ADViCE

AI Innovation for
Decarbonisation's **Vi**rtual
Centre of **E**xcellence

AI for decarbonisation

Assessing the UK landscape for artificial intelligence and its use in decarbonisation

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Contents

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With thanks to the inputs and insights from the following companies:

— Carbon RE

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Executive summary

This report provides insights into, and an overview of, the AI and decarbonisation R&D and innovation landscape in the UK. It captures key use cases, organisations, projects and trends to inform government and policymakers, academia, industry and investors.

It sets the foundations for further work in this burgeoning area: identifying gaps and market opportunities that will be the basis for the remainder of the ADViCE project; providing a set of recommendations for future activity; and looking at future avenues for further investment and growth.

This report is part of Stream 1 of the UK Government's Artificial Intelligence for Decarbonisation programme: establishing an AI for Decarbonisation Virtual Centre of Excellence, also known as 'ADViCE'. This stream is being delivered by a collaborative consortium that includes Digital Catapult, Energy Systems Catapult and The Alan Turing Institute.

AI for Decarbonisation: the UK landscape

- There are currently around 330+ companies developing sustainability-aligned' AI solutions for the agriculture, built environment, energy and manufacturing sectors
- Across these sectors, 77% of AI innovators are based in London and the South East
- Data analytics and insights platforms are currently the most developed, and seemingly most in-demand AI solutions[1]

We use the term 'sustainability-aligned' to differentiate from decarbonisation, as these solutions are being developed for a broad range of environmental and sustainability purposes.

Executive summary

Summary of considerations for future AI and decarbonisation initiatives	
Cross-sector collaboration and knowledge sharing	More financial and collaborative opportunities that bring together cross-sector stakeholders – from AI start-ups to academics and large industry players – will be critical for AI innovation in the UK to scale.
Responsible innovation and building trust	Ensure coordination in existing UK efforts to provide toolkits and roadmaps that support high carbon-emitting sectors in considering responsible AI adoption; build trust; and drive further innovation in this space. This will also support the adoption of shared standards and regulation.
Enabling corporate agility and skills pipelines	Support for large companies to update legacy systems and develop skills and knowledge. This will drive agility in traditional practices and increase the benefits that AI can bring. This means outlining business models to ensure the UK can readily decarbonise, as well as keeping pace with technological innovation.
Cross-technology decarbonisation exploration	In the context of the UK's cyber-physical infrastructure vision, there is an opportunity for DESNZ and DSIT to explore decarbonisation innovation through the lens of complex systems and how multiple technologies can converge to support the UK's net zero ambitions.

Introduction

In its 2021 Net Zero Strategy, the UK Government set out its ambition to lead on the international stage, making the UK the global home for net zero initiatives, and the place for safe and responsible AI innovation and adoption.[2] These goals can work in tandem, enabling new AI products and services to support high carbon-emitting sectors in decarbonisation.

Why decarbonisation?

Scientific communities and national governments around the world have acknowledged the need to take significant action to limit and reduce greenhouse gas (GHG) emissions.[3] COP26, held in 2021, signed off the Glasgow Climate Pact, outlining the ambition of industrialised economies to curb GHG emissions and build resilience in efforts to tackle climate change.[4]

'Decarbonisation' refers to actions and techniques that can support the reduction of carbon emissions, from supply chain operations to industrial processes and energy production. This relies on novel and innovative tools to enable the shift from intensive use of fossil fuels to renewable and low-emission energy.[5] The United Nations Framework Convention on Climate Change also uses 'decarbonisation' to refer to alternative ways of living and working that reduce emissions and capture and store carbon.[6]

Innovation and industrial decarbonisation

Decarbonisation can be enacted through a range of measures. At its core, decarbonisation marks a significant shift in all sectors of the economy, from the uptake of low-carbon energy sources to renewable solutions like wind turbines and solar power. The UK Government, for example, presented its plan to decarbonise industries as part of the Industrial Decarbonisation Strategy (2021).[7] This plan includes action on the deployment of carbon capture, utilisation and storage (CCUS) and low-carbon hydrogen; fuel switching; the development of digital technologies for industrial applications; and improvement in the energy efficiency of industrial sites.

Innovation is critical to decarbonisation, driving new solutions that will enable sectors to reduce their GHG emissions. However, to decarbonise on a large scale requires a significant shift in traditional industry methods and practices. Advanced digital technology innovation can be the driving force to provide new and disruptive opportunities, accelerating decarbonisation around the world.

The global decarbonisation solutions market is growing. Worth an estimated 1.68 trillion USD in 2022, its anticipated annual growth rate is 11.6% between 2023 and 2030.[8] Companies around the world are now actively defining strategies to achieve net zero, such as decarbonising supply chains, better accounting for emissions, and engaging in carbon removal and carbon offsetting initiatives.[9]

Why is decarbonisation relevant in the UK?

The UK has long-standing ambitions to become a lower carbon economy by achieving low energy consumption and pollution levels.[10] As a signatory to the Paris Climate Agreement, the UK has committed to reduce its economy-wide GHG emissions by at least 68% by 2030, compared with 1990 levels.

As the roadmap for attaining this objective, the UK Government unveiled its Net Zero Strategy: Build Back Greener in 2021, followed by the Powering Up Britain blueprint for the future of UK energy in 2023.[11] These strategies set out the government's vision for reducing emissions and decarbonising high-emitting sectors of the economy, including energy, construction, industry, and agriculture. In 2020, 24% of carbon emissions were from the transport sector alone, with 21% from the energy supply sector. Although high level carbon emissions in the UK have seen a steady decline,[12] companies must accelerate their decarbonisation efforts to meet the UK's Net Zero 2050 objectives.

Artificial intelligence in the context of this project

AI is at the forefront of the UK's strategic development priorities in science, innovation and technology, and its adoption is rising significantly across multiple sectors. It has been identified as a key enabling technology for decarbonisation efforts, particularly in its capacity to capture, manage and assess large datasets at a pace beyond human capability.[13]

There are a number of global approaches to, and definitions of, AI. This report relies on key definitions that have emerged in central UK outputs, legislation and expert arenas. For example, The Alan Turing Institute (the UK's national institute for data science and AI, and a key partner on the ADViCE programme) defines AI as:

The design and study of machines that can perform tasks that would previously have required human (or other biological) brainpower to accomplish. AI is a broad field that incorporates many different aspects of intelligence, such as ***reasoning, making decisions, learning from mistakes, communicating, solving problems, and moving around the physical world.*** *AI was founded as an academic discipline in the mid-1950s, and is now found in myriad everyday applications, including virtual assistants, search engines, navigation apps and online banking.*[14]

UK Research and Innovation (UKRI) defines AI as:

A suite of technologies and tools that aim to reproduce or surpass abilities (in computational systems) that would require 'intelligence' if humans were to perform them. This could include the ***ability to learn and adapt, to sense, understand and interact; to reason and plan; to act autonomously; and even to create.***[15]

For the purposes of this report, we consider AI to refer to the approximation of cognitive abilities that, in the case of ADViCE, align to sustainability and decarbonisation objectives.

Global and local AI market growth

The global AI market was estimated at 103.7 billion USD in 2022,[16] with PwC indicating that this figure could grow to 15.7 trillion USD by 2030.[17]

It is the UK's ambition to be the greatest place to work and live with AI, with principles of applied ethics, transparent laws, and regulatory frameworks that encourage innovation. In 2020, the Digital Future Index ranked the UK third globally for private investment into AI firms, trailing only the US and China, and third in the world for AI research in innovation.[18]

Analysis from The Data City indicates that there are 3,000 AI companies in the UK with 129,000 employees. The overall sector contributes £42 billion to the UK economy: through AI innovators, and users applying AI to their existing businesses. The sector is expected to be worth £80 billion by 2027 in the UK.[19] While these figures demonstrate the UK's momentum in AI innovation, the use of AI technologies is still limited to a minority of businesses, with only 2% of businesses piloting AI, and 10% planning to adopt at least one AI technology.[20] This calls for further support for the implementation of AI-driven innovation across industry verticals.

