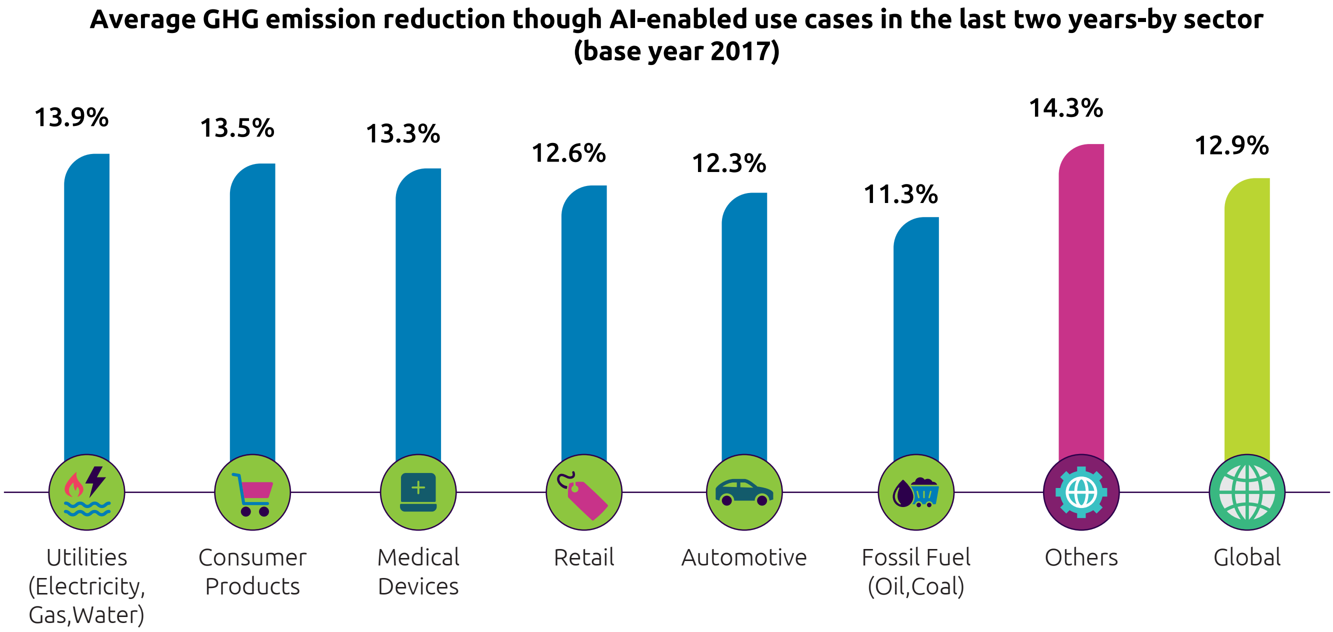
Figure 3. AI-enabled use cases have helped organizations achieve several sustainability benefits, including reducing GHG emissions by 13% in two years



Source: Capgemini Research Institute, AI in climate action survey, July–August 2020, N=190 organizations that have been able to fully scale or partially scale AI projects for climate action. Reduction of waste includes waste in broader terms of utilization deadweight – empty trucks/facilities and in disuse/disposal of products before completion of useful life (e.g., produce/vehicles).

Utilities and consumer products organizations have experienced the biggest gains in reducing GHG emissions using AI (see Figure 4).

Figure 4. Utilities and consumer products have realized the biggest GHG reduction using AI-enabled use cases



Source: Capgemini Research Institute, AI in climate action survey, July-August 2020, N=190 organizations that have been able to fully or partially scale AI projects for climate action. Others include process industry (cement, paper, petro-chemical, paper) and discrete industries (electrical and electronics, air and railway equipment, etc.)

14%

average GHG emissions reduction attained by the utilities sector from AI-enable use cases.

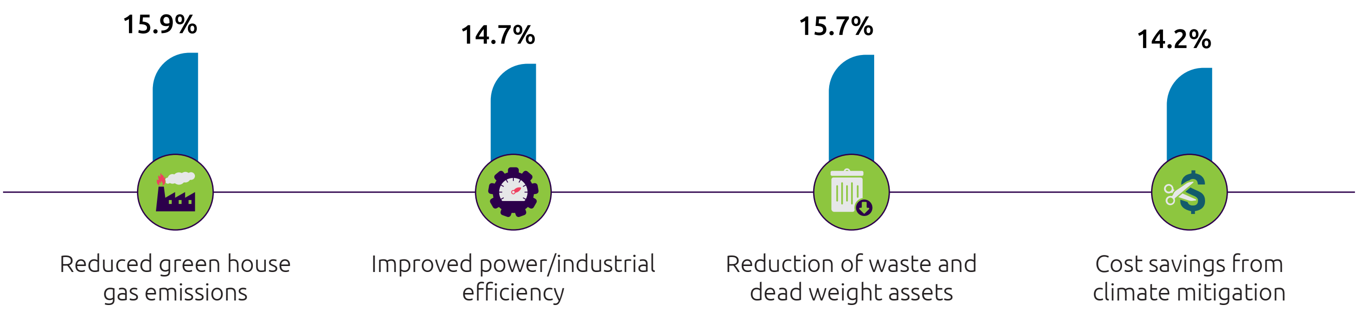
AI-enabled use cases have the potential to significantly limit GHG emissions

"We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run" - Roy Amara, former president of The Institute for the Future.[27]

Our survey shows that organizations expect to cut GHG emissions by 16% in the next 3–5 years through AI-driven climate action projects (see Figure 5). Speaking about the future of AI for climate change, Gabriela Prata Dias, head of the Copenhagen Centre on Energy Efficiency, said, *"There are hundreds of very interesting opportunities that are coming up based on the use of AI. I truly think that there are huge opportunities for energy systems at a household, municipal, or even country level that could improve their performance with the aim of reducing the energy demands associated with providing the same level of services."*

Figure 5.1. AI has the potential to deliver considerable climate gains across sectors

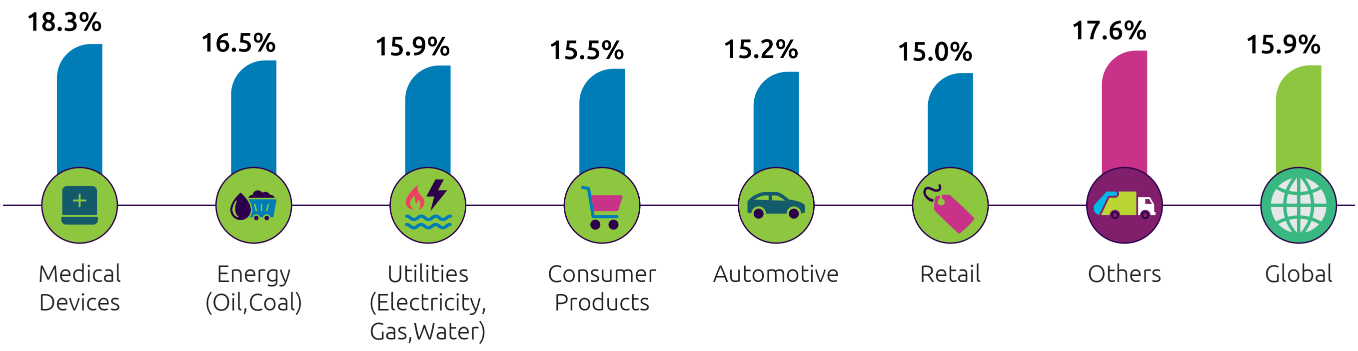
Average benefits expected from use of AI-enabled use cases climate action in the next three to five years



Source: Capgemini Research Institute, AI in climate action survey, July–August 2020, N=190 organizations that have been able to fully scale or partially scale AI projects for climate action. Reduction of waste includes wastage in broader terms of utilization deadweight – empty trucks/ facilities and in disuse/disposal of products before completion of useful life (e.g., produce/vehicles).

Figure 5.2. AI has the potential to deliver considerable climate gains across sectors

Average future emission reduction using AI-enabled use cases for the next three to five years (base year 2019)



Source: Capgemini Research Institute, AI in climate action survey, July–August 2020, N=190 organizations that have been able to scale AI projects fully or partially for climate. Others include process industry (cement, paper, petro-chemical, paper) and discrete industries (electrical and electronics, air and railway equipment, etc.).

While this is a significant reduction in GHG emissions, would it be sufficient to get anywhere close to international emission reduction agreements such as the Paris Agreement? For instance, in line with the Paris Agreement, the EU has set a target of reducing its emissions by at least 40% by 2030 and is considering increasing it to 60% reduction against 1990 levels.[28]

To explore whether GHG emission reduction through AI may help companies to align their climate impact to a global warming well below 2°C, we partnered with a climate change start-up – 'right. based on science' – and used their X-Degree Compatibility (XDC) Model (see insert on "What is the XDC Model and how to interpret it?" and Appendix "The XDC Model" for further information).

What is the XDC Model and how to interpret it?

The XDC Model calculates the contributions of a company, portfolio or any other economic entity to climate change, answering the question: How much global warming could we expect, if the entire world operated at the same economic emission intensity as the entity in question? Results are expressed in a tangible degree Celsius (°C) number: the XDC. The XDC Model, a science-based and peer-reviewed methodology, is the only one of its kind to integrate a full climate model (also used by the UN Intergovernmental Panel on Climate Change, or IPCC).

The main input parameter for the XDC Model is a metric called Economic Emission Intensity (EEI) – a relationship between the emissions produced per generation of one million euro Gross Value Added (GVA).[29] The EEI shows the ability of an organization to decouple their economic growth from their emissions. A growing EEI indicates that the organization's emissions outpace its economic growth which is unsustainable and harmful for the climate. Ideally, organizations' EEI must reduce with time as they reduce their GHG emissions or grow them slowly while growing their business. This reduction in EEI must be more than that intended by international targets (for instance, by 2030, 45% of 2018 levels for most sectors).

"There are hundreds of very interesting opportunities that are coming up based on the use of AI. I truly think that there are huge opportunities for energy systems at a household, municipal, or even country level that could improve their performance with the aim of reducing the energy demands associated with providing the same level of services."

Gabriela Prata Dias,
Head of the Copenhagen Centre on Energy Efficiency

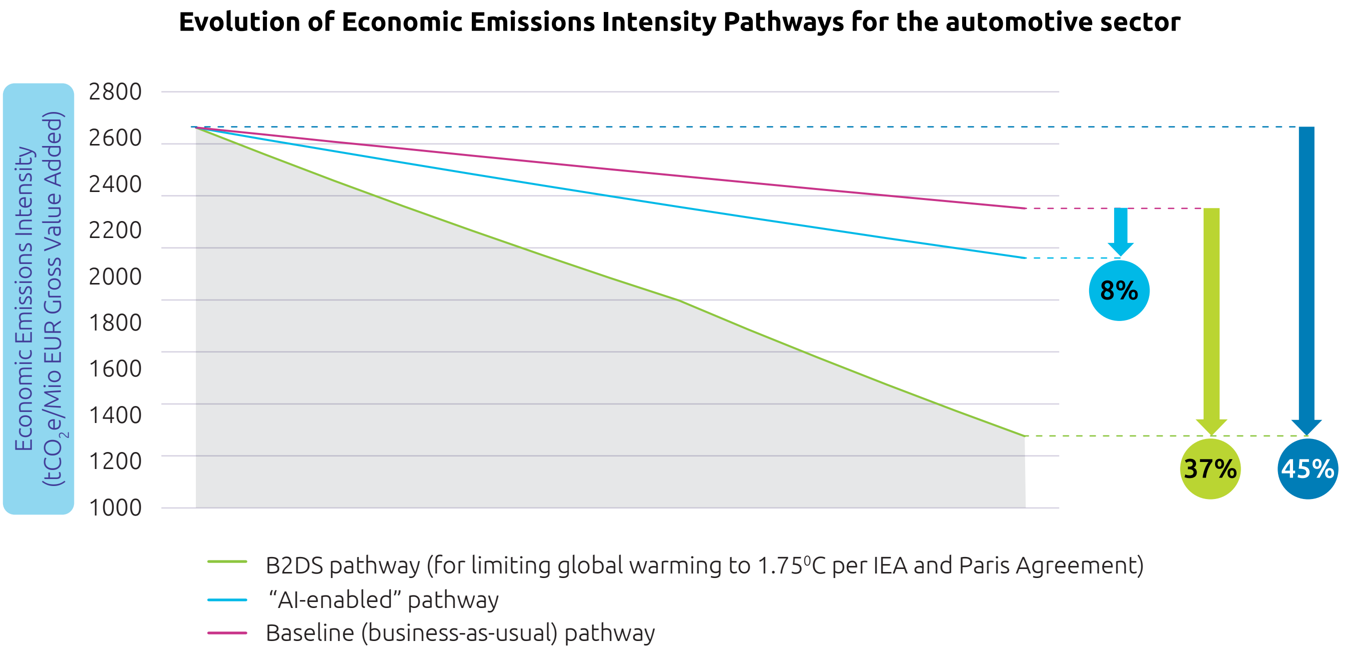
Using the XDC model and its input parameter – the Economic Emission Intensity (EEI) – it is possible to assess at what rate the GHG emissions of organizations and sectors will evolve over time in various scenarios. To model the effect of AI-enabled climate use cases on organizations' EEI – i.e. quantifying the extent to which AI help reduce EEI – we use two scenarios (see Appendix B for a more detailed view of the scenarios):

1. **Baseline Scenario:** here, the GVA and the sector's emissions continue to grow in line with historic trends with no planned emission reduction initiatives, such as using AI to curtail emissions. As the net effect of this, the EEI of organizations reduces gradually. This is in line with the "Shared Socioeconomic Pathway 2" (SSP2) scenario.

2. **"AI-enabled" Scenario:** here, the sector implements AI technologies and delivers the resulting GHG emission reduction benefits. GVA growth is assumed to follow historic trends; for the GHG emissions reduction rates, sector-specific estimates from our survey are used (the detailed methodology is described in the Appendix). For the automotive sector example, as shown in Figure 6, this scenario represents a total EEI improvement of 8% in 2030 over the Baseline Scenario. This means that by using AI-enabled use cases for emission reduction, automotive organizations can meet more than a fifth of their EEI reduction requirement by 2030.

We then compare these two scenarios with the "Beyond 2 Degree Scenario" (B2DS) of the International Energy Agency – a scenario that aims to limit global warming to 1.75°C,[30] in line with the Paris Agreement. Using the XDC Model and the emissions budgets from the B2DS, we compute an EEI target pathway for each sector. This EEI target pathway represents how fast organizations' EEI must reduce in this sector to be compliant with the Paris Agreement. For instance, the target pathway for the automotive sector requires an EEI reduction of 37% by 2030 over Baseline levels (see Figure 6).

