

How AI can enable a Sustainable Future

Executive Summary



Foreword

Today's information age is driving unbelievable advances at tremendous speed. AI will enable humans to harness vast amounts of data and make breakthrough advances in areas like healthcare, agriculture, education, and transportation. We're already seeing how AI-bolstered computing can help doctors reduce medical mistakes, farmers improve yields, teachers customize instruction, and researchers unlock solutions to protect our planet.

But as we've seen over the past 20 years, as digital advances bring us daily benefits, they also raise a host of complex questions and broad concerns about how technology will affect society. We have seen this as the internet has come of age and become an essential part of our work and private lives. And this seems certain to continue as AI evolves and the world focuses on the role it will play in society. As we look to the future, it's important that we maintain an open and questioning mind while we seek to take advantage of the opportunities and address the challenges that this new technology, and others like it, create.

How these technology advances will affect the planet is among those questions, and one we have a limited amount of time to answer given the urgency of challenges such as climate change and biodiversity loss. If you look at the past 200 years, a series of industrial revolutions have radically improved the standards of living for human beings. But each past industrial revolution has borrowed from the future to pay for the present by achieving economic growth through the degradation of our planet's health. Today's technological revolution must break this pattern, and for the first time deliver sustainable economic growth.

Microsoft and PwC have a shared belief that, with a great deal of urgency, we must address the diminishing health of our environment. We also share a belief that new technologies like AI can be a game-changer in this space. But to create the kind of global action needed, it needs to be more than a belief—it needs to be backed by data, by solutions, and by new partnerships.

That is why, together, we undertook this research. Applying our expertise in AI, data science, economics, and sustainability, we examined four sectors of the economy that are primed to be, or in many cases are already being, disrupted by AI to better understand the potential economic and environmental benefits. These sectors are Agriculture, Energy, Transport and Water.

For us, some key conclusions emerged.

First, there is enormous potential for AI to be an important tool in the effort to decouple economic growth from rising carbon emissions. In other words, there is a path towards a prosperous, just, and more sustainable future with advanced technologies.

Second, this outcome relies on bringing together several factors. The solutions we explore are not AI acting on its own; in most cases multiple complementary technologies come together, including robotics, the internet of things, distributed energy resources, electric vehicles, and more. AI also requires large amounts of compute power, which translate to energy consumption. Without new incentives that accelerate a market change towards clean energy—from renewables to electric vehicles—the efficiency gains from AI won't deliver their full emissions reduction potential for the world. On the flip side, our own projections of GDP and environmental gains could

be at the low end of what plays out in reality. The signals are that a more rapid and global low-carbon transition lies ahead than that reflected by our Business As Usual scenario, driven by the increasing cost-competitiveness of low carbon alternatives and continued ratcheting of environmental policy.

Third, there are important issues of justice to consider, to ensure that benefits are inclusive. The largest gains we see map to the countries that are already at the forefront of AI adoption, and are not evenly experienced today. Without incentives and policy change to ensure all regions are ready to capture these benefits, these economic and climate inequalities will be exacerbated. Just looking at jobs, the good news story of more high-skilled jobs also carries a reality of jobs displacement, and a pressing need for upskilling and reskilling to avoid leaving people behind.

This all means we need to think beyond the technology itself to address the wider implications on society and our environment. From the need for strong ethical frameworks, to the evolution of laws, the importance of education and training for new skills, and even labor market reforms—these must all come together if we're going to make the most of this new technology.

Finally, we need to address these issues together with a sense of shared responsibility. In part this is because AI technology won't be created by the tech sector alone. Creating a better future requires that people in government, academia, business, civil society, and other interested stakeholders come together to help shape this future. And increasingly we need to do this not just in a single community or country, but on a global basis. Each of us has a responsibility to participate—and an important role to play.

This report is just the first step in building a case for deeper exploration of how AI can create a more sustainable future. There are many additional sectors to examine and areas to explore, and we hope this research inspires others to conduct similar work. We have greater ambitions than driving academic research, however. Research should be a means to an end, and this case, that end should be global progress on climate change and nature. We know enough today from science to understand that there is a limited amount of time to make the kind of changes needed to allow the seven billion people on this planet to live, work, grow, and thrive.

We hope the pages that follow will help spark increased efforts to help make the fourth industrial revolution become the first one to deliver a better future for both society and our environment.