AI for decarbonisation

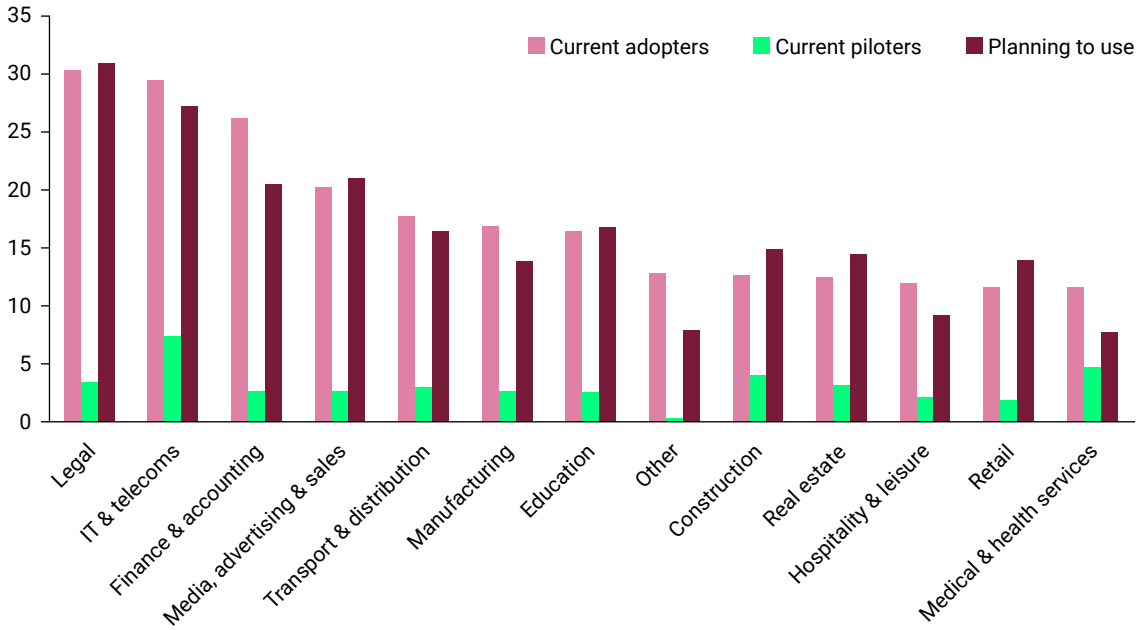
AI for decarbonisation broadly refers to:

AI innovation and building new tools to support decarbonisation, and the readiness of high carbon-emitting sectors to adopt AI for this purpose.

The innovation gap

While the AI and decarbonisation markets are both growing in size and importance, innovation where the two meet is much less than in other areas where AI is being adopted more readily. Currently, IT, telecommunications and legal are showing the highest rates of AI adoption in the UK.[21]

Share of businesses adopting AI by sector, 2020 (%)



The Net Zero Innovation Portfolio

To achieve the UK's net zero ambitions, the government has deployed £1 billion to build net zero infrastructures/solutions through the Net Zero Innovation Portfolio, which is spearheaded by the Departments for Energy Security and Net Zero and Science, Innovation and Technology.

The portfolio aims to commercialise low-carbon technologies, systems and business models in power, buildings and industry. Priority areas include:

- Future offshore wind
- Nuclear advanced modular reactors
- Energy storage and flexibility
- Bioenergy
- Hydrogen
- Homes
- Direct air capture and greenhouse gas removal
- Advanced carbon capture, usage and storage
- Industrial fuel switching
- Disruptive technologies

Under 'disruptive technologies' the Artificial Intelligence for Decarbonisation Programme has been set up to support and promote the adoption of AI decarbonisation applications. The programme aims to support entrepreneurs in developing technologies, products and processes for energy efficiency, generation and storage.

An essential aspect of this project is developing a UK-shared consensus of the broad-ranging, long-term benefits that disruptive technologies can bring, and that can be used to drive the decarbonisation of the highest carbon-emitting sectors in the UK. This means exploring concrete AI solutions and applications that can support companies to decarbonise.

The role of ADViCE

This report is part of Stream 1 of the programme: establishing an AI for Decarbonisation Virtual Centre of Excellence (ADViCE). This stream is being delivered by a collaborative consortium that includes Digital Catapult, Energy Systems Catapult and The Alan Turing Institute, all of which bring extensive knowledge and delivery experience in technical, business and industry solutions across AI, policy monitoring and analysis.

The stream's aim is to drive cross-sector collaboration and coordination, define key challenges that are tractable to AI solutions, and disseminate information to relevant stakeholders.

ADViCE engages with AI and decarbonisation stakeholders across relevant sectors. By facilitating the dissemination of knowledge, it aims to coordinate and foster collaboration on AI innovations with decarbonisation applications.

Project ambitions and success measures

The success of the ADViCE project will be measured by the degree to which multiple ambitions are achieved:

- Increased market growth of AI and decarbonisation technologies
- Reductions in costs for delivering net zero
- Increased technological readiness of AI solutions for decarbonisation applications
- Increased coordination and collaboration between the UK's AI sector and the project's four target sectors, to enable their further decarbonisation
- Increased opportunities to leverage private investment in AI for decarbonisation
- Increased consideration of ethics, bias and equity in AI with decarbonisation applications

Scope of the report

This report presents the current state of the UK market of AI solutions for decarbonisation purposes in four sectors where the carbon footprint is most significant: agriculture, built environment, energy and manufacturing.

Agriculture	Farming; livestock; agritech; sustainable agriculture; equipment and machinery; supply chain and distribution **Highest contributor to overall UK emissions (2021).[22] Responsible for 69% nitrous oxide emissions and 48% methane emissions, 1.7% of carbon dioxide emissions[23]**
Built environment	Residential, commercial infrastructure; real estate; green buildings; demolition and site clearance; inspections; testing **Responsible for 25% of UK GHG emissions[24]**
Energy	Renewables; electricity networks, generation, transmission; fuel generation; utilities; energy storage; energy management; energy efficiency; energy networks; smart grid; offshore **Responsible for 24.8% of CO2 emissions (2022)[25]**
Manufacturing	Machines, robotics, automotive, chemical, fabrication **Responsible for a sixth of the country's total emissions[26]**

The transport sector specifically is not included within the scope of the project. However, there are some notable overlaps within the built environment and manufacturing sectors, both with regards to transport infrastructure and development.

The analysis undertaken delves into the different innovation and adoption factors that characterise the market, pinpointing opportunities and spaces that may require additional support. In this report, **AI innovators** are the core AI companies that are building in-house solutions. **AI adopters** are those companies within the sectors in scope that are adopting AI to drive new processes.

This report provides a snapshot of innovation in AI for decarbonisation in the UK. It offers a high-level review and analysis of the current state of play that will function as a starting point for the wider project. In conjunction with the AI for Decarbonisation challenge report, led by Energy Systems Catapult, it provides insights that will steer the direction of the rest of the project's deliverables to ensure its success. The ecosystem analysis charts the diverse array of organisations and use cases, offering investment data along with details about the companies' size, location and strategies. Using these findings, the report aims to determine the areas of intervention needed to effectively build on existing strengths and bridge identified gaps.

Technology innovation and climate ambitions:

UK and global policy landscape

> The UK has an opportunity over the next ten years to position itself as the best place to live and work with AI; with clear rules, applied ethical principles and a pro-innovation regulatory environment. With the right ingredients in place, we will be both a genuine innovation powerhouse and the most supportive business environment in the world, where we cooperate on using AI for good, advocate for international standards that reflect our values, and defend against the malign use of AI.[27]
>
> **National AI Strategy, UK Government (2021)**

Uniting UK AI and decarbonisation policies

In 2022, Oxford Insights ranked the UK third in the world for its AI readiness, behind only the USA and Singapore, and first in Europe.[28]

Net zero remains a priority across the UK's innovation and policy landscape. Despite being in the top 20 countries for pollution globally, in 2022 the UK ranked second (behind Norway) for its ability to achieve its 2050 net zero emissions target.[29] Aligned with the UK's ambition to become a global science and technology superpower, it is clear that net zero and AI policies are playing a critical role in the UK's positioning and priorities on the global stage.

Key AI policy areas in the UK

In the broader innovation landscape, the UK has established itself as a key global player for the responsible and safe use of AI technologies. Since 2014, it has invested more than £2.3 billion into AI, across a range of R&D and innovation initiatives. The UK is also positioning itself as a leader in safe AI systems and their deployment, with the Bletchley Declaration aimed at ensuring wider international cooperation on harnessing responsible AI for good.[30]

The UK's National AI Strategy, published in 2021, responds directly to the widening adoption of AI technologies. It lays out a scope of actions to ensure that maximum benefits are achieved for every sector and region in the economy, as well as delivering excellence in AI innovation while prioritising the safety, security, choices and rights of UK citizens.[31]

The strategy acknowledges the core factors for enabling a successful UK AI environment, including the need for a skilled and diverse labour force, increasing access to data sets, increasing business investment and international collaboration, access to computing power, and engaging the wider public. The strategy's aim is to support the country's transition to what it refers to as an 'AI-enabled economy', where the benefits of AI can be felt widely. It also aligns the use of AI with global challenges and the United Nations' Sustainable Development Goals, which include net zero, health resilience and environmental sustainability.