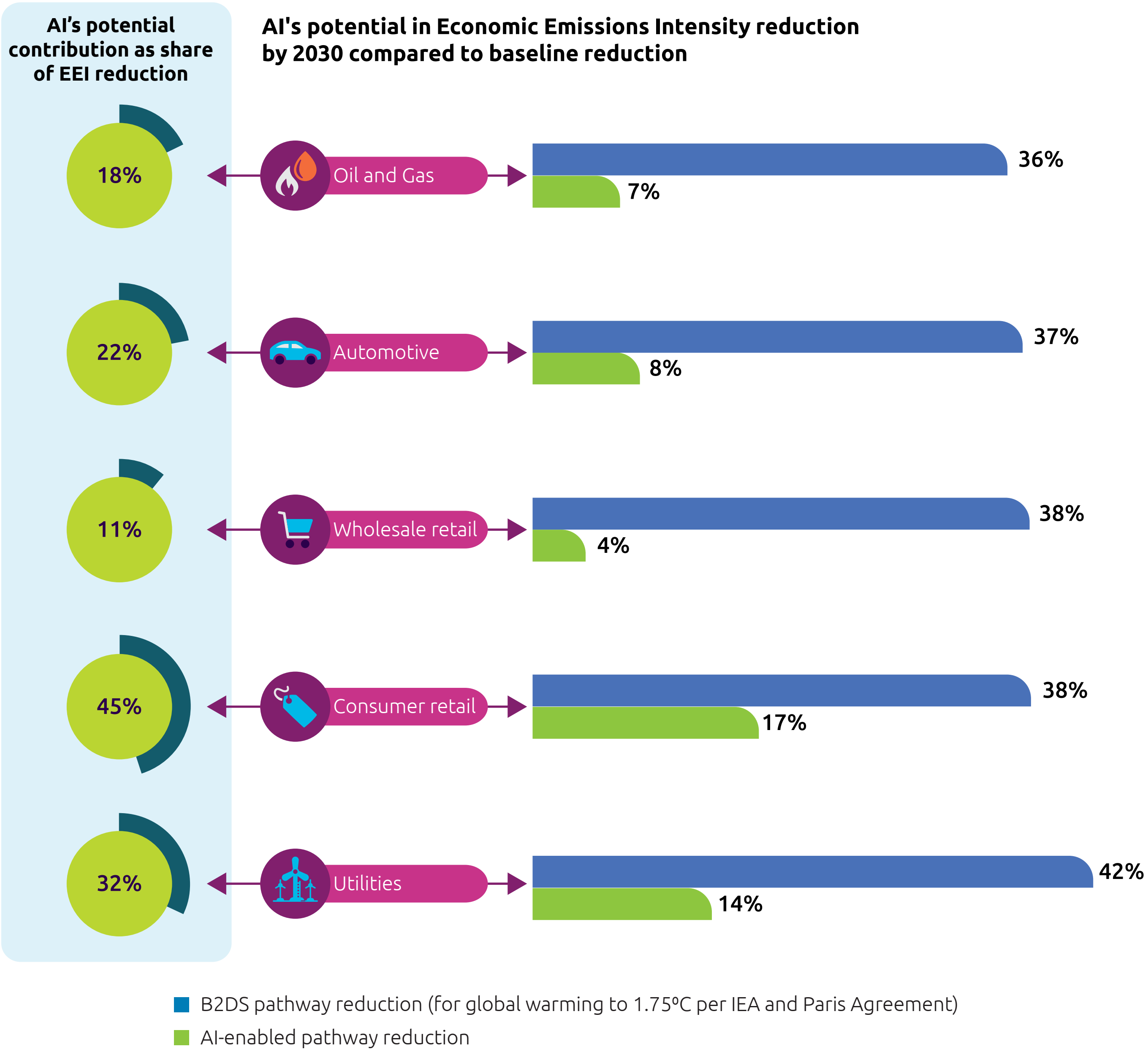
Figure 6. AI-enabled use cases have the potential to assist automotive organizations to meet more than one-fifth of their Paris Agreement emission goals by 2030



Source: Capgemini Research Institute and right. based on science analysis.
The Economic Emissions Intensity of an organization or a sector is the amount of emissions produced by it per generation of one million euro Gross Value Added (GVA). The EEI must ideally reduce with time as organization/sector grows while reducing its emissions. This reduction compared to 2018 levels is represented by EEI pathways. The B2DS Pathway represents EEI reduction aligned to the Paris Agreement goal of containing global temperature increase to under 2°C (1.75°C for B2DS). The Baseline Pathway assumes that GVA and emissions continue to grow as per historical trend. As the net effect of this, EEI reduces gradually. The AI-enabled Pathway (optimistic adoption) represents the reduction in EEI when organizations adopt AI-enabled use cases and derive their benefits on GHG emission reduction as observed in our research.

We conducted the above analysis for five sectors in our survey and for each sector, and we found that the use of AI-enabled use cases yields a 4–17% of EEI reduction by 2030 compared to the Baseline Scenario (see Figure 7). In terms of the share of target EEI reduction, AI-enabled use cases can deliver 11–45% of the requirement between 2018–30. Consumer retail has the greatest potential for AI-driven improvements at 45%, while wholesale retail offers the least at 11%.

Figure 7. AI-enabled use cases have the potential to aid organizations to achieve 11-45% of their EEI reduction targets by 2030



Source: Capgemini Research Institute and right. based on science analysis.

45%

The potential of AI's contribution to reach the required goal of IEA's Beyond 2°C Scenario for the consumer retail sector.

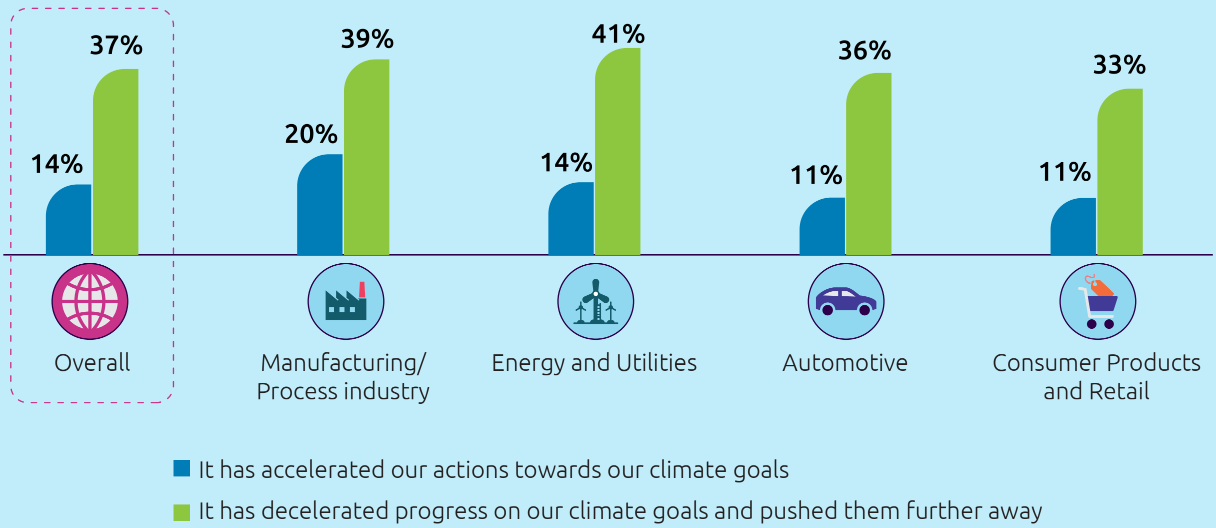
The COVID-19 crisis has slowed organizations' progress on climate goals

The COVID-19 crisis has made people more aware of sustainability issues. It has also led to some positive policy initiatives, especially in Europe. The European Parliament has put a "Green Deal" at the core of its economic recovery from COVID and it aims for the EU to be climate neutral by 2050.[31] In October 2020, the European Union parliament voted to cut greenhouse gas emissions by 60% by 2030 compared to 1990 levels.[32]

However, in the immediate term, we found that over a third of sustainability executives (37%) said that the COVID-19 crisis has decelerated their climate goals (see Figure 8). The deceleration is at the highest in the energy and utilities industry. As Dr. Faith Barol, executive director of the International Environmental Agency noted, *"Despite a record drop in global emissions this year (2020), the world is far from doing enough to put them into decisive decline."*[33]

Figure 8. Impact of COVID-19 pandemic on progress against climate goals: accelerated vs. decelerated

How has the COVID-19 crisis affected your long-term climate goals?

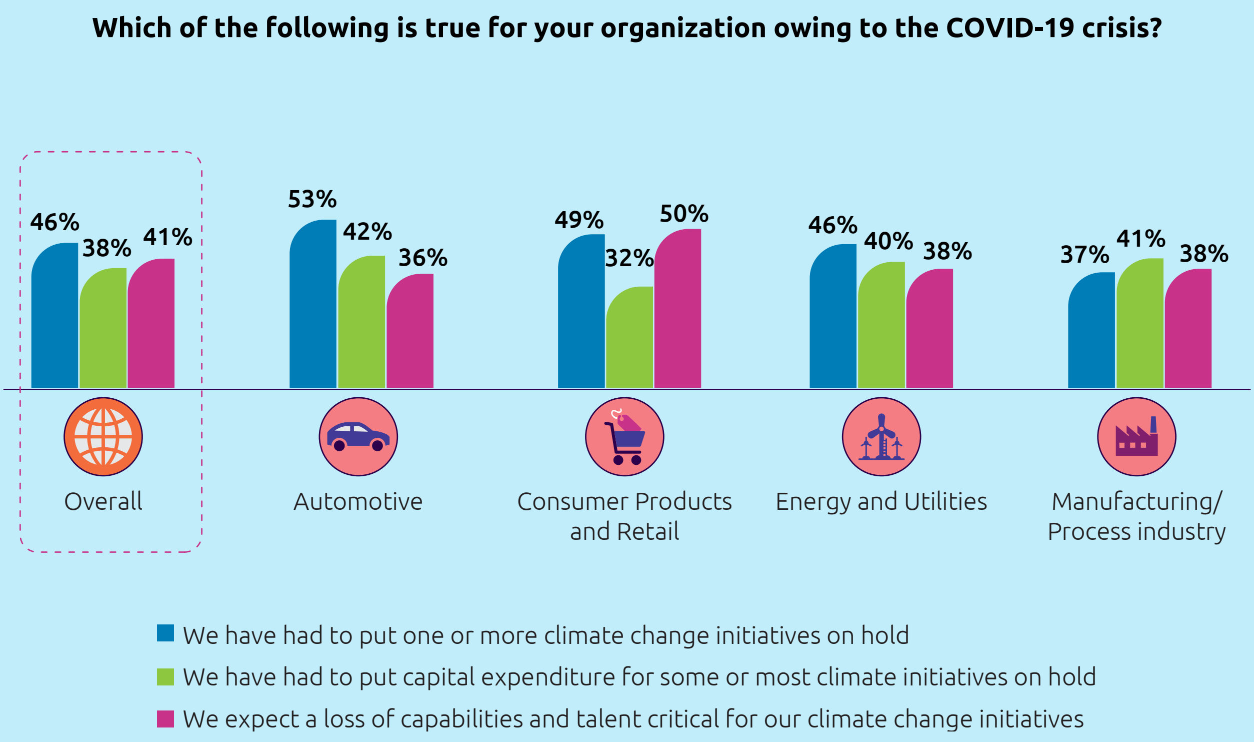


Source: Capgemini Research Institute, AI in climate action survey, July–August 2020, N=400 sustainability executives.

Looking deeper into potential reasons behind this deceleration, and as Figure 9 shows, we found that:

- 46% said they had put one or more climate initiatives on hold (this increases to 53% in automotive).
- 38% have put a hold on capital expenditure allocated for climate initiatives (increases to 47% in process manufacturing).

Figure 9. One in two organizations have put climate initiatives on hold owing to the COVID-19 crisis



Source: Capgemini Research Institute, AI in climate action survey, July–August 2020, N=400 sustainability executives.

41%

Share of organizations that expect a loss of capabilities and talent critical for climate change initiatives due to Covid-19.

3. Even though climate action is a strategic priority, most organizations are struggling to support climate action with AI capabilities

Climate action is a top priority for organizations

Climate action and controlling emissions are major strategic priorities for organizations and their leaders:

- 67% have made long-term business decisions to tackle the consequences of climate change.
- 60% of sustainability executives said that climate change strategy is embedded in their business strategy.
- 70% of sustainability executives said they have a governance body to oversee their organization's climate objectives and/or review the progress achieved by the sustainability/climate change team.

As Figure 10 shows, the most popular areas of focus are driving carbon-neutral operations, focusing on achieving net-zero greenhouse gas emissions.

Figure 10. Top five actions that form a part of organizations' climate action

1. **Carbon-neutral operations:** Carbon emissions balanced by carbon savings
2. **Paris Agreement temperature alignment:** Contributing to limiting temperature increase
3. **RE-100:** Shifting to 100% renewable energy for all operations and energy use
4. **Emission reduction:** Setting goals for science-based overall reduction of GHG emissions from operations
5. **Industry benchmark:** Benchmarking organization's climate progress vis-à-vis its industry

Source: Capgemini Research Institute, AI in climate action survey, July–August 2020, N=400 sustainability executives.

As they set their ambition and goals, half (52%) have aligned their chosen approach and actions to the wider United Nations' Sustainable Development Goals (SDG) agenda, and 37% plan to do so the future. However, in terms of their long-term strategy, 84% executives said that they would rather compensate for (or offset) their carbon footprint than deploy technology solutions to reduce their footprint (16%). This points to a less than optimal approach. This is because we will continue to see technology becoming cheaper but carbon credits are likely to get costlier (as current price levels are substantially lower than the price levels deemed consistent with achieving the temperature goal of the Paris Agreement).[34] This approach points to the fact that organizations may not be looking at the issue holistically and with a long-term view.

Few organizations are successfully combining their climate vision with AI capabilities

As we have shown above, AI can play a substantial role in ensuring organizations meet Paris Agreement goals. However, this would require having a cohesive climate strategy backed by AI capabilities. Our analysis shows that only a small minority of organizations has what it requires to successfully leverage AI solutions for climate action. As we heard from John Reilly, co-director, MIT Joint Program on the Science and Policy of Global Change, *"By this time industries are aware that greenhouse gas emissions that they release are affecting the climate. There is also the concern about how companies might be affected by climate change and how their facilities might be/are being disrupted from major storms or how the supply chains are being disrupted. They are taking various measures to reduce their emissions, although they are obviously concerned about underlying profitability. It will be critical for organizations to think innovatively including with the use of emerging technologies such as AI, to harness their climate actions."* We call this leading group the "Climate AI Champions" (see "How do we classify Climate AI Champions?" for a more detailed explanation of how we define this cohort).

"By this time industries are aware that greenhouse gas emissions that they release are affecting the climate. There is also the concern about how companies might be affected by climate change and how their facilities might be/are being disrupted from major storms or how the supply chains are being disrupted. They are taking various measures to reduce their emissions, although they are obviously concerned about underlying profitability. It will be critical for organizations to think innovatively including with the use of emerging technologies such as AI, to harness their climate actions."

John Reilly
Co-director, MIT Joint Program on the Science and Policy of Global Change

13%

Share of organizations that have been able to couple strong AI applicabilities with concrete climate action and strategy.

How do we classify Climate AI Champions?

In our analysis, we found very few organizations that have aligned their climate vision and strategy with their AI capabilities. To understand which organizations have achieved alignment, and which are therefore in pole position to turn AI's climate potential into action and value, we analyzed all surveyed organizations based on these two dimensions:

1. Climate action vision and governance

Climate vision

This covers whether an organization has an overarching climate strategy along with the relevant goals they are pursing

Execution and governance

We evaluate whether an organization has embedded their vision with their business strategy and look at their sustainability/climate change governance structure

Climate action alignment

We look at their priorities and whether execution effort is focused on the areas of their value chain responsible for the greatest amount of carbon emissions.

2. AI capabilities and execution

AI capabilities/talent

We assess organizations on whether leadership and employees are willing and able to use data for climate action

Ability to scale AI use cases

We evaluate organizations based on their success to date in scaling AI use cases for climate action

AI investment and propensity

We assess their appetite for using AI along with their committed budgets/investment

We found four broad groups of organizations within our 400 surveyed organizations (see Figure 11):

AI Advocates

They have strong AI skills but lack climate change governance, vision and execution (26% of organizations).

Climate AI Champions

They have a mature climate change vision, strategy, and strong record of accomplishment of AI implementation for climate action. They constitute 13% of all surveyed organizations.