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A time of rapid change

The coming few decades look set to be a time of unprecedented change for humans. On one hand, our ingenuity has unleashed an information and intelligence age – where the ascendancy of emerging technologies, including AI – is set to reshape industries, scientific discovery, human engagement and endeavour, and even economic power. On the other hand, the extraordinary advances of previous generations, which in the last century delivered exponential economic growth and huge strides in human welfare, have also left us with a planet that scientists warn is under unprecedented environmental strain. This has led to the so-called “Anthropocene” age – where human activity is the dominant influence on our environment and our natural systems are changing at unprecedented rates¹, from climate change to biodiversity loss, ocean warming and acidification, deforestation, and water and air pollution.

Today as we sit at the intersection of the Artificial Intelligence (AI) age and the Anthropocene age, not enough has been done yet to bring these two worlds together. And let’s not forget that it’s society today that will not only feel the impact of climate change first, but will also be the first to experience rapid digital transformation, automation and augmented human ingenuity. It is incumbent on us, therefore, to transform industries, markets, and behaviours to change the course of climate change; and to lay the foundations for a positive, safe, and responsible digital future. These priorities aren’t isolated: powerful new technologies, including AI, can play a critical role in underpinning the solutions needed to tackle our most pressing societal challenges – from digital monitoring and enforcement for conservation, to decarbonising energy and transport.

Much has been written about the impact of AI on society, economy, and jobs in particular. PwC’s own report [Sizing the Prize](#), for example, suggests that the potential contribution of AI to the global economy by 2030 could be as much as US\$15.7 trillion, impacting millions of jobs and making it the biggest commercial opportunity in today’s fast-changing economy. For climate change impacts on the economy and the environment, research is even more extensive and has underpinned the political commitment of 197 countries to limit the rise in global average temperature to “well below 2°C” as signatories to the UN [Paris Agreement](#). Many assessments of the economic costs of climate change, from the early [Stern review](#) to the latest [National Climate Assessment](#) in the US – which shows potential costs to the US economy of over US\$500bn per year in 2090 from doing nothing – demonstrate significant and growing economic costs of inaction.

Despite this growing body of evidence, less has been done to evaluate these two futures in parallel: to assess the economic and environmental gains that the AI era can help to harness, and to understand better how this new and powerful tool can help to shape our economy and environment against the backdrop of the Anthropocene.

What can AI do for our economy and environment?

As these two disruptive and powerful megatrends – digitalisation and decarbonisation – take hold globally, we have made a very preliminary assessment of some of the opportunities that AI can offer, for economic growth and emissions reduction potential, between now and 2030. We have done this for a small subset of sectors (four) that are critical to the economy, environment, and natural systems, namely agriculture, water, energy and transport. Within each, we have covered only a subset of potential AI levers and look at a business as usual growth trajectory. Across these, we assessed the speed and potential scale of impact, building on PwC's proprietary jobs automation models², 'AI for Earth' use case database³, and proprietary economic models. Our analysis covers GDP⁴ estimates, GHG⁵ emissions, as well as the likely impact on jobs at a global scale and across seven regions⁶.

We recognize that our research has limitations⁷, and acknowledge the difficulties of fully capturing the impacts, including accurately estimating rebound effects and evolving sectoral interactions. We have attempted to be as transparent as possible and use a Computable General Equilibrium (CGE) modelling⁸ approach that is widely employed by International Organizations and national governments to make these types of assessments.

Even within this narrow scope, we have reason to be optimistic: AI adoption in these sectors, even on current pathways, is predicted to deliver substantial economic and environmental benefits.

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Figure 1ES: AI for the environment headline results⁹



+4.4% GDP
(\$5.2Tr)



-4.0% GHGs
(-2.4Gt)



+1.0% net jobs
(+38.2 million)

Source: PwC Analysis

Our main findings

- **Using AI for environmental applications has the potential to boost global GDP by 3.1 – 4.4%¹⁰ while also reducing global greenhouse gas emissions by around 1.5 – 4.0% by 2030 relative to Business as Usual (BAU)¹¹.**

Productivity benefits of AI applications across the four key sectors can generate an overall global economic uplift, yielding a potential gain of US\$3.6 – 5.2 trillion¹² driven by optimised use of inputs, higher output productivity and automation of manual and routine tasks. In parallel, these applications can accelerate the move to a low-carbon world with a reduction in worldwide greenhouse gas emissions by 0.9 – 2.4 gigatonnes of CO₂e, equivalent to the 2030 annual emissions of Australia, Canada and Japan combined,¹³ and an overall reduction in carbon intensity of 4.4 – 8.0% relative to BAU. The AI applications modelled will also create 18.4 – 38.2 million net jobs globally (broadly equivalent to the number of people currently employed in the UK), offering more skilled occupations as part of this transition.