More recently, the UK Government's pro-innovation AI regulation framework (2023) lays out its approach to ensuring the right environment for the country to harness the benefits of AI and remain at the forefront of technological developments. It is underpinned by five cross-sector principles that aim to guide regulator responses, balancing AI risks and opportunities:

- Safety security and robustness
- Appropriate transparency and explainability
- Fairness
- Accountability and governance
- Contestability and redress

In addition, it pays attention to associated risks posed by AI, including human rights, safety, fairness, privacy and agency, societal wellbeing, and security.

It is clear that the UK is positioning itself at the forefront of the responsible innovation, adoption and use of AI technologies, placing governance and regulation at the heart of its strategies.

Key decarbonisation focus areas in the UK

Meanwhile, the government has introduced wide-ranging policy measures and strategies to achieve sustainability goals. The UK has established its ambition to become a net zero economy by 2050, a firm commitment to cutting emissions to tackle climate change. In 'Powering Up Britain: Net Zero Growth Plan,' the Department for Energy Security and Net Zero announced that between 1990-2021 the UK cut emissions by 48% and decarbonised quicker than any other G7 country. However, the plan emphasises that the long term trajectory will focus on "improv[ing] the UK's competitiveness, deliver[ing] an industrial renaissance and level[ling] up the whole of the United Kingdom."[32] The Government's missions for decarbonisation, innovation and growth have become enmeshed, ensuring agile solutions to maintain the UK's decarbonisation efforts and net zero ambitions.

The UK's Net Zero Strategy, published in 2021, outlines the prioritisation of adopting a coordinated approach to reaching the decarbonisation goals that the Government has established,[33] uniting "local and national government, Devolved Administrations, and with businesses and civil society organisations [...] making it easier and fairer for individuals, businesses and households to decarbonise so that our whole society can work together to reduce emissions".[34]

Shared priorities and alignment

Decarbonisation efforts and AI development are complementary areas – not only because they are both major policy priorities in the UK and beyond, but also because their goals are not dissimilar:

- Responsible approaches to technology innovation and sustainability
- New methods for achieving goals on a local and broader industrial scale in an efficient and timely manner
- Making the best use of, and enabling widespread access to, data
- Improving processes to drive Industry 4.0

With AI, these efforts can be multiplied, with faster results and more concrete data and analysis, while omitting human error. The ADViCE programme, as a national front door and centre of excellence, unites key companies and organisations that are demonstrating the potential emerging from the intersection of decarbonisation efforts with the UK's ambitions to drive advanced technological adoption. It is also a significant step towards the strategic ambition to "work with businesses to continue delivering deep cost reductions in low carbon tech – driv[ing] investment into new low carbon technologies – taking an innovation-led approach".[35]

The international picture

Globally, AI adoption grew to 35% in 2022, with 44% of companies looking to embed AI into their applications and processes. IBM's Global Adoption Index states that two thirds of these companies (66%) were already using or planning to use AI specifically to address sustainability-related goals.[36]

The UK is recognised globally for its leadership in research and private investment in AI innovation. Data from the Tortoise Global AI Index affirms the UK's position, ranking it only fourth behind the US, China and Singapore for AI innovation in 2023.[37] The Index reflects that these countries are global leaders when it comes to investment levels, innovation and implementation capabilities, and also considers other countries at the forefront of AI development, including South Korea, Israel, Germany and Switzerland.

AI, particularly its cross-sectoral use and application in sustainable development, is a global focus for research and development. The use of AI to monitor environmental impacts is particularly prevalent as a central use case, as is its capacity to build predictive capabilities and provide new insights that enable more effective and timely decision-making.[38] A large number of sectors are seeing the benefits of AI worldwide: agriculture, manufacturing, construction, oil and gas, water and power supply, transportation and food are all using at least one AI technology, and are planning to use more in the future.[39]

Key global policies and interventions uniting AI and sustainability objectives

A vast array of policy priorities and global partnerships are being forged to advance the use of AI for sustainability objectives. Momentum has grown since the launch of the 'AI for Good' initiative launched by the United Nations in 2017.[40] This initiative demonstrates a collective international commitment to harness AI's potential for positive environmental impact.

The creation of the AI Commons in 2021 bolsters this collaborative effort, providing a platform for knowledge-sharing and fostering innovation in AI and sustainability. Concurrently, there has been a notable improvement in global cooperation between nations, particularly in initiatives striving for a common governance framework. Noteworthy endeavours such as Climate Change AI and the OECD AI Policy Observatory have emerged, playing a pivotal role in formulating policies that facilitate responsible and sustainable AI development.

In the United States, the enactment of the National AI Initiative Act in 2020 is a cornerstone for the promotion of AI research and development in the US, and has created a collaborative environment with global partners. The act is backed by initiatives such as the National AI Advisory Committee (NAAC), which provides counselling to the government on AI applications, including those directed towards environmental preservation and achieving net zero targets. The Industrial Efficiency & Decarbonization Office (IEDO) complements this work, with a substantial $135 million funding allocation aimed at spearheading solutions for decarbonising sectors such as industry, energy and buildings.

In China, the New Generation Artificial Intelligence Development Plan initiated in 2017 underscores the nation's aspiration to become a global leader in AI by 2030. This ambitious plan prominently emphasises the potential applications of AI in environmental protection and sustainable development, aligning China's technological advancement with ecological priorities on a global scale.

In April 2022, the European Commission unveiled the AI Act (AIA), a pivotal legislative proposal designed to harmonise AI regulation across the EU. In parallel, a series of initiatives has been launched to fortify the continent's AI capabilities and integrate them into the broader digital and green transitions. The Digital Europe programme, along with the Green Deal and Digital Strategy, collectively strive to make the EU climate-neutral by 2050, with AI playing an instrumental role.

In addition, projects such as AI4Cities have offered AI solutions tailored to European cities, expediting their journey towards carbon neutrality. The AI4EU platform serves as a showcase for projects spanning the continent, highlighting those dedicated to promoting the quality and trustworthiness of AI tools. Noteworthy research initiatives like HORIZON Europe and CLIMATE-KIC are also exploring AI's potential in specific use cases aimed at decarbonising cities and industries.

Global trends

As already indicated by the initiatives and policy measures outlined, some of the key areas being explored globally across AI and decarbonisation can be summarised as follows:

- Fostering global collaboration to share key insights and knowledge, decreasing fragmentation
- Globally reaching and cohesive governance and regulation
- Sharing successful use cases and opportunities for sustainability and decarbonisation that are enabled by AI

Climate change is a global challenge, and the UK's efforts to spearhead technological innovation to solve critical sustainability challenges form part of a wider picture of initiatives with shared ambitions. The UK's confirmed participation in Horizon Europe will enable new R&D collaborations to drive the responsible use of AI to benefit wider society.