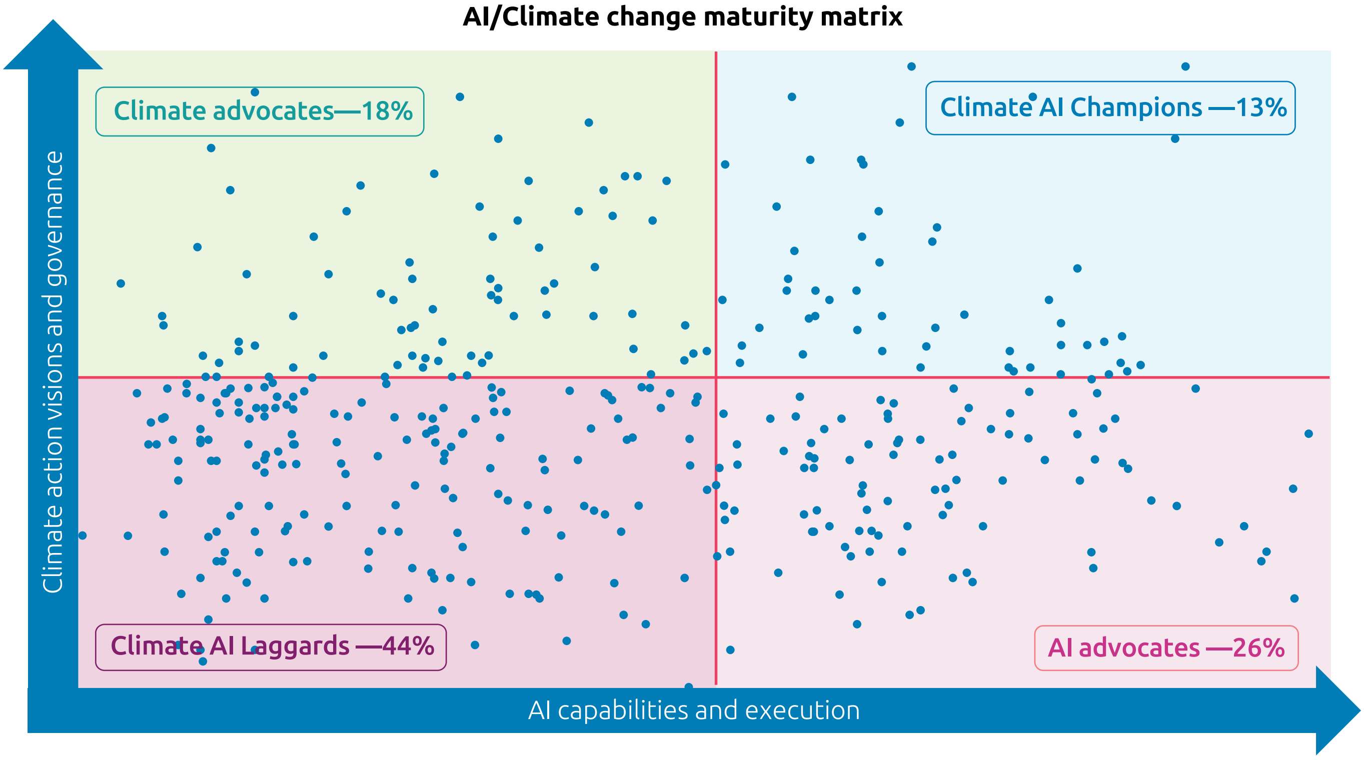
Climate AI Laggards

They lack both climate change vision and execution capability and do not possess the required AI capabilities (44% of organizations).

Climate Advocates

While they have a strong climate change vision and execution capability, they lack the AI capabilities to deliver (18% of organizations).

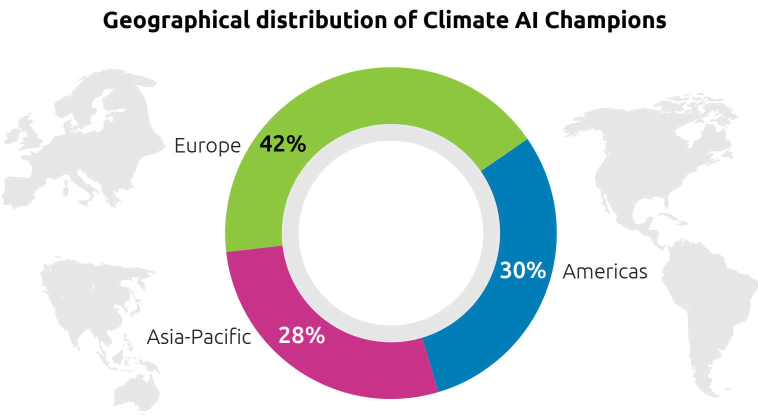
Figure 11. Only 13% of organizations combine climate vision and execution with AI capabilities



Source: Capgemini Research Institute, AI in climate change survey, July–August 2020, N=400 organizations.

Four in ten of our climate AI champions come from the EU, followed by the Americas and APAC (see Figure 12). Our sectoral analysis shows an equal distribution of Climate AI Champions among all our four sectors.

Figure 12: Climate AI Champions mostly hail from Europe



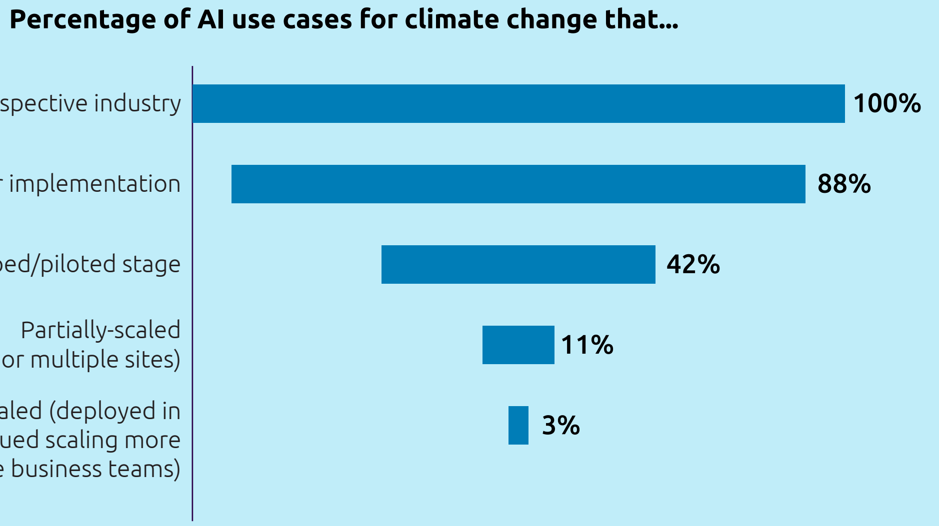
Source: Capgemini Research Institute, AI in climate change survey, July–August 2020, N=51 Climate AI Champions.

Lack of investments and skills is holding back both experimentation and the drive to scale in climate AI

Despite the considerable potential for AI for climate action, our research shows that this potential is largely untapped in terms of either experimentation or scaled deployment. As Figure 13 shows, while awareness is strong, far fewer have experimented with – or deployed – the 70 use cases we evaluated:

- While organizations have evaluated 88% of them for implementation, only 42% have been prototyped/piloted.
- 11% of all use case have been partially scaled and only 3% of all AI use cases have been fully scaled.

Figure 13. 88% of AI use cases for climate action are evaluated but less than half of them are experimented with



Source: Capgemini Research Institute, AI in climate change survey, July–August 2020, N=400 organizations.

Our survey also reveals why there is a lack of progress from evaluation of use cases (88%) to the pilot/prototyped stage (42%):

- More than eight out of 10 organizations spend less than 5% of climate change investment towards AI and data tracking.
- Half of all organization (54%) have fewer than 5% of employees with the skills to take up data and AI-driven roles.

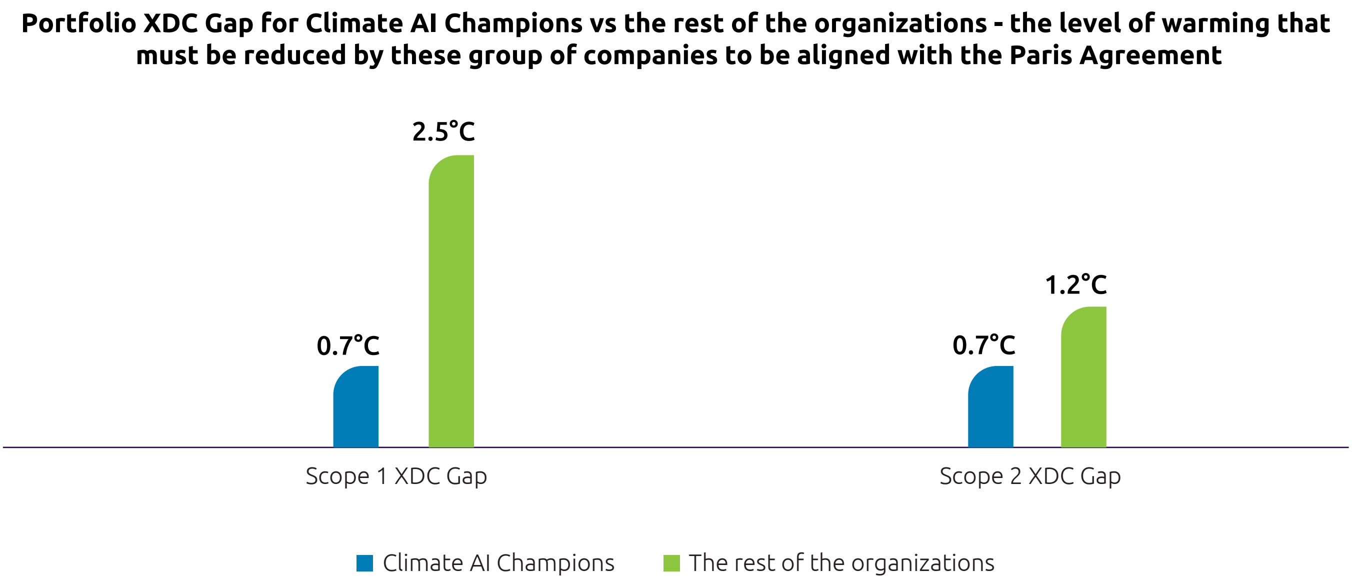
These challenges closely echo the findings from our other research on scaling enterprise AI.[35]

Climate AI Champions can take more cohesive climate action with the help of AI

To ascertain how well placed Climate AI Champions are to meet their climate goals vis-à-vis the rest of the organizations, we analyzed the temperature alignment of the Climate AI Champions with Paris Agreement goals and compared it with the other companies in our research. To do so, we have analyzed the individual companies in our survey and consolidated them on a group – or "portfolio" – level according to the classification above. This analysis results in a temperature alignment. The Portfolio XDC Gap signifies the gap that remains to be closed to meet the Paris Agreement target of <2⁰C warming (See Appendix AII on the "Portfolio XDC Metrics" for more details on this methodology.) A gap of 0⁰C represents complete alignment with the Paris Agreement. We have further broken down the resulting Portfolio XDC Gaps based on Scope 1 and 2 emissions (see Appendix D on "Emissions Accounting" for more details on emission scopes).

As Figure 14 shows, Climate AI Champions have significantly lower Portfolio XDC Gaps than their peers in both emission 1 and 2 scopes (see appendix "Emissions Accounting" for detailed scope definitions and "The XDC Model" for a description of XDC metrics). This indicates that the ability to leverage AI in tandem with a concrete climate strategy brings Climate AI Champions closer to the Paris Agreement goals.

Figure 14. Climate AI Champions are closer to Paris-Alignment compared to their peers in both scope 1 and 2 emissions.



Source: Capgemini Research Institute, AI in climate change survey, July–August 2020, N=400 organizations; right. based on science analysis. Data indicates the °C gap that organizations must close, in order to meet their sector-specific requirements in line with the Paris Agreement. Scope 1 accounts for emissions that are from internal emissions and Scope 2 accounts from electricity usage from local grids and utilities. Check appendix for emission scopes and XDC Gap definition.

0.7⁰C

The gap for Climate AI Champions to achieve their Paris Agreement goal for Scope 1 emissions, compared to 2.5⁰C for the remaining organizations.

However, while Climate AI Champions are performing better than their peers, both groups still have positive (>0) XDC Gaps, signifying that they are not yet aligned with the Paris Agreement. The XDC Gap can only be closed by decoupling emissions from economic growth, resulting in a reduction of Economic Emission Intensity (EEI), for example through the implementation of technology. This analysis demonstrates the potential of strong AI capabilities in alignment with a mature climate strategy to achieve a reduction in EEI, indicated by a closing XDC Gap.

Organizations will also need to combine the increased use of AI with further measures, e.g. stronger climate strategies, financial incentives and investments, and risk management, to close the gap further. For Climate AI Champions, the next frontier is ensuring that gains from AI implementation make themselves felt across their supply chain and indirect emissions. For the rest of the cohorts, AI can play a critical role in building carbon tracking, reporting and estimation.

What makes Climate AI Champions stand out?

As discussed, and shown above, Climate AI Champions have made considerable gains in applying climate AI to their direct emissions. This is a result of them having their core operations as a focus of their climate strategy (see Figure 15):

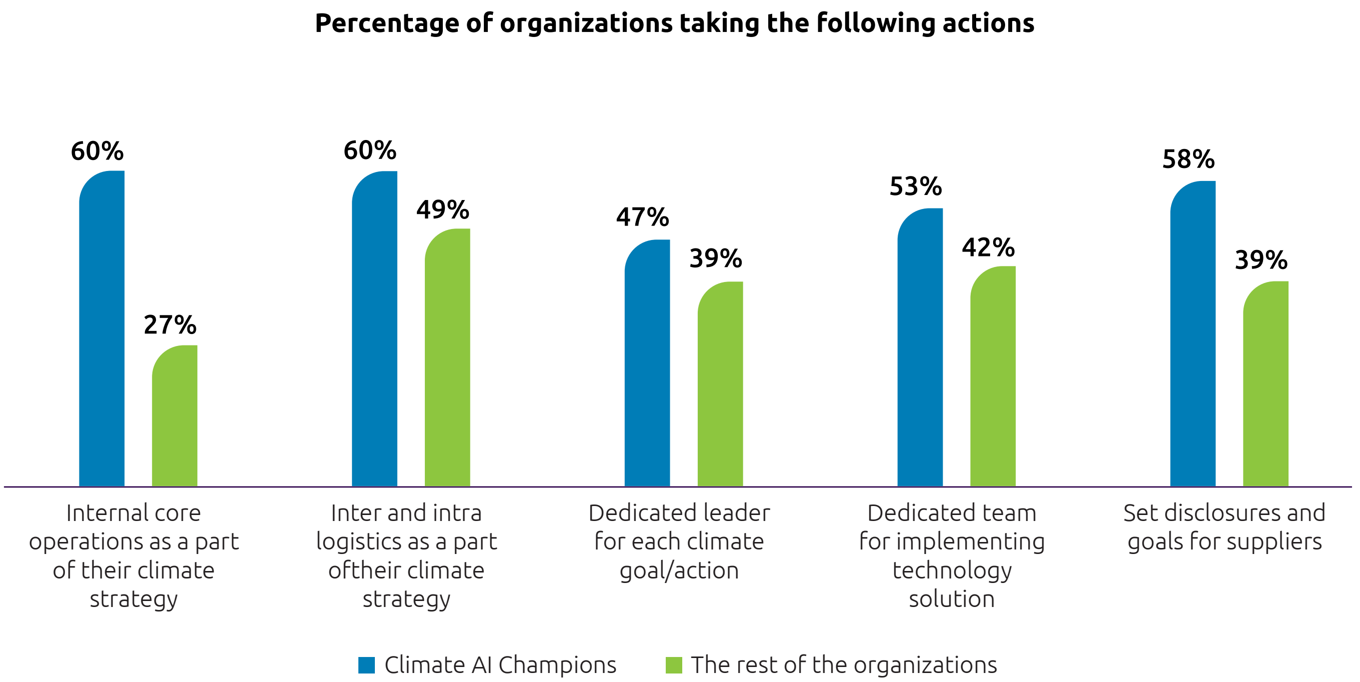
- 60% of Climate AI Champions have internal core operations in the scope of their climate strategy compared to 27% of the rest.
- 60% of Climate AI Champions have intra- and-inter logistics in the scope of their climate strategy compared to 49% of the rest.

Climate AI Champions are also able to drive their climate action and AI action by building dedicated leadership and technical teams to drive implementation:

- 47% have a dedicated leader for each climate goal and action compare to 39% of others.
- 53% have a dedicated team for implementing tech solutions compared to 42% of others.