- **Economic benefits could be predominantly captured by Europe, East Asia and North America regions as they each achieve GDP gains in excess of US\$1 trillion¹⁴.**

Latin America and Sub-Saharan Africa currently stand to gain the least. This distribution is due in large part to each region's current digital readiness, levels of tech adoption¹⁵ and current policy trends. These gains could be higher if more rapid digital transformation can be realized. Nevertheless, this projected disparity highlights concerns over how gains from AI for environment can be more evenly distributed, particularly as these less affluent regions are also likely to be most adversely affected by the physical impacts of climate change. Environmentally-oriented AI applications carry a big GHG mitigation potential for almost all regions, with North America and East Asia

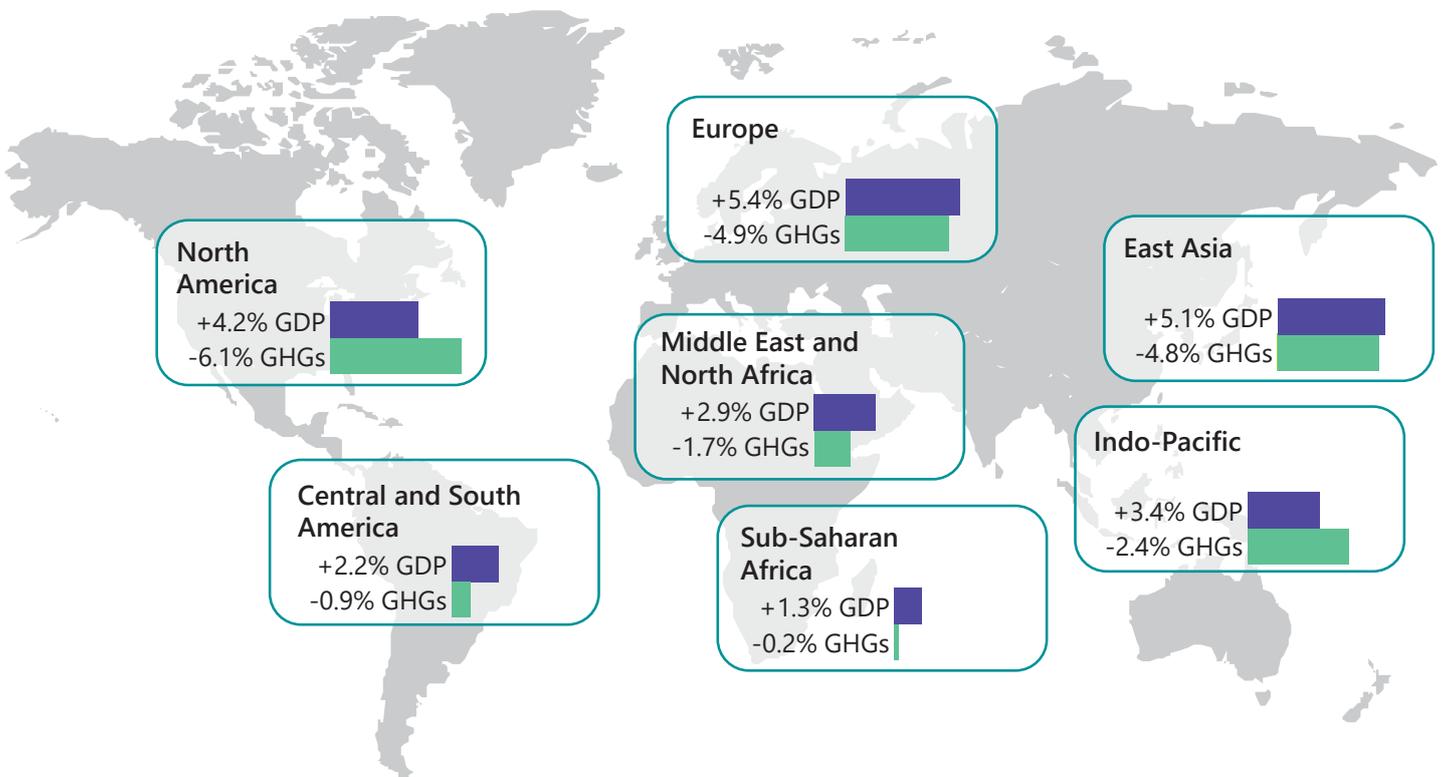
potentially reducing their GHG emissions respectively by 1.6 – 6.1% and 2.7 – 4.8% in 2030.