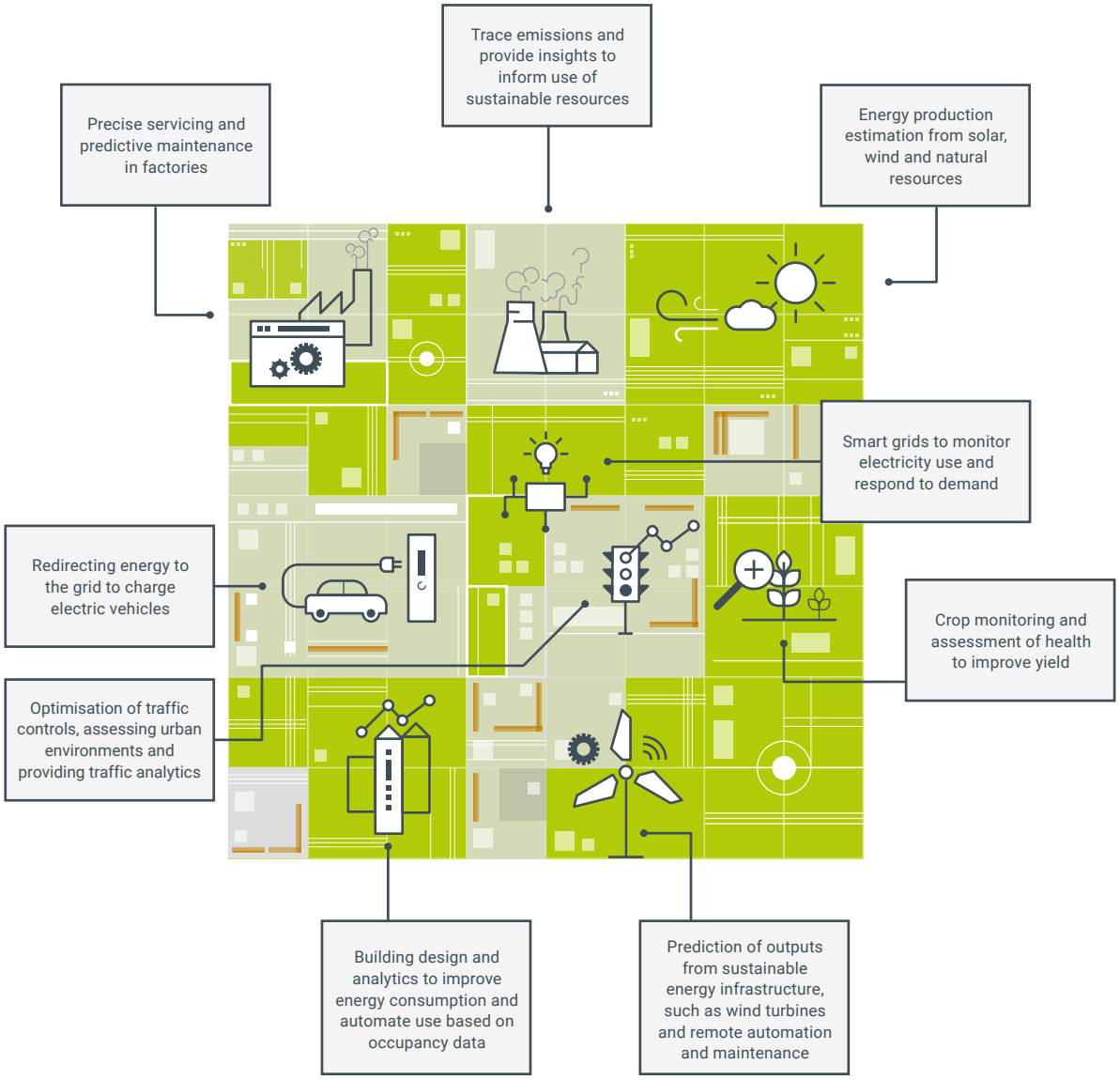
AI and decarbonisation: innovation

It is evident that both the public and private sectors are recognising the significant technological and commercial value that AI can add to taking positive action for decarbonisation. While policy and innovation strategies provide the context through which AI and decarbonisation efforts can be united, AI is already being applied as a critical tool to drive cross-sector decarbonisation efforts.[41]

This chapter focuses on different use cases and the benefits AI can provide, with reference to the sectors in scope of the ADViCE project.

Overview: AI tools and decarbonisation

A variety of AI applications are being built to support the sustainability, efficiency and optimisation of processes within the in-scope sectors.



Examples of AI tools that can be deployed in economy-wide environments

What are the benefits of AI?

At a high level, AI technologies offer a number of benefits, including fundamental adaptability and autonomy. For example, algorithms embed predefined rules and instructions that, when integrated into broader systems, enable the autonomous execution and delivery of tasks without needing human input. Machine learning (ML) is largely focussed on harvesting and training itself on large quantities of data that can be read and interpreted in real time. This serves a range of applications, including the analysis of large-scale datasets issued across energy consumption, emissions, physical data and supply chain processes. Other AI areas, such as deep learning, use neural networks (including large language models/LLMs) to track and interpret data to acquire context and meaning.

> "AI-based analytics can identify hidden, potentially useful information patterns within large datasets that can be transformed into actionable outcomes and knowledge to support improved decision making."[42]
>
> **'AI and Data Democratisation for Intelligent Energy Management,' Vangelis Marinakis et al (2021)**

Through the use of AI systems and techniques for sustainability challenges, BCG[43] has developed the following framework to understand AI's benefits, based on top level approaches. These include measurement, mitigation, removal, adaptation and resilience, and fundamentals.

Framework for using AI to combat climate change

TOPICS	Mitigation			Adaptation and resilience		Fundamentals
SUBTOTALS AND EXAMPLES	Measurement	Reductions	Removal	Hazard forecasting	Vulnerability and exposure management	
	Macro-level measurement e.g. estimating remote carbon natural stock	**Reducing GHG emissions intensity** e.g. supply forecasting for solar energy	**Environmental removal** e.g. monitoring encroachment on forests and other natural reserves	**Projecting regionalised long-term trends** e.g. regionalised modeling of sea-level rise or extreme events such as wildfires and floods	**Managing crises** e.g. monitoring epidemics	**Climate research and modeling** e.g. modeling of economic and social transition
					Strengthening infrastructure e.g. intelligent irrigation	**Climate finance** e.g. forecasting carbon prices
	Micro-level measurement e.g. calculating the carbon footprint of individual products	**Improving energy efficiency** e.g. encouraging behavioral change	**Technological removal** e.g. assessing carbon capture storage sites	**Building early warning systems** e.g. near-term prediction of extreme events such as cyclones	**Protecting populations** e.g. predicting large-scale migration patterns	
		Reducing greenhouse effects e.g. accelerating aerosol and chemistry research			**Preserving biodiversity** e.g. identifying and counting species	**Education, nudging, and behavioral change** e.g. recommendations for climate-friendly consumption

USES FOR AI	Gather, complete and process data	Strengthen planning and decision making	Optimise processes	Support collaborative ecosystems	Encourage climate-positive behaviors
	– Satellite and IoT data – Filling gaps in temporally and spatially sparse data	– Policy and climate-risk analytics – Modeling higher-order effects – Bionic management	– Supply chain organisaton – Simulation environments	– Vertical data sharing – Enhanced communication tools	– Climate-weighted suggestions – Climate-friendly optimisation functions

Source: BCG 2022

Generative data, which refers to the ability to produce new outputs based on wide datasets, is seen as the most widely-used form of AI across the agriculture, built environment and manufacturing sectors.[44]

AI can also be leveraged alongside other emission-monitoring technologies – such as sensors on carbon landfill, drones and satellites – to analyse this data, and this can be applied to a wide range of industries. Overall, with its ability to process large and complex datasets, AI emerges as a pivotal instrument for informed decision-making and process transformation for stakeholders, whether businesses, governments, NGOs, or investors.

A high-level analysis of the ways AI is being and can be implemented across the target sectors is provided below.

AI tools driving sustainability across key sectors

AI in manufacturing

Across manufacturing, AI can be implemented to streamline and optimise processing, using AI models to dissect datasets, and to reduce energy consumption and emissions across the supply chain. Largely cited aims of AI companies building solutions for the sector include assessing materials, making processes more efficient, and mapping and assessing infrastructure.

Use of predictive maintenance in factories can ensure that machinery is serviced precisely to prevent significant operational disruptions. This enables future planning, reducing downtime and energy wastage. AI can also be integrated into a wide range of manufacturing systems, including AI-powered robotics and automation systems that can reduce the energy consumption of processes. This, in addition to the optimisation of supply chain operations, ensures that transport emissions are cut within the value chain.

Use Case 1

Rivelin Robotics, Sheffield – AI Robotics for Factories of the Future

Rivelin Robotics is harnessing the power of AI to develop automated robotics for metal processing tasks, including support removal and polishing. Using state-of-the-art sensors, AI analytics provides dexterity, versatility and ease of operation, leading to a reduction in defects and operational costs, while removing human risk and variability.

Their mission is to support more factories to take up additive manufacturing processes as a major contribution to a sustainable future, due to minimised waste, reduced energy consumption and increased operational efficiency.

AI in energy

Energy forecasting enabled by AI models contributes to the stability and security of energy systems. AI can support grid management optimisation, reducing the need for fossil fuel back-up solutions, through accurate prediction of renewable energy based on historical and real-time weather forecasting data. AI can also evaluate demand patterns and adapt energy use in real-time, so that energy loads can be shifted during off-peak hours, and stress can be reduced during peak periods. AI algorithms can also be applied to improve electricity flow and optimise grid operation and electricity networks, reducing transmission losses and associated costs. Largely cited aims of AI companies building solutions for the sector include automation and optimisation of infrastructure, including the grid; network analytics; improved monitoring; increased energy efficiency; and predictive maintenance.

Use Case 2

measurable.energy, Reading – Using machine learning to eliminate wasted energy

measurable.energy has developed a software and hardware platform which, powered by machine learning, eliminates wasted energy and emissions in buildings. The solution automates the process of finding and removing energy waste at scale to reduce carbon emissions.

They have developed a range of readily accessible plug sockets and fused spurs that recognise devices, monitor their energy consumption and automatically switch them off when they are not needed. The technology measures the carbon emissions being produced, and automated responses reduce carbon emissions and electricity costs.

measurable.energy recently won the CogX award for Best Innovation in IoT & Sensors and was named Tech SME of the Year at the Thames Valley Tech Awards.