Climate AI Champions also take into account the indirect emission contributions from their extended supply chain of partners and vendors: 58% set extensive disclosures and goals for their supplier compared to 39% of the rest.

Figure 15. Climate AI Champions have taken more progressive and concrete steps towards climate action.



Source: Capgemini Research Institute, AI in climate change survey, July–August 2020, N=400 organizations.

Interview with Matthias Berninger, SVP Public Affairs & Sustainability, Bayer

How are you using AI for climate action at Bayer?

We acquired Climate Corp. roughly two years ago, which is helping Bayer collect more and more data. One of the ways is that we use sensor technology to better understand what happens in the soil. Soil is a huge carbon sink if it's leveraged in the right way and it can also be a huge problem if it's going the other way. So that's a business where we have a lot of data points that we are leveraging with computing technologies and artificial intelligence applications.

Do your AI and sustainability teams collaborate for climate outcomes?

Yes, we do. For example, the implementation of quantitative sustainability targets is only possible through a conversation and through a strategic collaboration with the IT teams. An area where we look at AI is for outcome-based pricing models. So, for example, how can you transform a business that is built on selling seeds and pesticides to a business that sells a solution combined with a guaranteed outcome. Outcome-based pricing models like these are hugely important for sustainability and require deep integration of IT and artificial intelligence with what you're trying to achieve.

The same is true in the biological space and if you look at the Bayer seed business. It's basically a business that uses everything from GMO to gene editing to genome analysis. The whole process of developing new seeds is a fully integrated business that uses all kinds of artificial intelligence. Computing power meeting biology is one of those big trends that I believe will replace the classic discussion about artificial intelligence fairly quickly.

60%

Share of Climate AI Champions that focus on internal core operations as a part of their climate strategy vs. just 27% of the rest of the organizations.

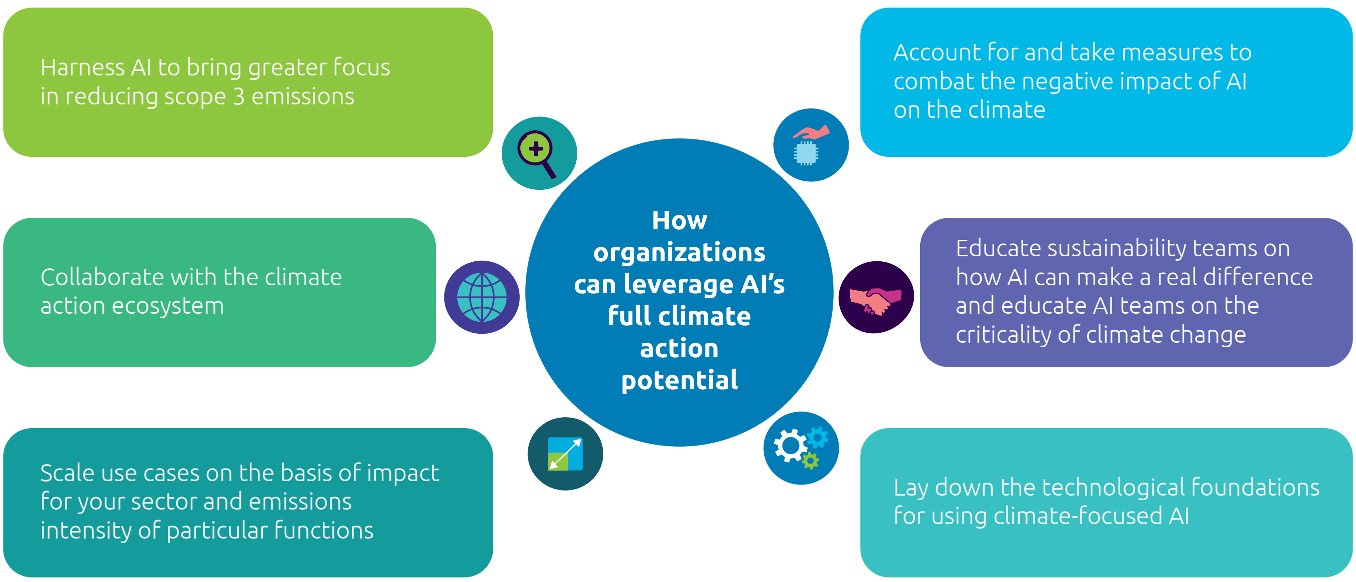
4. Recommendations: How organizations can leverage AI's full climate action potential

Sustainability and the determination to address climate change is an increasingly important element of performance and critical for an organization to meet its stakeholders' expectations, including investors, consumers, employees and communities. To meet increasing societal and stakeholder expectations, organizations are looking beyond just 'profit' to a wider business 'purpose'. *"Companies with strong sustainability strategies significantly outperform the market – that is the conclusion of recent papers from some of the world's leading business schools."* says Tom Schalenbourg, sustainability development director at Toyota. *"As a result, investors are paying more attention to sustainability. In turn we see an increasing number of our customers passing on these changing expectations from their shareholders into strict sustainability criteria for their suppliers. Integrating sustainability into the business strategy has become a prerogative for businesses in every sector to continue to attract investors, customers as well as talented employees."*

It is critical, therefore, that organizations leverage AI's potential in the sustainability space. As Meghna Tare, chief sustainability officer, University of Texas, said, *"Tackling climate change has to be part of a strategic plan for every organizations. Artificial intelligence (AI) appears naturally poised to address transformational challenges of sustainability such as climate change, transportation, building, and energy efficiency. Integrating AI into long term vision and strategy will get the buy in of the employees and drive innovation at scale"*

We believe that six action areas are critical as shown in Figure 16 below.

Figure 16. Key actions for organizations to leverage to full potential of AI for climate change



Source: Capgemini Research Institute analysis.

Account for and take measures to combat the negative impact of AI on the climate

Despite the advances made in cognitive computing, AI systems can consume a lot of power and can generate high volumes of climate-changing carbon emissions. Even before beginning to deploy AI use cases, organizations need to carefully assess the environmental impact. Organizations need to build greater awareness and take actions to ensure that the benefits of their AI deployments outweigh their emissions 'cost'.

A study last year found that training an AI language-processing system under research stage produced 1,400 pounds of emissions – about the amount produced by flying one person roundtrip between New York and San Francisco.[36]

However, it was pointed out that this 2019 study focused on natural language processing (NLP) models, which are among the largest AI models given their objective of mastering the human language.[37] As we heard from David Rolnick, chair, Climate Change AI and assistant professor of Computer Science at McGill University, *"The training of some AI models, in particular for natural language processing, can use considerable time and energy, though other AI models can run on a laptop."*

Use available tools to measure, monitor and track carbon footprint of AI:

There are various approaches to assessing the environmental impact of AI. The ability to measure and report on the CO_2 footprint would help increase the general awareness of the severity of the problem. A working paper from researchers of Stanford, Facebook AI Research, and McGill University details out a tool that could help measure both how much electricity a machine learning project will use and how much that means in carbon emissions.[38] In another paper issued in July 2019 by the Allen Institute for AI, the authors proposed using floating point operations as the most universal and useful energy efficiency metric.[39] Another group developed a Machine Learning Calculator, which aims to quantify the GHG emissions of machine learning.[40]

We tried the initial method to ascertain the GHG footprint of some of the popular AI use cases. The factors that were used to arrive at these analyses were: duration of the process, average power drained, cooling consumption factor, and unit conversion factor. Our analysis shows, for instance, that the GHG emissions produced in training and executing AI systems vary widely from a few grams of CO_2 eq. to a few kilograms, yet they are very small in comparison with the overall GHG footprint of a large organization (see Figure 17).

Figure 17. GHG footprint of a sample of individual AI applications

AI use case	GHG emissions produced in...		Average organization emissions
	Build/training phase	Run/execution phase	
Image recognition system for quality control at a plant	**10 kg** of CO_2 eq.	**0.3 kg** of CO_2 eq.	**6 million ton of CO_2 eq.** – the average annual Scope 1 emissions for a top 30 consumer products manufacturer.
AI-based optical character recognition for a large energy company	**0.78 kg** of CO_2 eq.	**0.96 kg** of CO_2	**40 million ton of CO2 eq.** – Scope 1 emissions for a large oil & gas major in Europe.

Source: Capgemini Research Institute Analysis. Carbon Disclosure Project, Climate Change 2019 reports submitted by large organizations across sectors.

It is also worth noting that similar algorithms under differing conditions (training data, server hardware, training time, cloud provider etc.) can have different GHG footprint.

Given this is still an emerging area of research, this recommendation is based on what knowledge is already available. In the coming years, we expect this field to develop much further and expect greater insights into the assessment and monitoring of AI systems.

Build capabilities to measure AI's carbon footprint over its lifecycle: AI applications result in GHG emissions due to electricity consumption primarily during their development phase which involves training the AI algorithm and the execution phase involving running the AI application. The lifecycle of an AI project extends beyond these stages and also involves cloud/hardware procurement, data collection, storage, among others. All these stages would have a GHG footprint which must also be accounted for. Organizations can also build capabilities and work with tools mentioned above to effectively measure, monitor and report the carbon footprint of their AI projects. Organizations can also work on a more detailed lifecycle assessment for AI systems in order to assess the environmental impacts associated with all stages of the AI system (data collection, storage, training, testing, operation, as well as the procurement of hardware and cloud services and so on) as well as various AI-enabled use cases.

"Tackling climate change has to be part of a strategic plan for every organizations. Artificial intelligence (AI) appears naturally poised to address transformational challenges of sustainability such as climate change, transportation, building, and energy efficiency."

Meghna Tare
Chief sustainability officer, University of Texas

Conduct an impact analysis before deploying AI at scale: Consider energy-based costs vis-à-vis benefits of deploying new AI models. Conduct a full cost benefits analysis before AI deployment to assess the tradeoff between efficiency gains and costs (including energy costs) of deploying AI. The use of AI must be taken forward for experimentation and scale only if the overall impact on the climate is significantly more positive than negative.

Choose a region for your server which ensures smaller environmental impact: The environmental consequences and the GHG footprint of AI projects can vary significantly on the basis of the location of the servers and data centers hosting AI applications, due to the energy mix of a particular location. Thus, organizations need to make careful considerations about various geographies and the kind of emissions they can expect from their server or data center.

Design and deploy efficient and sustainable AI applications: While individual AI applications may have small GHG footprint in comparison to the overall GHG emissions of large organizations, it is important to acknowledge this footprint and take active steps to manage it. We believe that optimizing AI training and execution can significantly limit its climate impact, when designed and deployed responsibly. We advise organizations to design efficient and sustainable AI applications, which ensures high accuracy while keeping in mind other factors such as environmental costs, server costs in mind as opposed to AI of the highest accuracy and precision that has no consideration for the impact on climate. As Lynn Kaack, chair, Climate Change AI and a postdoctoral researcher at ETH Zurich mentioned, *"When you use technologies like IoT with AI to increase operational efficiency in a transportation or energy system, it doesn't mean that you're actually reducing emissions unless you optimize for that. If you optimize for costs, then you don't necessarily optimize to reduce greenhouse gas emissions. So, it's really important how you use AI, and to view those technologies as a tool to help with a larger strategy to address climate change."* Ongoing research points to ways in which machine learning can be made greener, such that the training of AI models is not as energy intensive as it is slated to be. The path to making AI green depends on how it is designed, developed, and used.

In addition, MIT researchers have developed a new automated AI system for training and running certain neural networks. Results indicate that, by improving the computational efficiency of the system in some key ways, the system can cut down the pounds of carbon emissions involved – in some cases, down to low triple digits.[41] Techniques such as Transfer Learning help AI practitioners use pre-trained models for AI algorithms that require vast computing power (and thereby electricity), such as computer vision and natural language processing. It significantly reduces computing requirement for the training phase, thereby bringing down electricity consumption and GHG emissions. Also, field programmable gate arrays (FPGAs) are being recently adopted for accelerating the implementation of deep learning networks due to their energy efficiency.[42]

Organizations can focus on various training techniques to design and deploy similar forms of efficient AI.

Collaborate with the AI expert community internal and external to the organization: A large community of AI experts collaborates globally across open source forums. Participating in these forums helps in large scale sharing of innovation, best practices, and resources. Encourage internal collaboration across teams of AI experts, practitioners, data scientists, that may be separated geographically, or into various business units and functions. AI models and codebases with best practices for energy conservation and sustainable use must be shared internally for wider adoption and overall resource saving.

Educate sustainability teams on how AI can make a real difference and educate AI teams on the criticality of climate change

Climate change cannot be a single team's responsibility. There has to be wider and shared accountability across many teams and the employee base. *"Climate change is everyone's responsibility,"* says Zoisa Walton, CEO of Octopus Energy. *"Everybody is accountable for our mission and what we're doing to support global issues like climate change. Everybody is responsible for how our customers react to it."* While AI has a significant role to play in tackling climate change, as we showcased in section 1 of this report, business and sustainability executives are not yet aligned on the idea, neither are AI teams intentional about building sustainable AI and using it to harness climate action. This is an area where critical steps need to be taken (see Figure 18).

Figure 18: Building awareness and education are critical for climate action

Build awareness of sustainability teams on AI	
• Educate sustainability executives and employees on AI's potential and shift leader and employee mindsets • Bring about behaviourial change to drive greater sustainable AI adoption	*"There's a big component of behavioral change that needs to be addressed when it comes to adopting advanced technology solutions such as AI for climate change because human behavior is not always 100% controllable and may influence how technology is used."* • Gabriela Prata Dias, head of the Copenhagen Centre on Energy Efficiency.
Educate AI teams on sustainability and climate change	
• Make AI teams aware of: – The climate impact of their projects and how they can minimize their AI footprint and be more sustainable – Thinking innovatively about ways in which AI can be used to accelerate climate action for the organization and also learn to develop AI systems that work for sustainability initiatives • Drive top-down cultural and mindset change to bring an unrelenting focus on climate change, alongside an "AI-first" mindset.	*"The first step is to really care about climate, which means actually embedding climate impact as a priority in all that you do. The second thing is communicating that and empowering your employees to make climate a priority. And the third one is measure – you cannot make the right decisions unless you know what is going on both within your organization and from your suppliers and consumers."* • Carolyn Hicks, co-founder and head of finance and operations at Brillpower, a clean-tech startup

Source: Capgemini Research Institute analysis.

Lay down the technological foundations for using climate-focused AI

While getting the technology foundations for AI right is critical, only 33% have access to tools that incorporate AI algorithms for climate action.

Without this foundation, organizations will struggle to accurately track and monitor their carbon emissions and use the resulting data to power climate-focused AI tools. Organizations that are taking a lead in this area are actively tracking thousands of data points to produce critical insight and performance reporting. *"Where possible, we track our emissions using actuals from our sites."* says James McCall, Senior Director Global Climate and Supply Chain Sustainability, P&G. *"This includes detailed information such as electricity or natural gas invoices and onsite energy monitoring. This site level data, across 140 sites globally feeds into our central sustainability tracking software, resulting in over 30,000 data points. This data provides the backbone for monthly/quarterly internal reporting, footprint reduction projects, and on an annual basis for our external citizenship report – allowing P&G to turn data into action."*

Kuehne + Nagel – a global transport and logistics company based in Switzerland – launched a big data and predictive analytics powered platform called Sea Explorer that allows their customers of sea freight services to track various parameters of shipping vessels from a business and environment perspective.[43] For instance, customers can track and optimize business KPIs such as transit times, carrying capacity, and balance them with indicators of carbon emissions, allowing them to reduce carbon footprint within supply chain.

Laying the technological foundations does not just mean investing in the infrastructure but also bringing the right talent pool into the organization for designing, developing, and running these systems. In our survey, only 32% respondents said that they have understanding of where AI can be used and 24% said they have the required AI skills they need to implement AI focused on the climate change space.

33%

Share of organizations that have access to tools that incorporate AI algorithms for climate action.

Build a data-driven culture

The experts in our survey point to the absence of a data-driven culture (86%) as one of the major challenges in adopting AI for climate change. Organizations need to take a data-driven and scientific approach to tackling climate change with AI.