- **AI applications in energy (up to -2.2%) and transport (up to -1.7%) have the largest impact on GHG emissions reduction of our sectors covered, but water and agriculture still have an important role to play for the environment more broadly:** our analysis suggests that agricultural AI applications can help reduce emissions by up to 160Mt CO₂e in 2030 whilst providing more food, and using fewer resources. Moreover, the agriculture and water sectors have a vital role in preserving the health of our Earth's natural systems, including biodiversity conservation, ocean health, freshwater quality, biogeochemical flows, forests and land system change, and related impacts on the security of food and water supply.
- These projections rely not just on AI, but on the adoption of a wider complementary technology infrastructure. For example, in the energy sector, AI-enabled distributed energy grids will reach their maximum potential with the adoption of related innovations in distributed grid infrastructure including distributed generation, distributed storage, Industrial IoT¹⁶, electric vehicle charging, dynamic pricing, and smart meters. Likewise, in transport, AI-enabled autonomous vehicles must offer more than energy efficiency gains through smart navigation and eco-driving, but also ultimately be electric vehicles and incentivize ride-shares, to counter a potential rebound effect of increased vehicle miles.

These projections rely not just on AI, but on the adoption of a wider complementary technology infrastructure.



ES2: AI for the environment headline results¹⁷ for global GDP and GHGs



Source: PwC Analysis

- More broadly, we also explore how these AI applications can offer environmental benefits beyond GHG emissions, including impacts on water quality, air pollution, deforestation and land degradation, and biodiversity. For example, AI can analyse satellite data and ground-based sensors to monitor forest conditions in real-time and at scale, providing early warning systems for investigation of illegal deforestation, with potential to save 32 million hectares of forest globally by 2030. Air pollution is one of the largest environmental risks to human health, where using AI to provide more

accurate and localised early-warnings of poor air quality can help reduce this burden. Our analysis estimates that using AI in this way could provide additional economic benefits of US\$150m globally in 2030 in reduced healthcare costs and health impacts.

AI applications, therefore, offer a range of positive impacts for the environment. Or to put the headline results another way, there is a huge opportunity foregone if leaders and decision-makers do not help enable AI innovations for the environment.



Areas for further exploration

Our analysis and results raise a number of broader themes, which are important to bear in mind both to contextualize our findings, and to further develop and mature our understanding of how AI, the economy, and our environment intersect:

- **Sectoral coverage:** we look at a range of AI applications across four sectors, but do not cover wider sectors of the economy, including the traditional 'hard to abate' sectors (e.g. chemicals, steel and cement, shipping and aviation) where there could also be significant gains. There might also be AI levers that could work in the opposite direction and increase greenhouse gas emissions (e.g. mining).
- **Future energy supply:** our modelled BAU baseline includes a limited transition to renewables and a continued reliance on fossil fuels, including coal, in the future energy mix. In reality, the signals are that a more rapid low-carbon transition is underway, both in developed and developing countries. This is being driven by the increasing cost-competitiveness of low-carbon alternatives, and continued ratcheting up of environmental policy and carbon pricing following the global agreement of governments to limit warming to well below 2 degrees Celsius. Given many of the AI applications we look at link to electrification, the future energy mix of the grid will be crucial to maximising emissions reduction as many AI applications use additional electricity.
- **Regional impacts and outlooks:** those regions which see the least potential benefits from AI for environment (e.g. Sub-Saharan Africa and Latin America) due to lower levels of digital readiness are also likely to see some of the more significant climate change impacts. However, there are two important factors to consider. First, the more that global emissions can be reduced, through AI and other means, the more these regions' economies will be bolstered through avoided impacts. Second, through targeted investment today in digital upskilling and digital infrastructure in these regions, there is an opportunity to leapfrog developed nations and far exceed these modelled projections to unlock substantial economic and environmental gain.
- **Measures of wealth:** many of the benefits from using AI for the environment are not fully captured by current economic frameworks. GDP is an annual measure that captures the 'flow' of income. To capture fully the benefits of AI (e.g. preserving the 'stock' of biodiversity and habitats etc.) alternative welfare and 'balance sheet' methods need to be developed and used alongside traditional GDP estimates.

Each of these factors are important areas for future research to better understand, and by extension unlock, the full opportunity of AI for our economy and environment.

What we can do and a 'call to action'

We will need to move forward holistically on a number of broader areas, however, in order to realise fully any of the opportunities analysed or identified. The positive scenario for our future won't emerge unguided; there will be trade-offs, and challenges, as well as opportunities. The public and private sector alike, particularly technology firms and companies deep in their digital transformation, will need to champion responsible technology practices that consider social and environmental impact and long term value creation. We also need to consider the policy and market reforms needed to make new solutions scale over incumbent practices and systems, and the role of different stakeholders, including governments and regulators.