AI predictive maintenance can be implemented in the sector across assets such as power plants, increasing operational efficiencies and tracking equipment health. Predictive maintenance can be used across the energy subsectors – including power generation, transmission storage and distribution – to improve resilience and reliability by monitoring and adapting to consumption across different environments, from homes and businesses to city-wide energy usage.

AI can also predict where, and when, demand will increase, enabling greater use of solar and wind powered energy. And by improving the forecasting of changes in demand, AI can help better manage the cost of potential network expansion.

Use Case 3

Otaski Energy Solutions, Gateshead – AI-enabled sustainable solutions for smart city and electric vehicle (EV) infrastructure

Gateshead-based OtaskiES has developed an advanced AI-based energy management system (AI-EMS) that uses energy price forecasts to help users optimise their EV charging and discharging, enhancing energy flexibility and efficiency. Their flexible energy management system is equipped with DC bi-directional charging technology, and can support peak demand and reduce energy costs by using low-cost, off-peak energy; optimising charging efficiency across an entire fleet; introducing new business models like vehicle-to-vehicle (V2V) charging; and integrating energy storage, renewables, and EV fleet energy trading with the grid/building (V2G/V2B).

Users can connect their EV batteries to their home, businesses, devices, and the grid, allowing them to sustainably optimise energy use, reduce energy costs, and generate returns on their investment. This technology empowers users to have more control over their energy usage and be less vulnerable to fluctuating energy costs and availability.

AI in agriculture

The environmental footprint of the agriculture sector is largely based on farming methodologies, and new ways to improve efficiency form a large part of ambition in agricultural technology innovation (agritech) innovation.

Precision agriculture uses management strategies that gather, process, and analyse data to improve management decisions and provide insights into estimated variabilities.[45] Farming companies can harness the analytical capabilities of AI systems to gather data from sensors or satellites and use resources like water, fertiliser, and pesticides more efficiently. This minimises waste and reduces the environmental pressure on soil.

AI can be used to detect disease and pests on crop yields to enable more targeted and effective interventions, as well as reducing the use of chemicals for delayed treatment. Largely cited aims of AI companies building solutions for the sector include improving accuracy and efficiency, making sense of large amounts of data, and the optimisation of asset management and farming delivery.

Use Case 4

FruitCast, Lincoln – Optimising soft fruit farming using AI crop scanning

Seed company FruitCast is revolutionising soft fruit farming through advanced AI-driven crop scanning technology. Their innovative approach contributes to yield accuracy and plays a crucial role in reducing the carbon and waste footprint of agricultural practices.

Having recently secured an investment of £2.8 million, and backing from Cambridge Enterprise, Ceres AgriTech, and the University of Lincoln, FruitCast is poised to drive further impact in the agriculture sector.

AI-powered applications can also be used to obtain more precise models and predictions for weather conditions, soil moisture levels and plant growth. This enables earlier, more informed, and data-driven decisions to reduce the consumption of resources. Similarly, AI weather forecasting enables better planning of activities such as planting, irrigation, and crop protection to safeguarding yield and reduce crop wastage.

Use Case 5

Better Origin, Cambridge – Turning food waste into animal feed

Food waste accounts for 10% of the world's greenhouse gas emissions. Cambridge-based Better Origin has developed a bioconversion AI-powered insect farm that combines technology with insects' ability to upcycle nutrients.

Their solution mitigates food waste emissions and produces carbon-neutral protein that can be used for animal feed. The AI system processes food waste, while feeding the insect larvae and measuring and determining their growth stage.

Better Origin aims to make high-yielding and carbon negative agricultural practices more accessible to small-scale farmers.

AI in the built environment

Through cross-cutting AI usage with spillovers from energy (use in buildings) and manufacturing (building materials and infrastructure), AI can track energy usage across public, commercial, industrial, and residential buildings, reducing the dependence on oil and gas.

AI can also support, at an early stage, the process of designing and creating building infrastructure to ensure the highest levels of ventilation, insulation and energy-saving materials. AI can help to ensure that sustainability is a consideration throughout the life of a building, from construction to demolition. Largely cited aims of AI companies building solutions for the sector include monitoring assets like fleet distribution or improving operational efficiency and safety. This supports better decision-making through data analysis, and improved performance of smart city infrastructure.

Use Case 6

Carbon Re, London – AI for materials

Carbon Re a joint spin-out from Cambridge University and UCL that is accelerating the decarbonisation of foundation materials, including cement, steel, and glass.

Carbon Re's mission is to reduce gigatonnes of carbon emissions and secure a zero-carbon future for cities. Their first product, Delta Zero Cement, uses AI and machine learning to optimise fuel use and product quality, as well as reduce carbon emissions in cement production.

AI smart-powered building systems can enable dynamic control of utilities, such as lighting, by tracking and responding to occupancy levels, time of day, weather conditions and temperature. By recognising and forecasting occupants' behaviour patterns, AI can increase occupant comfort and optimise consumption.

Use Case 7

Contilio, London – 3D AI analytics for construction sites

Contilio is a built environment AI insights platform, delivering huge savings in CO2 emissions, operational costs, and time for asset owners, developers, and general contractors globally.

The company's generative 3D AI technology represents a breakthrough in 3D semantic understanding, enabling fully automated, AI-powered quality verification, quantity tracking, CO2 tracking and cognitive digital twins for construction and operations.

Assessment across sectors

Based on secondary research and database analysis, some of the broad uses of AI for sustainability purposes across the sectors in scope are listed below. There are some areas of crossover, for example, monitoring of energy in buildings, or manufacturing and assessment of materials for construction.

AI applications in the energy sector

Internet of Energy (IoE)

- Automated building management energy insights
- Data analysis for industrial assets and asset management
- Pattern recognition, self-learning systems and predictive analysis

Intelligent automation for renewable energy sources

- Remote solutions for offshore energy assets
- Mapping hard-to-reach places (such as the ocean floor) using neural networks and satellite data

Grid optimisation

- Automation of distributed energy resources
- Optimising energy demand and supply with data
- Improved monitoring

Emissions traceability

- Algorithms for hyper-local carbon flow assessment

AI applications in the agriculture sector

AI enabled analytics for forecasting

- Yield forecasting
- Satellite imagery and weather forecasting

'Per plant intelligence' and precision farming

- Remote sensing data
- Variability mapping on crops

Advanced AI and intelligent robotics

- Food management and data optimisation
- AI-operated facilities e.g. greenhouses
- Tracking supply chain emissions

AI applications in the manufacturing sector

Optimisation technology

- Precision autonomous manufacturing
- Workflow augmentation and automation

Autonomous robotics

- Autonomous large-scale 3D printing technology
- Advanced simultaneous localisation and mapping (SLAM) software enabling machines to learn from the space around them
- Automated tool design and smart tools

Predictive maintenance and forecasting machine failure

- Predictive decision-making
- AI damage detection

Emissions traceability platforms

- Tracking supply chain and equipment emissions

AI applications in the built environment sector

Optimisation of traffic controls

- Self-driving software for complex urban environments
- Smart city-style sensors and traffic analytics platforms

3D big data combining image processing, ML and AI

- Computer vision and edge cameras for foot traffic and live occupancy of buildings
- Digital wayfinding and location analytics
- Visualising airborne disease risk
- 3D pollution visualisation
- Gamified sustainable behaviour automated activity detection

Emissions traceability platforms

- Tracking supply chain and equipment emissions

Although there are a number of new AI use cases and tools being developed to support sustainability objectives, it is important to also consider adoption rates across these sectors and assess whether AI innovation is matching needs in order to reach national climate ambitions.

AI and decarbonisation: adoption

Within the scope of this report, analysis of UK AI adopters focuses on companies that are, at present, most readily adopting AI to support sustainability and decarbonisation ambitions. This section is complemented by the parallel ADViCE report, delivered by project partner Energy Systems Catapult, which explores adoption challenges in more depth.

UK-wide AI adoption: high level statistics

> It is anticipated that in the UK at large, AI adoption will increase to 22.7% of UK businesses by 2025, with an additional 267,000 businesses using AI in their operations […] By 2040, the overall adoption rate will reach 34.8%, with 1.3 million businesses using AI.[46]
>
> **AI Activity in UK Business, 2022**

Desk-based research indicates that AI adoption in the UK is on the rise, with ONS data showing that 1 in 6 companies in the UK is currently implementing at least one AI application.[47]

Analysis undertaken by the OECD on UK AI adoption[48] revealed that typical AI adopters are larger companies, often exhibiting higher levels of productivity. Younger companies, on the other hand, demonstrate a greater propensity to hire AI-related talent. Most AI-adopting and innovating firms are clustered in London and the South East. Capital Economics' 2022 assessment[49] found that, in the UK:

- Around 15% of all businesses had adopted AI technology (approx. 432,000 companies)
- As businesses grow, they are more likely to adopt AI: 68% of large companies have adopted AI, compared to 15% of small companies.
- Data management and analysis solutions largely drive adoption of AI
- 40% of businesses developed AI in-house; 40% purchased off-the-shelf solutions; 20% outsourced development of AI applications to external providers
- Average AI labour spend was £24,400 per small business, £1.7 million per medium business and £3.1 million per large business

UK AI Adoption in key sectors

Assessment of AI adoption information across the sectors is informed by desk research and insights from reports, academic papers, relevant news, and other reliable sources.