- Sustainability leaders, other than routinely tracking and reporting emissions, need to consider their major emissions areas and their profile of emissions,
- AI teams could potentially help in identifying what AI systems could be harnessed to reduce this based on the data available.
- AI and data teams also need to allow for greater data democratization and access to trusted data so as to allow for other teams and non-specialists to benefit from it.

A data-driven culture – with a focus on climate change – can also help attract the right talent, and help organizations differentiate as an employer of choice. This could be particularly beneficial for AI teams, where talent shortages are a major problem, as we shared earlier in this section.

"We are very focused on collecting and accurately storing and cataloguing emissions related data. Today, it helps us make sound decisions about sustainability and climate change. Tomorrow, it can be useful for AI systems that may help us with monitoring our emissions. Investing in data management today will allow us to adopt advanced technologies such as AI for tackling climate change in the future."

-Maya Colambani, Director of Sustainability at L'Oréal in Brazil.

Scale use cases on the basis of impact for your sector and emissions intensity of particular functions

Different sectors and functions in the value chain may have different AI use cases that could prove to be most beneficial. Prioritizing the right use cases for the right areas is critical, as we heard from Gabriel Blanco, chair, Technology Executive Committee, UNFCCC. Professor titular, Universidad Nacional del Centro de la Provincia de Buenos Aires, *"Not every technology or solution works in every place. It is not just a one size fits all. It does not happen that way. You need to start looking at how to assess existing technologies and adapt those technologies to particular contexts and circumstances, depending on need and applicability."*

- Predictive maintenance is important in the automotive sector. General Motors deployed a cloud-based image classification tool on nearly 7,000 robots to detect component failures before they happened. It was able to detect 72 instances of component failure that could have led to unplanned downtime.[44] This directly results in better industrial efficiency and thus better productivity per capita CO_2 emissions.
- In the public sector, Sveaskog – Sweden's largest forest owner and producer of sawlogs, pulpwood, and biofuel – has used AI on satellite images of forests to quickly and accurately identify forest areas affected by ravenous spruce bark beetles and to prevent them from spreading.[45] This helps quick management of affected trees, and ultimately preserve the local ecology.

Expert views on harnessing AI across functions and sectors

On food waste

“We’re not using AI right now, but we will use AI in the future, for example, to enable people to just snap a photo of their food, rather than having to write a description; AI would be able to help code that up. The OLIO app today is a fraction of our full vision. We will be harnessing AI and machine learning to continue to improve the efficiency of the platform and quality of the user experience."

- Tessa Clarke, co-founder of Olio, a free app that connects users (households or local businesses) who have unwanted food and those living nearby who would like it

On power systems

“AI can be very helpful in places where information or insights are lacking or might not be collected through traditional methods. For example, it’s very hard to assess when the next storms or drought could affect the power systems in Africa or Asia if you don't know power infrastructure currently operates. AI can then help fill these data gaps with new methods. With the use of machine vision, power infrastructure can be identified and information could be updated regularly. Moreover, natural language processing can be used to standardize such collected information and make it more widely accessible.”

- Johannes Friedrich, senior associate within the Global Climate Program, World Resources Institute

On clean energy sources

"AI can provide better forecasts for electricity grids. It can forecast, for instance, the solar power output, which helps balance supply and demand on the grid. This can in turn result in less need for power generated with fossil fuels. AI can also help with developing better batteries, for example, for understanding such aspects as the degradation behavior. Or it can help to find new materials in basic research, which is essential to develop the kind of next generation energy technologies that are needed to transition away from fossil fuels.”

- Lynn Kaack, chair, Climate Change AI and a postdoctoral researcher at ETH Zurich

Collaborate with the climate action ecosystem

Organizations need to collaborate with a global climate action ecosystem, which will include peer organizations, partners, governments and startups. *"I'd encourage businesses to find others in their sector or elsewhere who want to make a positive change because there are loads of those organizations out there,"* says Professor Tim Lenton, professor of climate change and earth system science, University of Exeter and Director of the Global Systems Institute. *"The more we see networks of businesses and other actors coming together, the better our chances."*

James McCall, Senior Director Global Climate and Supply Chain Sustainability, Procter and Gamble, also believes that a collaborative approach is critical. *"P&G is committed that by 2030, no P&G plastic will find its way to the ocean,"* he says. *"But we can't do that alone. We partner with groups like the Alliance to End Plastic Waste, which is a unique collaboration of companies across the end to end supply chain from plastic producers, to manufacturing, to waste disposal and recycling. AEPW brings together industry, governments, and civil society with a common, urgent focus of ending plastic in the environment."*

While organizations are focusing on industry collaborations, working with tech startups or firms to find innovative tech solutions is receiving less attention. At the same time, fewer are looking to explore newer avenues, such as academia for advanced research, or governments and regulators to shape policy:

- Fewer than half of organizations work with tech startups (47%) and tech companies (43%) to deploy innovative tech solutions.
- Only 28% of sustainability executives said they collaborate with NGOs and academia to fund high impact research and with local governments to shape policies.

"The climate community across science, politics, and the private sector – including the technology community and pioneers in the fields of digitalization and artificial intelligence – are not cooperating currently and are not well connected," says Dirk Messner president, German Environment Agency Board Member, Stockholm Energy Institute. *"There is a complete disconnect between the sustainability community on the one hand and on the technological pioneers on the other hand. Communities are not able to benefit from technological innovations in these fields to enhance climate protection."* Organizations need to work through a cross-section of collaborations, be it with science based targets to set climate related goals, or build cross-functional teams with academia and think tanks to progress and monitor climate goals and actions or be it working with governments to develop and support sound policies to encourage sustainable deployment of AI and other technologies to meet climate goals as well as to develop other climate-related policies.

28%

Less than a third of organizations collaborate with NGOs or academia for climate action.

"P&G is committed that by 2030, no P&G plastic will find its way to the ocean. But we can't do that alone. We partner with groups like the Alliance to End Plastic Waste, which is a unique collaboration of companies across the end to end supply chain from plastic producers, to manufacturing, to waste disposal and recycling."

James McCall,
Senior Director Global Climate and Supply Chain Sustainability, Procter and Gamble

Harness AI to bring greater focus in reducing scope 3 emissions

Organizations need to take more active steps to reduce their scope 3 emissions. If they fail to do so, reducing overall emissions will continue to be an uphill task. Organizations need to work with consumers, clients and partners to increase awareness of their carbon footprint and offer low-carbon solutions wherever possible.

Organizations need to also build renewed focus on supply chains to reduce scope 3 emissions. In July 2020, the European Commissioner for Justice committed to develop legislation by 2021 that would require European companies to carry out environmental and human rights due diligence in their supply chains. While the details have not yet been fully developed, it was explained that the legislation would be "intersectoral, mandatory, and of course with a lot of possible sanctions."[46] Speaking about the benefit of AI in supply chain, Steve Evans director of research in industrial sustainability, University of Cambridge mentioned, *"Benchmarking and simple information sharing in a way that's useful is important. I think that with AI, it is going to get easier to observe patterns in data and improve our benchmarking and thereby reduce impacts and risks across the supply chain."*

As we heard from Kate Larsen, founder and CEO at SupplyESChange, an advisory network guiding environmental and social improvements in supply chains, *"We are in early days of using AI for supply chains where so many companies' largest climate change footprints lie. AI depends on data and many companies have not been tracking enough onsite verified supply chain GHG data yet. So, AI is not going to be impactful enough to help incentivize reducing some of the largest climate change causing GHG emissions until we get more of the basics done; robustly and collaboratively auditing and verifying scope 3 emissions from supply chains to gain better data."*

Our recent research study on sustainability in the consumer products and retail sector found that nearly 80% of consumers want to make a difference when it comes to "saving the planet for future generations."[47] Companies are aware of how important this issue is to consumers. *"It's really strategic to be committed to climate change for many reasons,"* said Maya Colambani, director of sustainability at L'Oréal in Brazil. *"One of the main reasons is that the consumer is looking for a sustainable company. We have no way to escape from our duty and it's really important in order to reinforce our relationship with our consumer."* Speaking from the perspective of also making sustainable choices affordable to consumers, Sanand Sule, Co-founder of Climate Connect Technologies, said, *"If you give up your diesel or petrol car and if you adopt an EV as your next car, you take a step towards de-carbonizing the world. But, just because of the cost factor, consumers struggle to opt for it. I think along with consumer awareness, cost is an additional pain point."*

Organizations can take various steps to build consumer awareness. For example, by eco-labeling of apparels organizations can create transparency about the environmental impact of that particular apparel. Organizations can also have dedicated consumer-facing microsites showing product makeup and origin. Moreover, through AI-powered gamification, companies can highlight how consumers are bettering their carbon footprints with every buying action and offer more eco-friendly choices to those who care.[48] These sorts of innovations – along with clear guidance from standard setters – can transform awareness. *"It would be nice if there was a regulatory rule that required less waste in our area – batteries,"* says Carolyn Hicks, co-founder and head of finance and operations Brillpower, a startup. *"Then, we would not have to rely on the individual decision maker's choice - it would just happen. If battery products are properly endorsed with markings and stamps to say that a technology is more sustainable, it makes life a lot easier not only for consumers, but also the businesses doing the providing."*

Conclusion

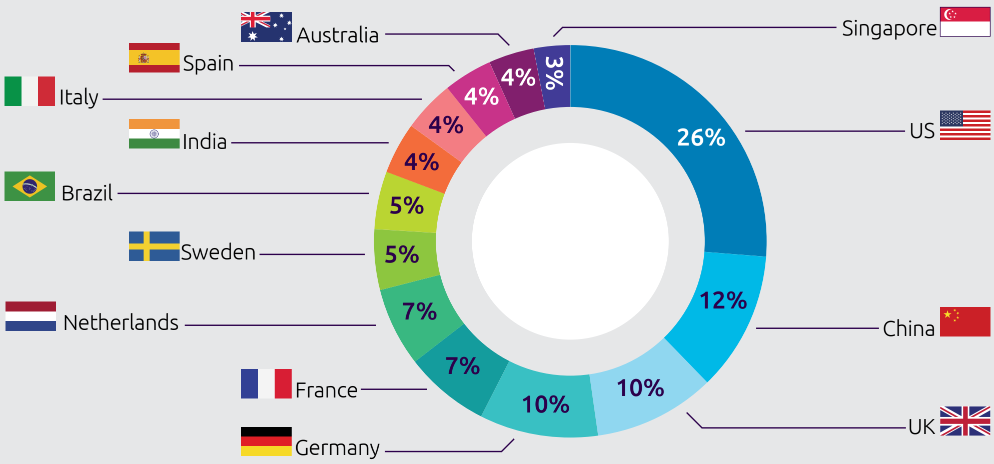
The coming decade will be critical when it comes to climate action and whether the world manages to avoid highly damaging climate change. Organizations across sectors need to take urgent actions to reduce their emissions. While many traditional methods are being implemented, innovation is critical, and we have found that using AI remains largely unexplored. Leveraging AI's full climate action potential sustainably is mission-critical for the world as a whole. To kick-start progress, organizations need to account for and take measures to combat the negative impact of AI on climate, educate sustainability teams on how AI can make a real difference and educate AI teams on the criticality of climate change, focus on building technological foundations, scale most impactful use cases, collaborate with the larger climate ecosystem and finally align scaling of AI use cases with emissions. Doing nothing is not an option.

Research methodology

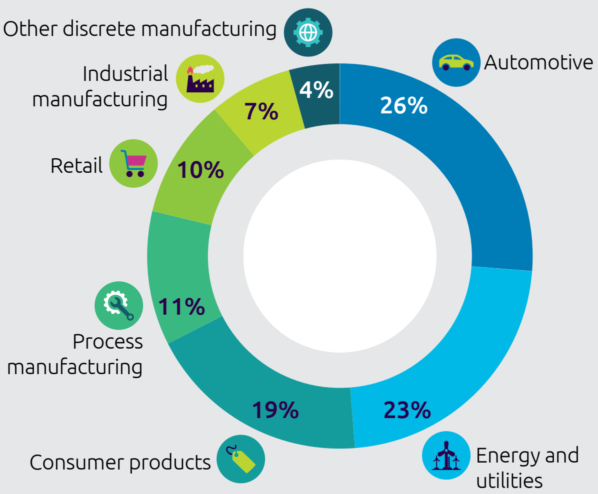
- To estimate and quantify the impact of AI on GHG emissions of organizations, we partnered with right. based on science for their expertise in XDC Model Methodology. It is the only methodology of its kind to integrate a full climate model (also used by the UN Intergovernmental Panel on Climate Change (IPCC)). It is science-based, peer-reviewed, forward-looking, TCFD-compatible, aligned with the EU Green Deal, transparent and Open Source (currently for academia; fully Open Source from 2021). Please see Appendix for more details on this methodology.
- On the primary research front, we surveyed 800 executives from 400 organizations. Each organization has two respondents: one sustainability executive and one business or technology executive. As well as the survey of executives, we surveyed a panel of 300 experts: regulators, academics, and AI subject matter experts.
- We complemented the surveys with in-depth interviews of over 40 sustainability experts, business/tech experts, AI practitioners and startups, think tanks and academicians working in the field of AI and/or climate change.

Organization survey

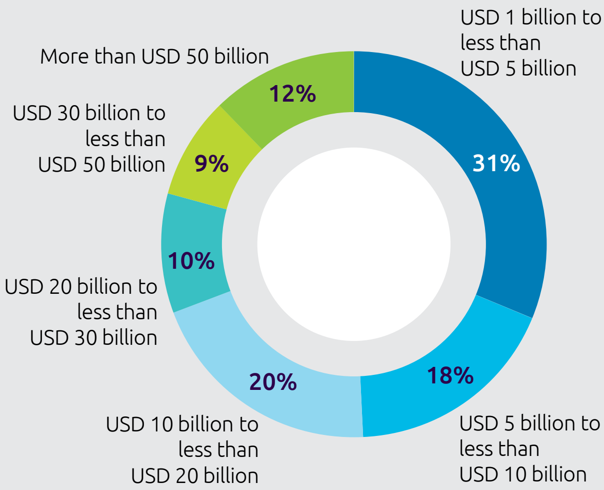
Organizations by headquarters



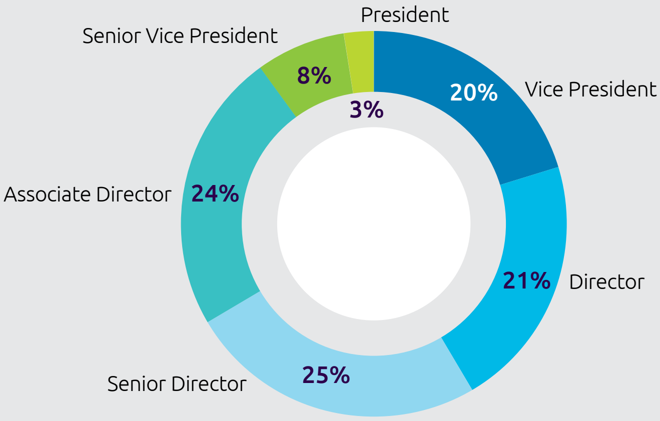
Organizations by sector



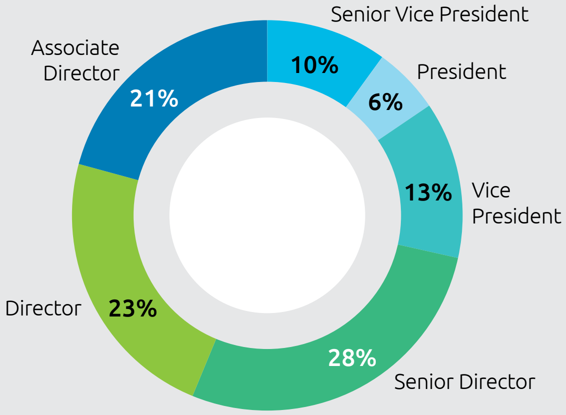
Organization by revenue



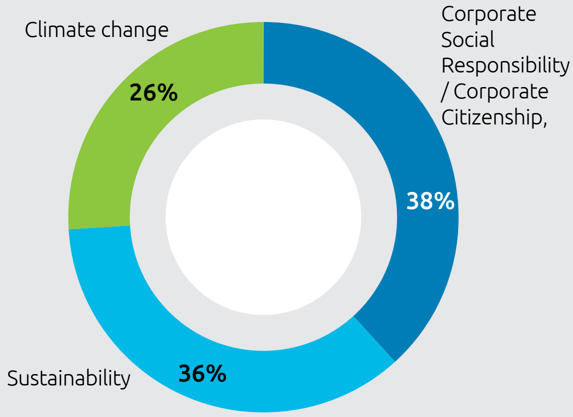
Designation -Business/Technology executives