We believe that to unlock the potential of AI for the environment, five principle 'enablers' will be key:

1. **Facilitating awareness, value alignment, collaboration and multi-disciplinary partnerships** (including technologists, industry, scientists, civil society, governments).
2. **Ensuring that we start with 'Responsible AI' and extend this principled approach to include societal and environmental impact.**
3. **Addressing digital infrastructure needs, access to AI tools and data, and wider complementary technologies.**
4. **Providing opportunities and training for upskilling and reskilling to adapt to sectoral transformations.**
5. **Encouraging R&D from research to scalable commercial deployment.**

All stakeholders across the public, private and third sectors must be involved in unlocking AI to tackle environmental challenges to its fullest potential. Each has a role to play in creating this 'enabling environment' to accelerate economic and environmental progress. Specifically, we outline actions the following stakeholders can play to create an improved enabling environment:

- **Governments:** take an agile approach to targeted regulation and policy support on items including data access, R&D and digital infrastructure and skills investment, in addition to wider environmental policy.
- **Tech developers:** take actions to create, provide and improve data assets and provide access to AI tools, data and wider complementary technologies.
- **Companies:** embed environmental impact considerations into AI strategies and deployment, identify disruption and transformation needs, and embrace upskilling and reskilling of workforces.
- **Academia:** encourage multi-disciplinary focus, combining AI and domain-relevant education and research, and industry partnerships.
- **Non-Governmental Organizations:** develop partnerships with technologists, invest in digital upskilling, and explore where AI and wider complementary technology innovations can create benefits.

While there are a range of recommendations explored in this report, the impact of AI on jobs – and the skills challenge – has to date received the most attention from the media and from society at large. All stakeholder groups are affected, and the pace of change is fast. With digitisation, automation and augmentation already transforming sectors, markets and global value chains, it is critical that companies and countries think ahead about both the markets and the workforce of the future.

We hope this work is a first step in a larger conversation to inject attention and investment into a tech-first approach to our most pressing environmental challenges. Moreover, we hope this report motivates others to build on this initial analysis to develop more comprehensive numbers around this topic. Both these efforts need to happen at speed for our planet, and for society, to survive and thrive.

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Endnotes

- 1 Stockholm University, Stockholm Resilience Centre [media release], Planetary Boundaries – an Update, January 2015, available at: <http://www.stockholmresilience.org/research/research-news/2015-01-15-planetary-boundaries---an-update.html>.
- 2 Developed based on the public OECD/PIACC database.
- 3 A PwC-developed database of over 150 applications of AI being used for the environment across geographies and sectors.
- 4 Gross Domestic Product.
- 5 Greenhouse Gas.
- 6 North America; Central and South America; Europe; Middle East and North Africa; Sub-Saharan Africa; East Asia; and Indo-Pacific.
- 7 AI applications outside the four sectors analysed could support further potential gains in the economy as a whole, and we did not assess their impact on global GHG emissions, either positive or negative. We also recognize that the environmental AI levers considered in this report could be already part of the baseline economic growth and carbon intensity change: whether this were the case, it is not expected to have a material impact on our results, both in absolute and percentage terms.
- 8 Our analysis has been conducted using a general equilibrium model. This means that the impact of environmental AI levers in our four sectors has been analysed considering demand and supply changes in the economy as a whole, and not in isolation. Our model takes into account economic growth across regions and sectors that may not be directly affected, e.g. energy demand may rise if the power sector becomes more efficient and electricity becomes available at a lower cost, offsetting part of the positive environmental impacts.
- 9 “Expansion” scenario results.
- 10 We modelled two scenarios in our analysis, which vary by our assumption of the extent to which AI generates efficiencies in the four sectors we consider. In our “Gradual” scenario we assume progressive growth continues in the adoption and application of environmental AI. In our “Expansion” scenario, we assume a step change in the utilisation of AI in the four sectors.
- 11 BAU is defined based on the assumption that no mitigation policies or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted.
- 12 All GDP figures are reported in 2017 prices and under market exchange rates.
- 13 2030 annual emissions estimates for these countries are based on Climate Action Tracker’s Country Assessments 2018, under current policy projections and excluding LULUCF; available at: <http://climateactiontracker.org>
- 14 Under the ‘Expansion’ scenario.
- 15 AI adoption is determined by country, and aggregated region, rankings on the Global Innovation Index, which is a function of current digital readiness and current trends; available at: <https://www.globalinnovationindex.org/>
- 16 Internet of Things.
- 17 “Expansion” scenario results.

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