Manufacturing

A 2023 Manufacturing Leadership Council report revealed the manufacturing sector is still largely in the relatively early stages of adoption, with 57% of manufacturers still piloting or experimenting with AI.[50] 29% have turned their AI initiatives into formal plans, and only 4% of respondents did not plan to use artificial intelligence.

The study showed that 63% of manufacturing leaders intend to increase their AI budgets during the year; only 3% planned to spend less on artificial intelligence; and the top priority for companies was to use AI to upskill their workforce.

Use Case 8

General Electric (GE) is using additive manufacturing to reduce the amount of waste it produces. The company has adopted 3D printing to create moulds and develop prototypes that are helping it to reduce the need for traditional manufacturing methods that produce excess waste.[51]

A study by Made UK found that the AI tool with highest adoption rate (35%) was data analytics. Approximately 15% of manufacturers cited AI robotics as a tool they were using to decarbonise activities.[52]

Agriculture

Collaboration between AI companies and agricultural businesses has resulted in a number of AI solutions being harnessed for decarbonisation, such as sensor technology, field robots and data analytics.

Use Case 9

In 2019, the **John Lewis Partnership** announced a three-year trial with the **Small Robot Company** to test its farmbots at the company's farm in Leckford, Hampshire. The trial planned to demonstrate the capabilities of robots to increase precision and efficiency, while reducing the damage caused to soil by current farming practices.[53]

A study conducted by Barclays in 2021 found that sensor technology accounted for 55% of AI adoption in agriculture in 2020.[54] The adoption rate for data analytics was significantly lower, accounting for 9%, followed by field robotics at 4%.[55]

Energy

An annual survey conducted by the DNV across companies in the energy sector found that 75% claimed their organisation would prioritise improving data quality and availability in the year ahead, supporting the evolution of AI and ML. Only 11% reported using some kind of AI solution in day-to-day operations, and a large subsection (25%) of those surveyed had no existing or planned AI activity on their corporate agenda.[56]

Use Case 10

In 2023, **Toyota Research Institute** announced a partnership with **Northwestern University, USA**, to find the most sustainable materials to use in future power applications, such as batteries and fuel cells, with an aim to decarbonise their transportation chain. In collaboration, they have developed a machine learning algorithm that can discover crucial materials to drive the clean energy transition.[57]

Use Case 11

In 2019, the **National Grid Electricity System Operator** (ESO) partnered with The Alan Turing Institute to use machine learning to refine renewable energy forecasts.[58] Given the need to maintain the balance of the power system in real time in order to respond to fluctuations in demand, the ESO relies on a combination of different energy sources. The Alan Turing Institute focused on leveraging data analysis and machine learning techniques to develop more accurate forecasting models for solar and wind energy, resulting in a 33% improvement in solar forecasts.

Built environment

In 2020, the construction sector's overall adoption of AI was estimated to be among the lowest in the UK, at just under 15%. This implies that about 288,000 companies in this sector had not implemented AI at that time.[59] Yet, AI integration has been successful in specific use cases, in particular in connection with energy usage and optimisation.

Use Case 12

Social housing provider **Mears Group** has recently acquired **IRT Surveys** to speed up and improve its carbon reduction work.

Prior to the acquisition, IRT had developed a use of AI to reduce heat loss in homes, working alongside **The Data Lab** in Scotland.[60] Their thermal imaging technology allows housing developers and associations to identify which properties need to be retrofitted to make them more energy efficient.[61]

Most prevalent AI tools

Most tools under development have been examined to better understand where demand is the highest. Research across all sectors shows that AI-enabled data and real-time analytics platforms represent the highest percentage of solutions being built. AI can filter large amounts of data to provide actionable insights that can be used to optimise processes and operations, and to inform better decision-making.

AI-enabled robotics and autonomous systems are also prevalent across the sectors in scope, being used to drive new processes, improve supply chain efficiency and improve safety by mitigating the need for human labour in dangerous situations.

Mapping UK businesses using Crunchbase and The Data City has revealed that there are four main applications being used to support carbon reduction.

- **Carbon management platforms:** AI can enable better measurement of CO2 emissions levels, alongside other emissions-monitoring technologies required for the collection of robust data such as sensors in landfills, drones, and satellites. These platforms can also assess carbon offsetting performance and carbon accounting.
- **Automation and robotics:** AI plays a crucial role in increasing process efficiency. For example, AI-enabled enhanced predictive maintenance boosts efficiency by pre-empting equipment failures and maintenance needs to minimise downtime. Robotics can also enhance safety, increase operational efficiency, and reduce costs.
- **Operationalisation of net zero ambitions:** AI solutions can enable forecasting and prediction based on real-time analytics, helping companies to plan ahead to deliver on their sustainability goals. For example, AI solutions can be used to refine energy production forecasts and predict weather forecasts for farming, as well as tracking carbon flow in real time. This refinement ensures a more reliable and consistent supply, while also providing significant savings.
- **Data collection, analysis, and visualisation:** AI's ability to process large and complex datasets makes it an essential instrument for informed decision-making and process transformation. AI can track data to report the carbon footprint of operations and supply chain in real time. Carbon emissions can also be visualised to bring data to life and suggest where operations can be improved.

As an indication of demand levels, these four charts show the most developed tools by sector.

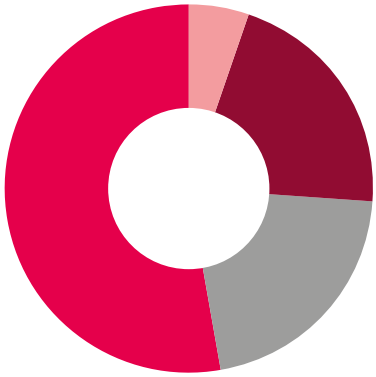
Built environment

Autonomous robotics
5.3%

Automated transport systems
21.1%

Sensors, smart tech and IoT
21.1%

Real-time insight and analystics platforms
52.6%



Agriculture

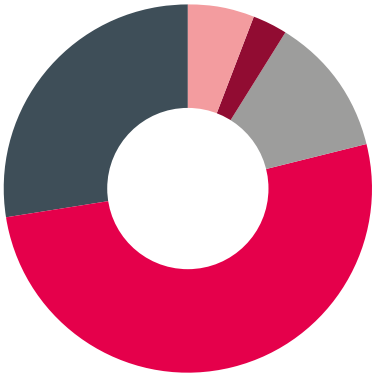
Remote monitoring
6.1%

Carbon accounting
3.0%

AI-enabled infrastructure
12.1%

Insight and data analytics
51.5%

Automation and robotics
27.3%

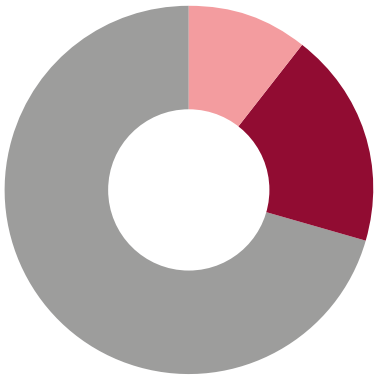


Energy

Autonomous robotics
10.8%

Automated facility management and sensors
18.9%

Software and analytics platforms
70.3%



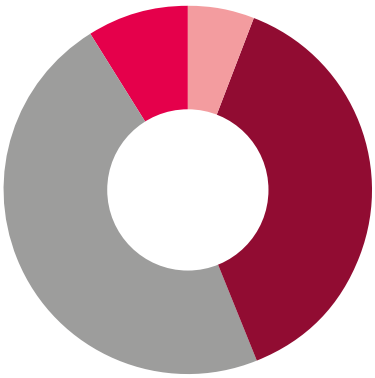
Manufacturing

Simultaneous localisation and mapping (SLAM)
5.9%

Autonomous robotics
3.0%

Real-time analytics platforms
12.1%

Carbon accounting
27.3%



Ecosystem analysis

This analysis aims to assess the UK's AI capabilities in addressing decarbonisation across agriculture, manufacturing, built environment and energy. It uses data from Crunchbase and The Data City to identify the different actors in this space, and provides a description of the companies building AI solutions targeted at the sectors of interest, outlining their geographic distribution, size, and types of solutions dominating the market.