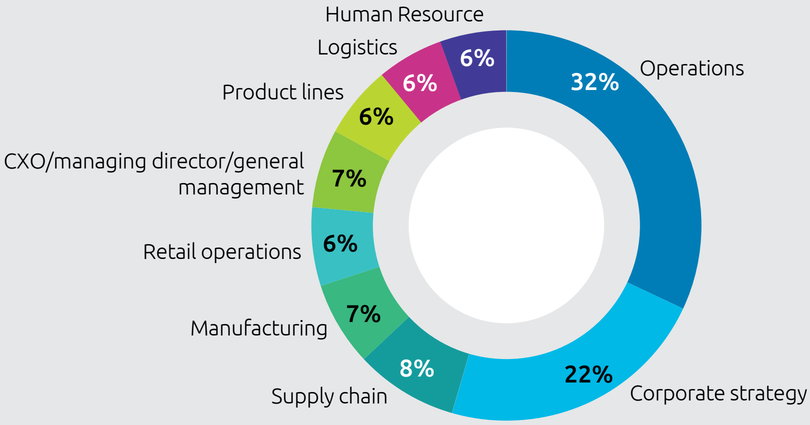
Designation - Sustainability executives



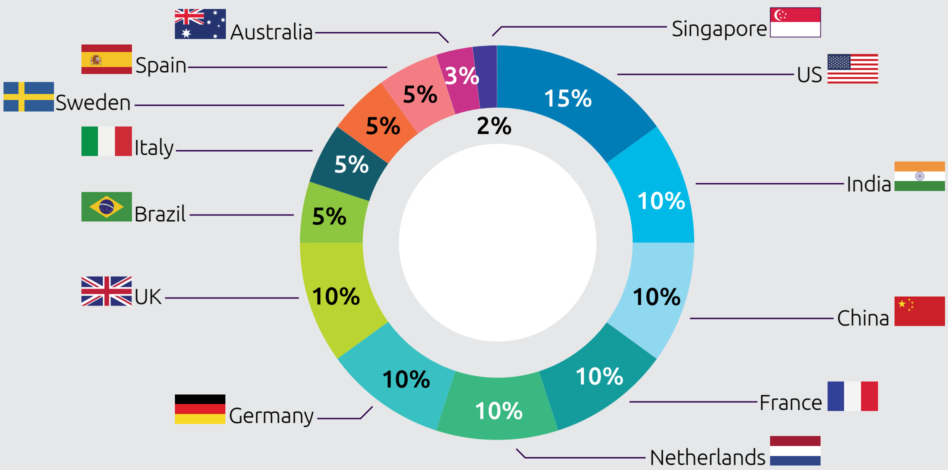
Functional Area - Sustainability executives



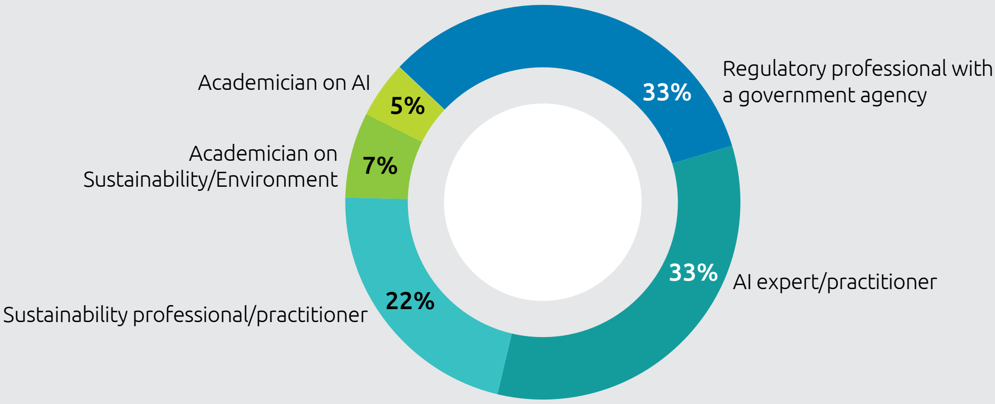
Functional area –Business executives



Expert by country of residence



Experts -by function of expertise



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Appendix

A. The XDC Model

The X-Degree Compatibility (XDC) Model, developed by right. based on science (right.), calculates the contribution of a company, portfolio or any other economic entity to climate change, answering the question: How much global warming could we expect, if the entire world operated at the same economic emission intensity as the entity in question under a given scenario? Results are expressed in a tangible degree Celsius (°C) number: the XDC. This science-based temperature alignment metric offers unprecedented transparency to companies, banks, investors, and the public on climate risk and climate alpha. Thus enabling the transition to a <2°C economy and to fulfilling the Paris Climate Agreement (Paris Alignment). The XDC Model is the only methodology of its kind to integrate a full climate model (also used by the UN Intergovernmental Panel on Climate Change (IPCC)). It is science-based, peer-reviewed, forward-looking, TCFD-compatible, aligned with the EU Green Deal, transparent and Open Source (currently for academia; fully Open Source from 2021).[49]

I. The XDC Climate Metrics

The XDC Model generates four basic climate metrics: the Baseline XDC, the Scenario XDC, the Sector Target XDC, and the XDC Gap.

The Baseline XDC: expresses the °C of global warming if the entire world economy were to operate with the same Economic Emission Intensity (EEI) as the company in question (see below for calculation process). The underlying assumption is that the historic ratio between emission and GVA growth remains stable. These growth trends have been defined by SSP 2 of the set of Shared Socioeconomic Pathways (SSPs).[50]

The Scenario XDC: is calculated with the same approach as the Baseline XDC, but with different assumptions on the growth of GVA and emissions. These growth rates can be defined individually, for example based on a climate strategy, other Shared Socioeconomic Pathways, or any type of scenario. This approach has been used in chapter 1 to calculate the XDCs and corresponding climate pathways for different sectors, under the assumption of emission reduction rates through AI that have been determined in the survey.

The Sector Target XDC: expresses the temperature that a company must achieve, to be aligned to a given global warming scenario. This target is specific to the company's sector. This is rooted in the idea that the feasibility of emission intensity reduction is not the same for every sector, as they start on different levels and have different potentials.

The XDC Gap: is the difference between the Sector Target XDC and a chosen other XDC (e.g. Baseline XDC or Scenario XDC). It expresses the alignment with the <2°C target – the larger the XDC Gap, the further away the company is from achieving <2°C-alignment. A negative (≤0) XDC Gap signifies, that the company is already operating in alignment to the <2°C target. The XDC Gap enables the comparison of temperature alignment of companies or other economic entities from different sectors, as both need to achieve different Sector Target XDCs and thus have a different goal to achieve.

II. Portfolio XDC Metrics

These metrics can be aggregated to a portfolio of companies to allow for a comparison on group-level. The aggregation of metrics results in a Portfolio Baseline XDC, a Portfolio Target XDC and the corresponding Portfolio XDC Gap. It is essential to note that only the Portfolio XDC Gaps may be compared, as the variation in the sector-makeup within different portfolios results in different Portfolio Target XDCs.
To compare the temperature alignment of Climate AI Champions to the rest of the sample, we have analyzed the individual companies in our survey and consolidated them on a group – or "portfolio" – level according to the classification above. These aggregated metrics result in:

- A Portfolio Baseline XDC – XDC metric of the portfolio of companies
- A Portfolio Target XDC – XDC target to be aligned with the Paris Agreement
- The corresponding Portfolio XDC Gaps – the difference between the above two metrics, signifying the gap that remains to be closed if the organization is to meet the Paris Agreement.

We have further broken down the resulting Portfolio XDC Gaps based on Scope 1 and 2 emissions (see Appendix D on "Emissions Accounting" for more details on emission scopes). The Portfolio XDC Gaps make it possible to understand the alignment of the corresponding groups to the Paris Agreement and to assess the effect of mature and aligned AI and climate strategies. A similar analysis is possible for scope 3 emissions. However, we have limited our analysis to scope 1 and 2, owing to several challenges associated with completeness, accuracy, and adequacy of scope 3 emissions data.

The XDC Gap can only be closed by decoupling the increase of emissions from economic growth, resulting in a reduction of Economic Emission Intensity (EEI), for example through the implementation of technology. This analysis demonstrates the potential of strong AI capabilities in alignment with a mature climate strategy to achieve a reduction in EEI, indicated by a closing XDC Gap.

III. Calculation of the Baseline XDC

The calculation process of the XDC Model is divided into three major sections: (1) Economic Emission Intensity of a company, (2) Projection of cumulative global emissions from base year until 2050, and (3) Calculation of the global warming resulting from the emissions determined in (2).

- Economic Emission Intensity. In a first step, the Economic Emission Intensity (EEI) for the company in question ascertained. EEI is defined as the amount of greenhouse gas emissions (in tons CO_2e) that the company emits per 1 million euro gross value added (GVA). GVA is defined as the sum of EBITDA and Personnel Costs. The emissions are entered into the model as Scope 1, 2 and 3 Emissions as defined by the Greenhouse Gas Protocol (see appendix e for further information). To avoid double counting, Scope 1 emissions are fully counted (100%) while Scope 2 and 3 emissions are only partially counted (50%).
- Global Emissions. The EEI from step one is projected until 2050 and scaled to a global level to compute the global emissions from the base year until 2050. This is the quantity of emissions that would reach the atmosphere if the entire world economy were to operate as emission intensively as the economic entity in question.
- Global Warming. In a third step, a full climate model (the FaIR model, see below) is used to calculate the amount of global warming that would occur if the amount of emissions calculated in step two were to be released into the atmosphere. By doing this, insight can be provided on the level of global warming that would result if every company were to operate as emissions-intensively as the company under consideration.
- The calculation of global warming associated with an amount of GHG emissions and other climate pollutants is based on the FaIR (Finite Amplitude Impulse Response)[51] climate model and consists of the following steps:
  - Quantification of induced increase of atmospheric greenhouse gas concentration
  - Radiative Forcing associated with increase of concentration
  - Global Warming (= XDC)

IV. Calculation of the Sector Target XDC

The calculation of the Sector Target XDC is based on three steps: (1) calculating the median EEI for each sector, (2) calculating the sector-specific EEI target pathway, (3) scaling the EEI pathway to the global GVA and (4) calculating the global warming resulting from the emissions determined in (3).
In step (2), the GVA growth rate follows the SSP2 scenario and the emission reduction rates are calculated from the IEA emission budgets

- Emission budgets. The International Energy Agency (IEA) has developed emissions budgets for all sectors in a 2 Degree Scenario (D2S) and a Beyond 2 Degree Scenario (B2DS).[52] This is rooted in the idea that the feasibility of emission intensity reduction is not the same for every sector, as they start on different levels and have different potentials.
- EEI Target Pathways. The sector-specific emission budgets are used to compute EEI pathways for each sector until 2050. Based on these pathways, we compute the global emissions from the base year until 2050.
- Global Warming. Just as with the calculation of the Baseline XDC, the emissions that have been computed in the previous step are fed into the full climate model to compute the global emissions from the base year until 2050. The result is the Sector Target XDC.

In the EEI Pathway analysis in chapter 1, the EEI Target pathway (which is the basis for the calculation of the Sector Target XDC) has been used.

B. Modeling the impact of AI adoption on GHG emission reduction

To understand the contribution that AI can make to climate action, we modeled the impact of AI on the sector-specific Economic Emission Intensity (EEI) along with our partner right. based on science. The EEI of a sector is calculated as the amount of its emissions[53] (measured in tons of CO_2 equivalent) per unit gross value added (the sum of EBITDA and personnel costs).[54]

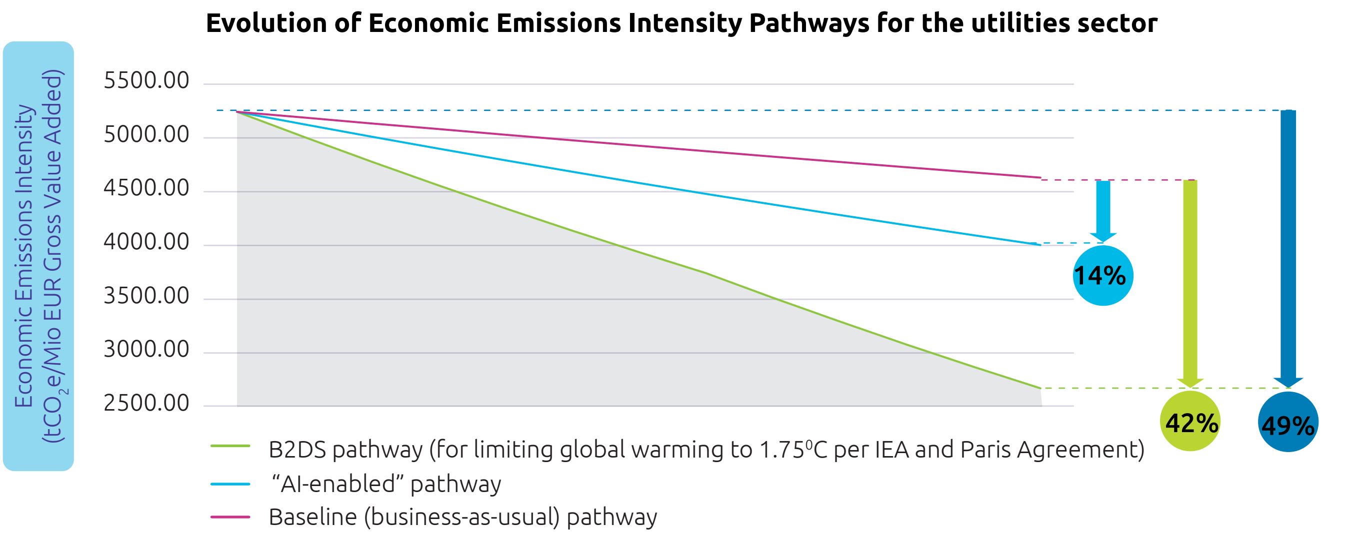
EEI Pathways (which are part of the XDC Model as previously explained in appendix a) allow us to assess to which extent a sector is able to decouple the growth of GHG emissions form the growth of economic activity (as measured by gross value added). For each of the five sectors, we computed the EEI Pathway for the "AI-enabled" scenario in two steps. For the base year 2018, the median EEI from the sector is used. Then, standard GVA growth rates and GHG emission reduction rates estimated from our survey were applied to calculate the EEI for the following years.

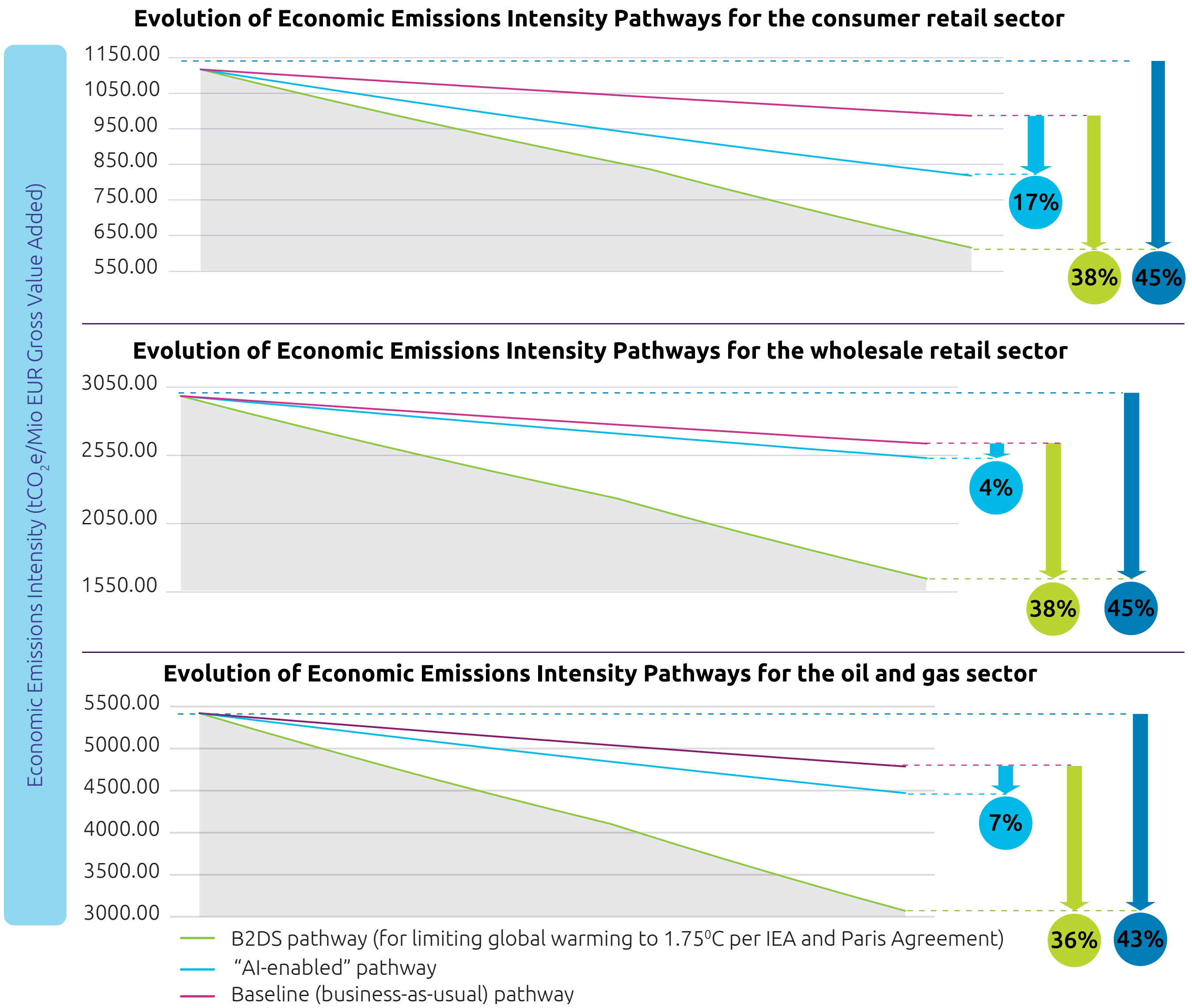
We calculated the reduction rates of the GHG emissions for the time span 2018 to 2030 as follows.

- The overall GHG emission reduction rates given for the time span 2017 to 2019 (Figure 4) and the time span 2020 to 2025 (Figure 6) were linearly extrapolated to obtain overall GHG emission reduction rates for the time span 2026 to 2030.
- The overall GHG emission reduction rates were converted into yearly reduction rates.
- We assumed that the GHG emission reductions as estimated in the survey uniformly apply to all emission scopes.
- We also assume an optimistic future in the next ten years, where organizations scale AI at double the level that exists today and realize up to 50% of GHG reduction through AI-enabled use cases as reported in our survey. It is to take into account the losses that invariably occur when an AI use case is scaled to the organizational level. For instance, if a use case is expected to reduce emissions by X% individually (in one project/location/facility), when scaled organization-wide, the resulting benefit for the entire organization will be less than X% – owing to various losses and additional complexities in the process. This allows us to explore the highest potential benefits of AI-enabled use cases for climate action.

These individually by Capgemini defined "AI-enabled" EEI pathways are then compared with right.'s standard EEI Baseline pathway and the EEI Target pathway which has been calculated in line with the B2DS scenario as explained in Appendix A.

Economic Emission Intensity Models for various sectors





Disclaimer from right. based on science regarding the XDC Model

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C. Complete list of AI use cases for climate action

Use cases marked in green are the most adopted use cases by industry.

Automotive sector:

Working example: Machine stoppage can lead to wastage of work-in-process inventory and loss of productivity. AI can help analyze historical reasons of failures and combine it with real time data such as images from production line to predict upcoming failures of machines. In one such example, an automotive giant managed to increase throughput by 25–30 vehicles per day. This prevented unplanned stoppages of assembly line leading to overall improvement in productivity, and more efficient utilization of power and resources.

Part of value chain	AI for climate action use case	Emission scope improved by the use case
Research & Development	i. Using AI to improving engine efficiency and reduce use of fuel	3
	ii. Using AI to optimize performance based on driving conditions while increasing efficiencies	3
	iii. New fuel (hybrid) systems using machine learning	3
	iv. Designing lighter components for overall vehicle weight reduction	3
	v. Power output optimization for electric vehicles based on driving conditions and tackling range.	2
	vi. Virtual testing and simulation for new model/product testing and design	1
	vii. Setting of internal carbon pricing for all components, supply chain and production through AI-based insights	1
Supply chain & manufacturing	i. Raw material supply chain tracing using machine learning/AI	3
	ii. Tracing carbon emission of supply chain using big data analytics/AI	3
	iii. Logistics optimization using AI	3
	iv. Predictive maintenance at manufacturing facility to increase efficiency and lower usage of resources	1
	v. Sustainable prototyping and testing processes e.g., use of additive manufacturing in prototyping and recycling waste produced	1
	vi. Improving energy efficiency of manufacturing facilities	1
Sales & aftersales	i. Tracking use phase carbon footprint of vehicles using AI	3
	ii. Collecting and keeping track of end of life vehicle using machine learning	3
	iii. Using ML/AI in selecting and retrofitting components	1
	iv. Predictive maintenance of vehicles to ensure compliance	3
Internal operations	i. Ride sharing portal for day to day employee commute using blockchain/AI	1
	ii. IT operations optimization using edge computing/deep learning	1
	iii. Using AI to enable employees to work remotely through advanced remote working technologies, and reducing travel needs	1
	iv. AI to assess and mitigate financial and insurance risk due to climate change	1
	v. Automation of carbon emissions, tracking and reporting	1

Manufacturing sector:

Working examples:

- Prototyping can be resource-intensive based on the complexity of desired outcome and properties of the product being designed. AI can help design prototypes more efficiently while meeting or exceeding desired properties and dimensions of the product, thus reducing wastage.
- In AI-enabled predictive maintenance, computer vision can help identify and track early signs of failure or inefficiency in manufacturing assets. A timely fix flagged in time can help avoid wastage

Value chain	AI for climate action use case	Emission scope improved by the use case
Research & Development	i. Improving machine/asset efficiency of end products to reduce use of fuel/electricity	2
	ii. Designing lighter components for reduction in product weight	3
	iii. Energy consumption measuring platform using AI	2
	iv. Setting of internal carbon pricing for all components, supply chain and production through AI-based insights	1
	v. Selection of low-carbon raw material and packaging components through AI/big data machine learning	1
	vi. Optimizing low-carbon processes and operations (such as carbon capture and operational reuse) through AI control systems	1
	vii. Adoption of green hydrogen substitutes for industrial operations through AI assisted operations.	1
Supply chain & manufacturing	i. Raw material supply chain tracing using machine learning/AI	3
	ii. Tracing carbon emission of supply chain using big data analytics/AI	3
	iii. Logistics optimization using AI	1
	iv. Predictive maintenance at manufacturing facility to increase their efficiency resulting in less use of resources	1
	v. Sustainable prototyping and testing processes e.g., use of artificial intelligence in prototyping and recycling of waste produced in testing	1
	vi. Electrification of heating and industrial processes and machinery utilizing AI supported grid balancing and energy storage	2
Sales & aftersales	i. Recollecting and keeping track of end of life products/by-products using ML/AI	3
	ii. Using ML/AI in selecting and retrofitting components that are recollected	3
	iii. Shifting to product-as-a-service model supported by AI based utilization prediction	3
Internal operations	i. Ride sharing portal for day to day employee commute using blockchain/AI	1
	ii. Energy consumption optimization of IT infrastructure, employee work facilities using edge computing/deep learning	1
	iii. Using AI to enable employees to work remotely through advanced remote working technologies, and reducing travel needs	1
	iv. AI to assess and mitigate financial and insurance risk due to climate change	1
	v. Automation of carbon emissions, tracking, and reporting	1

Energy and Utilities sector:

Working example: Utilities need to accurately forecast energy demand to avoid energy waste. An accurate forecast also allows grid operators to more effectively use renewable energy in combination to the traditional sources of energy.

AI can help utilities process huge data coming from historical consumer usage, weather conditions, monthly/annual trends, monthly attrition/churn rate/volume growth to more accurately predict energy usage and maximize renewable energy production.

Value chain	AI for climate action use case	Emission scope improved by the use case
Research & Development	i. Energy consumption measuring platform using AI/ML	1
	ii. Renewable energy modeling/analysis/prediction using ML/AI	1
	iii. Setting of internal carbon pricing for all components, supply chain and production through AI-based insights	1
Production/ Generation	i. Raw material supply chain tracing	3
	ii. Algorithms to automatically identify defects and predict failures without interrupting operations (predictive maintenance)	1
	iii. Carbon-capture technologies assisted with AI production	1
	iv. Pipeline maintenance and leakage detection	1
	v. Forecasting using machine learning, data mining about weather, environment, grid operations.	1
	vi. Tracing carbon emission of supply chain	3
	vii. Logistics optimization	3
	viii. Use of smart grid	1
	ix. Use smart energy meter	1
	x. Minimizing the production of waste methane instead of flaring through AI/machine learning production optimization	1
	xi. Capture and management of by-products (such as methane) from well production utilizing AI prediction and anatomy detection. E.g., vapor/venting recovery units	1
Sales & aftersales	i. Consumer-behavior analysis using advanced analytics	3
	ii. Making electric supplies more reliable and bespoke to consumer needs	1
	iii. Generating and building AI-based consumer insights and awareness on energy utilization, home efficiencies and carbon footprint	3
	iv. Incentivizing electrification of building heating through incentives for utilizing renewable, energy-enabling predictive grid balancing.	2
Internal operations	i. Ride sharing portal for day to day employee commute using blockchain/AI	1
	ii. Energy consumption optimization of IT infrastructure, employee work facilities using edge computing/deep learning	1
	iii. Using AI to enable employees to work remotely through advanced remote working technologies, and reducing travel needs	1
	iv. AI to assess and mitigate financial and insurance risk due to climate change	1
	v. Automation of carbon emissions, tracking, and reporting	1

Consumer products and retail sector:

Working examples: In supply chain, AI can help process multiple variables – sources, destinations, routes, product types, external variables (route disruption, weather conditions, etc.) to arrive at the shortest, fuel efficient routes while fulfilling business constraints.

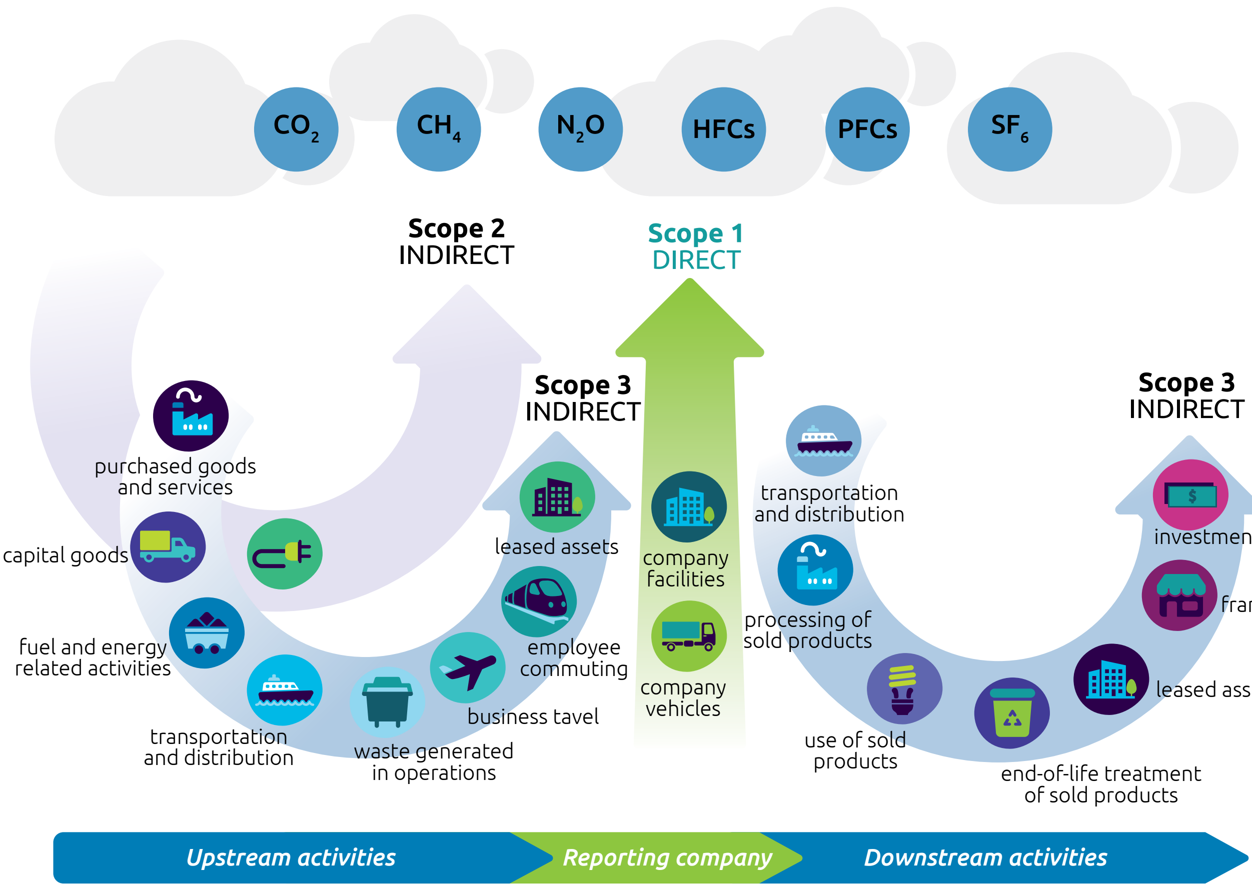
Value chain	AI for climate action use case	Emission scope improved by the use case
Research & Development	i. Improving efficiency of product development and personalization using AI	1
	ii. Using AI/machine learning to find and utilizing biodegradable substitutes and reducing packaging footprint	1
	iii. Selection of low-carbon raw material and packaging components through AI/big data machine learning	1
	iv. Setting of internal carbon pricing for all components, supply chain and production through AI-based insights	1
	v. Reducing waste	3
Supply chain & manufacturing	i. Automate assembly and identification of parts to reduce manual intervention	1
	ii. Predictive maintenance of machines	1
	iii. Using AI to optimize changes in products to achieve operational efficiency	1
	iv. Tracing carbon emissions within the supply chain using big data analytics	3
	v. Enhanced traceability of raw materials to optimize production using machine learning/AI	1
	vi. Improving energy efficiency of manufacturing facilities	2
Sales & aftersales	i. Effective inventory prediction/optimization and management	1
	ii. Route optimization using advanced analytics	1
	iii. Autonomous vehicles within distribution centers	1
	iv. Cold chain logistics optimization	3
	v. Last-mile delivery and electric vehicles operations optimization	3
	vi. Bridging the gap between supply and demand using predictive analytics	3
Internal operations	i. Ride sharing portal for day-to-day employee commute using blockchain/AI	1
	ii. Energy consumption optimization of IT infrastructure, employee work facilities using edge computing/deep learning	1
	iii. Using AI to enable employees to work remotely through advanced remote working technologies, and reducing travel needs	1
	iv. AI to assess and mitigate financial and insurance risk due to climate change	1
	v. Automation of carbon emissions, tracking, and reporting	1