This chapter also considers investment trends in AI for sustainability in the UK, and provides a non-exhaustive list of existing initiatives in the UK that both complement and support the objectives of the ADViCE programme.

68%

of those adopters are large companies[63]

36%

of companies looking for AI talent are based in London[64]

Most AI companies developing decarbonisation solutions are at seed investment stage

Statistical overview

Many sources providing data on the number of AI companies often include both AI innovators and adopters. We have prioritised the examination of AI developers, to determine how many innovators in the ecosystem there are across the sectors in scope, and who they are building solutions for.

AI for decarbonisation innovation

- 330+ UK companies are developing sustainability-aligned AI solutions for the industries in scope
- Most AI innovators (77%) are based in London
- Most AI companies developing decarbonisation solutions have 1-10 employees and are at seed investment stage

AI adoption

- 26% of companies in the UK are adopting AI solutions – not just sectors in scope[62]
- 68% of those adopters are large companies[63]
- 36% of companies looking for AI talent are based in London[64]
- Within the sectors in scope, AI is being most readily adopted by manufacturing

AI innovation for decarbonisation

Company numbers

There are an estimated 330+ UK companies developing sustainability-aligned AI solutions for the industries in scope. We use 'sustainability-aligned' to differentiate from decarbonisation, as these solutions are being developed for a broad range of environmental and sustainability purposes.

The Data City's Real-Time Industrial Classifications (RTIC) for 'Artificial Intelligence: Green Tech' states that there are 349 companies under the category of "companies using AI to create products and/or services aimed towards net zero, environmental monitoring or energy management"[65] in the UK.

Use of the Crunchbase platform returned 335 results for UK companies developing sustainability-aligned AI solutions for the industries in scope. The Crunchbase database search used for this analysis specifically explored companies with both 'AI' and 'carbon' keywords. It also searched for AI and the sectors of interest: 'AI' and 'energy', 'manufacturing', 'built environment' and 'agriculture'.

- AI and energy returned 90 results/companies
- AI and agriculture returned 47 results/companies
- AI and manufacturing returned 109 results/companies
- AI and built environment returned 59 results/companies, and notable crossover with other sectors (energy and manufacturing)

Certain companies fall into the category of AI specifically targeted for decarbonisation, actively contributing to the pursuit of AI-driven solutions to reduce carbon emissions. For example, Sylvera focuses on the development of machine learning tools for tracking carbon offsets. Emitwise is building an AI-powered carbon management platform, while CarbonChain specialises in carbon accounting to monitor, report, and mitigate supply chain emissions. Carbon Re provides AI-driven decarbonisation tools tailored for the cement and building materials industry, and Ecolibrium intends to operationalise carbon emissions through the application of machine learning.

Concurrently, there are other companies primarily engaged in the development of AI solutions that align with the net-zero and sustainability agenda. These encompass optimisation, efficiency enhancement, sustainable practice, and innovative data-driven solutions, collectively contributing to the global push for a more sustainable economy.

Company geography

- 70% of AI companies for energy are based in London, with others in Manchester, Derby, Bristol, Edinburgh and Glasgow
- 56% of AI companies for agriculture are based in London, with others in Cambridge, Salisbury, Derry, Edinburgh, Glasgow and Cardiff
- 62% of AI companies for manufacturing are based in London, with others in Birmingham, Cambridge, Edinburgh
- 58% of AI companies for the built environment are based in London, with others in Cambridge, Oxford, Bristol, Sheffield, Manchester and Edinburgh

Company size and investment stage

Across all sector application areas, the majority of AI innovator companies employ 1-10 employees, and are classified as seed companies, followed by early-stage ventures.

- In manufacturing, 65% of companies developing AI for the sector were categorised as seed stage, and 26% as early stage venture
- In agriculture, 72% of companies developing AI for the sector were categorised as seed, and 20% as early stage ventures
- In energy, 44% of companies developing AI for the sector were categorised as seed, followed by 34% as early stage venture
- In built environment, 75% of companies developing AI for the sector were categorised as seed stage, and 17% as early stage venture

AI adoption for decarbonisation

Assessing the number of companies adopting AI across the sectors in scope has been informed by expert papers, government publications, and news stories, as it's not possible to differentiate between AI adopters and innovators in databases. This section provides an indication of which sectors are most readily adopting AI for sustainability-aligned purposes.

A number of criteria and characteristics can be used to assess widespread AI adoption. A report undertaken by Capital Economics on behalf of the (then) DCMS in 2022 classed a business as having adopted AI technologies if it declared usage of one of the following AI technologies: machine learning, natural language processing and generation, computer vision and image processing and generation.

An OECD report undertaken in 2022 outlined key insights into identifying and characterising AI adopters in the UK. It differentiates between different types of AI adopters:

- Firms that carry out AI innovation
- Companies that have an AI core business
- Firms that require AI talent[66]

The Data City's RTIC search was used to gather information on AI adoption across sectors. The database scoped 350+ sectors with unique classifications, while providing insights from the keywords used by companies. This section assesses the following:

- The number of companies categorised within each of the sectors in scope, compared to the number of AI innovator companies.
- How closely the locations of AI innovator companies match the locations of adopters, indicating how readily available solutions are based on geographical proximity, as well as sector activity being matched by local AI innovation to drive new AI for decarbonisation solutions.
- Alignment between AI and carbon keyword rankings across sectors compared to other innovation and technology adoption areas, using The Data City's keyword analysis. This provides an indication of the prioritisation of AI and decarbonisation across companies' strategy.

Agriculture

The Data City analysis indicates that the largest hubs for 'agritech', defined as "the use of technology in farming to help improve efficiency, sustainability, and profitability" are mostly based in London, followed by Manchester and Cambridge.[67] Altogether, The Data City displays 1,203 companies categorised as agritech. However, within this RTIC, 'artificial intelligence' ranks low in company keyword usage, and low carbon keywords rank even lower. The most common agritech keyword in use at present is 'precision agriculture'. This suggests that while technology adoption in the sector is growing, other technologies are being adopted more readily than AI.

Built environment

The Data City analysis shows 516 companies categorised as 'building technologies,': "providing technology and services for increasing energy efficiency in buildings".[67]

485 of these companies are based in London, followed by 67 in Glasgow and 45 in Leeds. Of these companies, 56 are identified as focused only on AI, while 242 are identified as combining AI and IoT for energy management purposes, which indicates that this is the most readily adopted application in the built environment. While 'zero carbon' ranked highly in the keywords used by companies, 'AI' ranked significantly lower, suggesting that even if activities are undertaken to improve the carbon footprint, few of these relate to AI.

Manufacturing

The Data City reports 11,410 UK companies categorised as 'advanced manufacturing': "companies that use innovative technologies and processes to increase production and productivity".[68]

Of these companies, 546 are considered as adopting or "leveraging AI and machine learning to improve operational efficiency, launch new products, customise product designs and plan future financial direction". This shows that AI adopters in manufacturing far outweigh the number of AI innovators[69] developing solutions for the sector, and that the use of AI is largely focused on areas beyond decarbonisation and sustainability. While there is a significant number of advanced manufacturing companies spread across the country, business counts by city are largest in London (3,300) followed by Birmingham and Wolverhampton (1,700) and Manchester (957).

Within the industry keywords, a range of AI terminology is included, the highest rankings being 'machine intelligence,' 'neural networks,' 'language processing,' and 'deep learning.' In comparison to the other sectors, this suggests that manufacturing is more literate in AI adoption and usage. In contrast, 'low carbon' is little used. This suggests that while AI adoption in manufacturing is seemingly high, AI is often implemented for reasons other than decarbonisation.

Energy

The Data City has three RTICs totalling 20,198 companies across the energy sector. 'Energy generation,' ("companies producing or supplying energy"), with 9,877 companies; 'energy management,' ("companies maintaining smart grids and producing smart meters as well as organisations monitoring energy consumption using AI and IoT") with 7,122 companies; and 'energy storage,' ("companies developing new innovative technologies and methods to store electricity or heat") with 3,199 companies.

Within energy generation, 4,100 of businesses are London-based, followed by Glasgow (699) and Leeds (664). The most common keywords focus on grid, energy storage and generation, and 'carbon capture and storage' and 'low carbon technologies' rank fairly high. AI ranks below average company usage, indicating that at present, AI's adoption and use across the energy generation is low in comparison to other technology solutions.