D. Emissions accounting

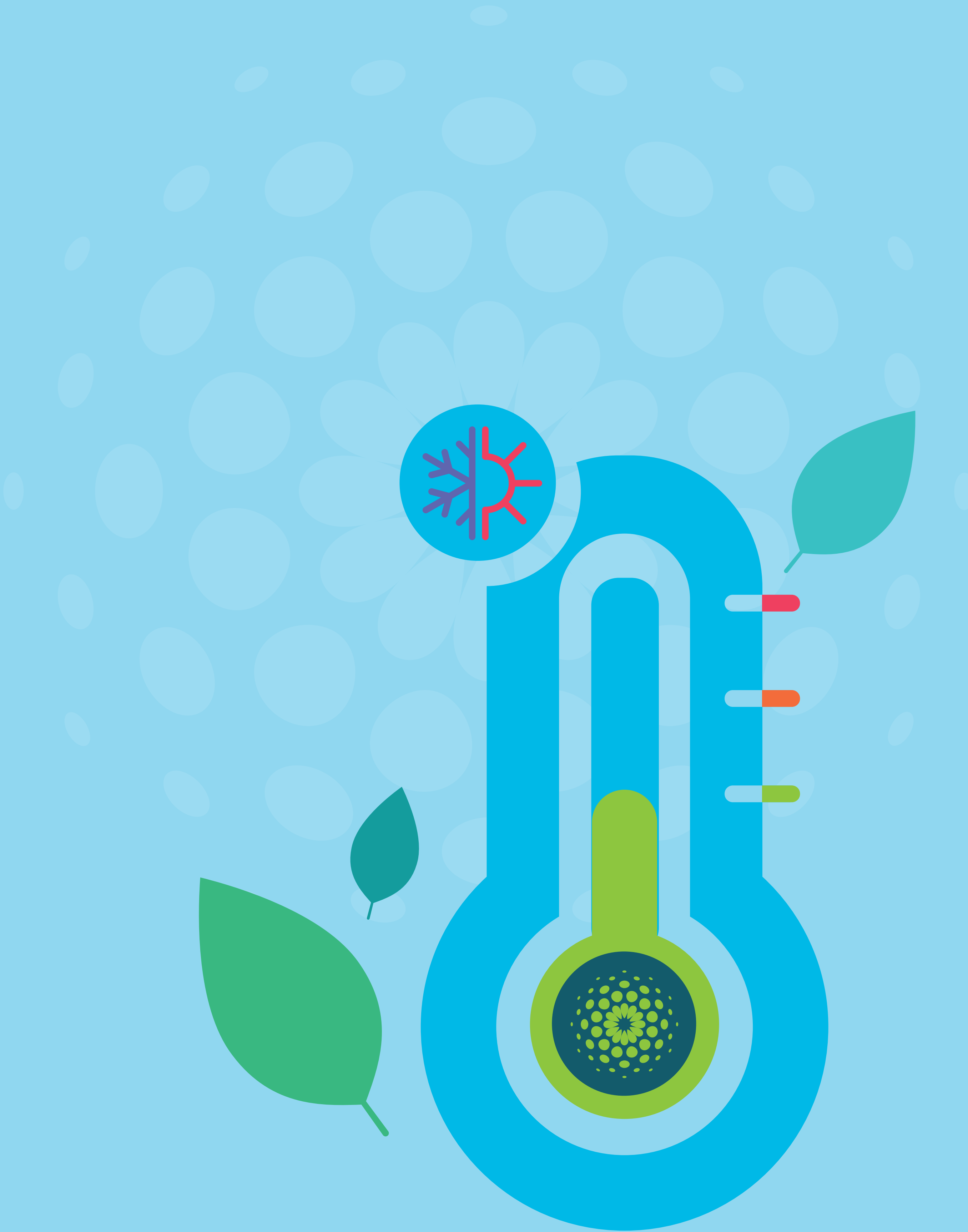
The Greenhouse Gas Protocol is a commonly used standard for the accounting of GHG emissions. It defines three scopes of emissions: [55]

- **Scope 1:** Direct GHG emissions. Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment.
- **Scope 2:** Electricity indirect GHG emissions scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.
- **Scope 3:** Other indirect GHG emissions scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company.

Figure: GHG emission scopes distribution



Source: Greenhouse gas protocol, "Technical Guidance for Calculating Scope 3 Emissions v1," accessed October 2020.



About the Authors

Anne-Laure Thieullent
Vice President, Artificial Intelligence & Analytics Group Offer Leader
annelaure.thieullent@capgemini.com

Anne-Laure leads Perform AI, Capgemini's Artificial Intelligence & Analytics group offer. She works with clients to scale Artificial Intelligence so it infuses everything they do, and they become AI-driven, data-centric and innovative. With 20 years of experience in big data, analytics and AI systems, from design to production roll-out, her passion is to bring companies what they need to transform themselves into intelligent enterprises. AnneLaure is committed to guiding clients to increase activating their data, while cultivating the values of trust, privacy and fairness. This is the foundation on which technology, business transformation and governance come together, to leverage the positive business outcomes of AI.

Vincent de Montalivet
Head of Sustainable AI, Capgemini
vincent.de-montalivet@capgemini.com

Vincent leads Sustainable AI, part of Perform AI –Capgemini Group AI & Analytics offering. He has been working in sustainable ICT for more than ten years and has held IT project management and business development roles across consulting, SMEs, local authorities and NGOs.

Dr. James Robey
Global Head of Environmental Sustainability, Capgemini
james.robey@capgemini.com

Dr James Robey has led the sustainability agenda at Capgemini since 2008, creating and driving a broad ranging program to reduce the Group's own environmental impacts whilst identifying opportunities to support Capgemini's clients with their own sustainability challenges. In addition, he teaches at a number of leading universities on the topic of Sustainable Business.

Kiri Trier
Director, Capgemini Invent Germany
kiri.trier@capgemini.com

Kiri Trier is the Sustainability Lead (director) for DACH at Capgemini Invent. She advises Capgemini clients on the transformation of their traditional business into a sustainable business by defining and implementing the right sustainability strategy,integrating all sustainability requirements like ESG, SDGs and GRI. She has over 15 years of experience in innovation management and business modelling.

Florent Andrillon
Vice President, Energy Transition Global Leader, Capgemini Invent
florent.andrillon@capgemini.com

Florent Andrillon is the energy transition lead for Capgemini Invent, where he advises companies from different sectors on their energy and low carbon transformation projects.

Jean-Baptiste Perrin
Vice President, Invent for Society Global Leader, Capgemini Invent
jean-baptiste.perrin@capgemini.com

Jean-Baptiste leads Capgemini Invent's social impact business initiative : Invent for Society. With a strong background in public sector and sustainable development, he is a Vice-President within Citizen Services at Capgemini Invent France and currently develops business synergies with our most recent acquisitions including social impact agency Purpose.

Michiel Boreel
Global Chief Technology Officer at Sogeti and Executive Vice President of Capgemini
michiel.boreel@sogeti.com

Michiel Boreel is the Global Chief Technology Officer at Sogeti and Executive Vice President of Capgemini.Since 1994 Michiel leads a small think tank within SogetiLabs called VINT (Vision, Inspiration, Navigation Trends) with the goal of inspiring customers to apply new technology in business. Constant theme in all of the SogetiLabs research is the question what impact IT has on society and how technology can be applied to create meaningful business innovation. Since the start of the institute it has published over 15 books and many reports.

Philippe Vié
Vice President, Capgemini group Energy, Utilities and Chemicals sector leader
philippe.vie@capgemini.com

Philippe has over 25 years of Energy and Utilities industry experience and dedication, with a strong focus on Utilities transformation projects, including sector and digital technologies levers. Philippe leads the Capgemini landmark publication, the World Energy Market Observatory (WEMO).

Katja van Beaumont
Vice President, Content lead - Consumer Products, Retail, Distribution, Capgemini The Netherlands
Katja.van.Beaumont@capgemini.com

Katja is a thought-leader at Capgemini in the private industries. With over 20 years of experience in delivering transformational business initiatives enabled by technology, she is a visionary leader, elevating aspirations and bringing about a lasting positive impact for all stakeholders.

Marc Rietra
Vice President, Content lead - Consumer Products, Retail, Distribution, Capgemini The Netherlands
marc.rietra@capgemini.com

Marc is a thought-leader at Capgemini in the private industries. With over 20 years of experience in delivering transformational initiatives he has been leading customers to success, always bringing in a unique vision ensuring meaning and long-term value creation.

Steve Jones
Chief Data Architect, Capgemini Group Portfolio
steve.g.jones@capgemini.com

Steve Jones is the Chief Data Architect for Capgemini's Group Portfolio, with over a decade in Big Data and Cloud he's been at the front of helping our clients adopt new technologies to drive new business value and become more data driven. Steve was one of the first people to propose using mobile applications and analytics to help track and manage individuals carbon footprint and has continued to be at the front of Capgemini's CSR and Diversity initiatives.

Anne-Laure Cadene
Vice President, Capgemini Digital Engineering and Engineering Services
anne-laure.cadene@capgemini.com

Anne-Laure is a Research & Innovation director at Digital Engineering and Engineering Services of Capgemini. She has been with Capgemini since January 2019 and is based in France. She has over 20 years of experience, after a PhD in fluid mechanics.

Jerome Buvat
Global Head of Research and Head of Capgemini Research Institute
jerome.buvat@capgemini.com

Jerome is head of the Capgemini Research Institute. He works closely with industry leaders and academics to help organizations understand the nature and impact of digital disruption.

Amol Khadikar
Senior Manager, Capgemini Research Institute
amol.khadikar@capgemini.com

Amol is a senior manager at the Capgemini Research Institute. He leads research projects on key frontiers such as artificial intelligence, sustainability and the future of work to help clients devise and implement data-driven strategies.

Amrita Sengupta
Manager, Capgemini Research Institute
amrita.a.sengupta@capgemini.com

Amrita is a manager at the Capgemini Research Institute. She tracks the patterns of digital disruptions across industries and their impact on businesses.

Yashwardhan Khemka
Manager, Capgemini Research Institute
yashwardhan.khemka@capgemini.com

Yash is a manager at the Capgemini Research Institute. He likes to follow disruption fueled by technology across sectors.

Shahul Nath
Consultant, Capgemini Research Institute
shahul.nath@capgemini.com

Shahul is a consultant at the Capgemini Research Institute. He keenly follows disruptive technologies and its impact on industries and society.

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Vice President, Artificial Intelligence & Analytics / Perform AI Group Offer Leader

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Please contact

Valerie Perhirin
Managing Director in charge of Insight-Driven-Enterprise
valerie.perhirin@capgemini.com

Paul Dixon
Vice-President,Public Sector / Sustainability
paul.a.dixon@capgemini.com

Jean-Baptiste Perrin
Vice-President, Invent for Society Global Leader
jean-baptiste.perrin@capgemini.com

Florent Andrillon
Vice-President, Energy & Utilities / Sustainability
florent.andrillon@capgemini.com

For more information, please contact:

Global

Anne-Laure Thieullent
Vice President, Artificial Intelligence and Analytics Group Offer Leader
annelaure.thieullent@capgemini.com

Vincent de Montalivet
Head of Sustainable AI, Capgemini
vincent.de-montalivet@capgemini.com

Valerie Perhirin
Managing Director in charge of Insight-Driven-Enterprise, Capgemini Invent
valerie.perhirin@capgemini.com

Florent Andrillon
Vice President, Energy Transition Global Leader, Capgemini Invent
florent.andrillon@capgemini.com

Arthur Arrighi De Casanova
Director, Sustainability & Energy Transition, Capgemini Invent
arthur.arrighi-de-casanova@capgemini.com

APAC

Dr. Jingyuan Zhao
AI Leader
jing-yuan.zhao@capgemini.com

France

Marion Gardais
VP Presales & Solutioning
marion.gardais@capgemini.com

Germany

Fabian Schladitz
AI Centre of Excellence Leader
fabian.schladitz@capgemini.com

Europe

Robert Engels
AI Leader
robert.engels@capgemini.com

India

Padmashree Shagrithaya
AI Centre of Excellence Leader
padmashree.shagrithaya@capgemini.com

North America

Dan A Simion
AI Centre of Excellence Leader
dan.simion@capgemini.com

United Kingdom

Joanne Peplow
AI Centre of Excellence Leader
joanne.peplow@capgemini.com

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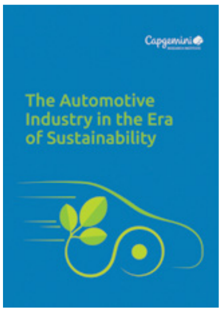

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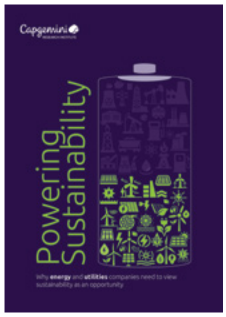

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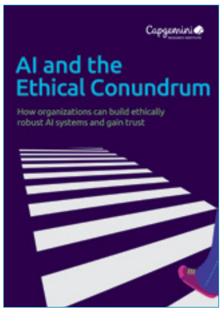

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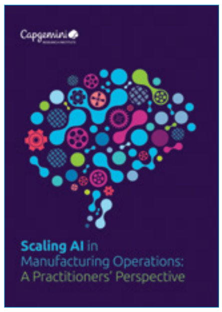

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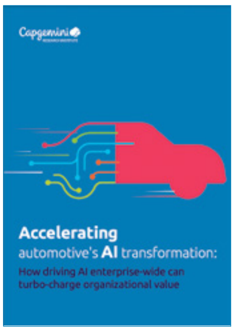

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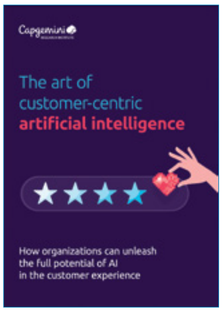

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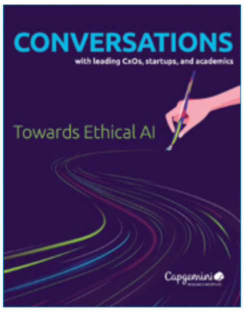

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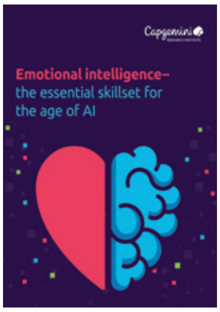

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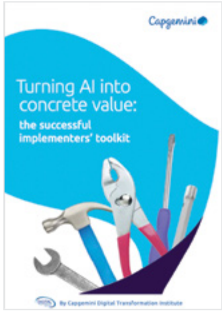

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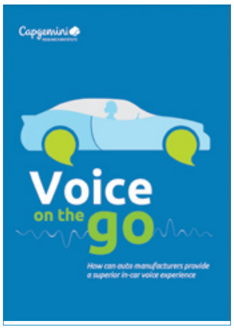

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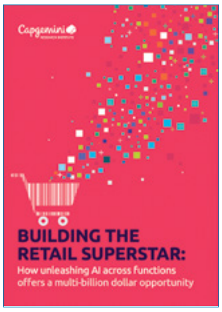

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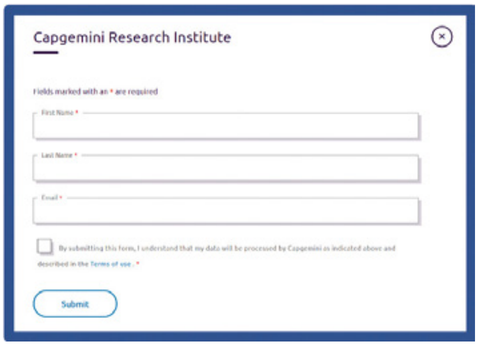

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