Within energy management, 4,100 businesses are London-based, followed by Manchester (634) and Leeds (506). The most common keywords focus on smart grids, vehicle to grid, smart systems and connectivity. Low-carbon technology is widely used, and other technologies (such as IoT) also rank much higher than AI, as well as keywords relating to data architectures, modelling and big data.

This indicates that data management is key in this space but may not yet be applicable directly to AI in most instances. It also suggests that AI solutions may not be as readily adoptable than other advanced digital tools.

In energy storage, 1,600 businesses are London based, followed by Oxford (181) and Manchester (179). Low-carbon technology ranks extremely high in the keyword count as well as clean tech. AI, however, is ranked low in company keyword use. This suggests that while the need for smart systems and low-carbon technologies is a priority in energy storage, the emphasis on AI use is lower.

AI and decarbonisation investment

The UK requires significant private investment in AI in order to meet net zero goals and significantly decarbonise industry. PwC calculated that the buildings and industry sector would require investment of up to £18.5 billion per year to meet goals by 2030,[70] and in 2020, it was estimated that £40 billion in investment was needed across transport, power systems, buildings, and digital sectors by 2030 to meet decarbonisation goals. The International Energy Agency estimates that the total capital investment into low-carbon energy systems and industrial processes on a net-zero pathway could be approximately £25 trillion between 2020 and 2030.[71]

To date, significant private investment can be seen across some of the most critical net zero areas. Most private capital investment tends to be in the renewable energy sector. However, investors have expressed concerns over unsupportive policy, lack of viable merchant models and price controls that prevent further investment into low carbon infrastructure and power grids.[72] Between 2020 and 2022, investment into cleantech experienced a 50% increase, totalling £945 million. The fourth quarter of 2021 saw the highest cleantech investment in the UK so far, £455 million.

According to Crunchbase data, the total amount of equity funding raised by AI companies building specifically for decarbonisation and sustainability initiatives, to date, totals £405.3 million.

Key investors

UK companies including Carbon Re, Perceptual Robotics, Better Origin, Urban Chain, Terra Robotics, Modularity Grid, Iceni Labs, Orca Hub and Corridor Technology have received funding grants from Innovate UK, as well as other public funding such as the Clean Growth Fund, Low Carbon Innovation Fund and Low Carbon Accelerator.

Based on those who have invested in multiple companies, prominent investors and funds supporting AI for decarbonisation solutions and innovation include:

- EIT InnoEnergy
- Clean Growth Fund
- Plug and Play
- Climate KIC Accelerator
- Sustainable Ventures
- Low Carbon Capital
- Low Carbon Innovation Fund
- Climate-KIC
- Climate VC

Innovate UK funding data, accessed via The Data City, indicates that 299 UK-based AI companies have received £331 million in funding to date. Most recipients are categorised as developing solutions for information and communications, while manufacturing ranks third. Although providing significant funding over time, IUK allocated most funding in 2018 (£80.5 million) compared to 2023 (£11.2 million). In the subcategory of 'GreenTech' under the AI RTIC, more companies have received IUK grants (376) but of lesser value (total £49 million). Most funding was granted to companies developing cleantech solutions in 2022.

Existing programmes and initiatives

Innovate and UKRI portfolio

UKRI has awarded a range of funding to AI and net zero solutions. Within the Engineering and Physical Sciences Research Council (EPSRC), there is a theme specifically dedicated to energy and decarbonisation, with the goal of "invest[ing] in research and innovation to secure a low carbon future through the creation of reliable, economically viable energy systems."[73]

UKRI Funding Case Study

ECO-AI – Heriot Watt University

ECO-AI received £3 million in UKRI funding in 2023. The project's mission is to address key barriers for large scale carbon capture and storage (CCS). It will develop an AI materials discovery company, AI solvers for modelling CO2 flow in geological storage formations and modelling CO2 target processes across individual sectors.

Meeting UK's net zero target through AI

In 2022, UKRI granted £13 million[74] to support research initiatives addressing sustainability challenges across transport, energy, environment and agriculture. This funding was made available to research and technology organisations as well as education institutions, for building AI capabilities geared towards net zero issues. These efforts focused on mitigating carbon emissions, improving carbon management, and advancing development related to carbon capture and storage.

Machine Intelligence Garage (2021)

Digital Catapult's Machine Intelligence Garage was designed to help startups develop and build machine learning and artificial intelligence solutions. It gave innovators with a well-defined business idea and technical capability the access they needed to computation power and relevant expertise – as well wide-ranging support across business, investment and applied AI ethics.

Using Digital Catapult's experimentation space, companies and researchers were able to try out new hardware and supporting technology solutions. And through workshops and experimentation days, Machine Intelligence Garage helped over 100 startups from a range of industries, including legal, manufacturing, creative and logistics.

BridgeAI – Innovate UK (2023)

The BridgeAI programme marks a £100 million investment from Innovate UK to drive the ethical use of AI adoption and bridge the AI divide in the UK. It has been set up to directly respond to low adoption rates in sectors with high growth potential, including agriculture, construction, creative industries, and transport.

The programme is offering a range of funding, upskilling and knowledge transfer opportunities for companies to engage with, to learn how to harness the power of AI through responsible and inclusive practices.

In addition to IUK KTN, the British Standards Institute and the Hartree Centre, the ADViCE programme will directly interface with BridgeAI, ensuring that adoption information is shared with the ADViCE ecosystem, and feed across key insights relating to the use of AI specifically for decarbonisation.

Local Industrial Decarbonisation Plans (LIDP)

The Local Industrial Decarbonisation Plans (LIDP) £5 million competition provides support for industrial manufacturers not located within existing industrial clusters to develop plans to reduce their carbon leakage. This opportunity supports the advancement of place-based industrial decarbonisation plans, enabling collaboration between closely located industrial businesses, as well as upskilling their capabilities ahead of introducing low-carbon emission technologies.

Our ambition is that the next stages of the ADViCE project would support and, where appropriate, feed into the LIDP upskilling and knowledge frameworks as they roll out across regions of the UK.

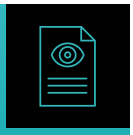
Existing centres of excellence and expertise

Within the UK, there is a strong ecosystem of centres of excellence exploring AI, decarbonisation, and net zero, with technology innovation uniting these areas. This report provides a snapshot of existing centres of excellence, although this mapping is an iterative process. ADViCE will continue to unite the ecosystem and act as a 'front door' to all innovation activity taking place in these areas across the UK. The project will also seek to engage the established ecosystem, uniting key domains of expertise to share knowledge and forge newfound collaborations.

To illustrate academic research and innovation across the UK, some example centres of excellence are outlined below:

Sustainability general

- Tyndall Centre for Climate Change Research – Manchester University
- Decarbonisation Network – University of Cambridge
- AI4NetZero research group – Heriot-Watt University
- Centre for Net Zero – Octopus Energy Group – London
- Centre for AI and Climate – London
- Net Zero Technology Centre – Aberdeen
- UKRI AI Centre for Doctoral Training in Environmental Intelligence: Data Science and AI for Sustainable Futures – University of Exeter



UKRI Centre for Doctoral Training

UKRI Centres for Doctoral Training in AI

UKRI is funding up to £117 million to support 10-15 Centres for Doctoral Training (CDTs) focused on AI applications. The priorities for these projects involve the development of AI solutions to track, model and reduce carbon emission for energy and agriculture.

Manufacturing

- Institute for Manufacturing – University of Cambridge
- Centre for Autonomous and Intelligent Systems – University of Huddersfield
- The EPSRC Centre for Innovative Manufacturing in Composites (CIMComp) of the University of Nottingham
- High Value Manufacturing Catapult (HVMC)

Agriculture

- Centre for Ecology and Hydrology
- Lincoln Institute for Agri-Food Technology – University of Lincoln

Built environment

- dCarb – University of Bath
- Centre of Excellence in Rail Decarbonisation – University of Birmingham
- The UK Collaboration for Research on Infrastructure and Cities (UKCRIC)

Energy

- Energy Demand Observatory and Laboratory (EDOL) – University of Oxford
- UCL Energy Institute – University College London
- Durham Energy Institute – Durham University
- Centre for Decarbonisation and Offshore Renewable Energy – Plymouth University
- AI Centre of Excellence – National Grid Energy System Operator
- Offshore Renewable Energy Catapult (ORE)
- Energy Systems Catapult (ESC)
- The Control and Power (CAP) Research Group – Imperial College London
- Power and energy systems – University of Manchester
- Institute for Energy & Environment – University of Strathclyde, Glasgow

While the UK and global AI markets are growing, more opportunities are needed for AI innovators in decarbonisation and sustainability. These should aim to boost the diversification of tools being developed, respond to industry demand, and increase adoption rates – as well as providing further encouragement for AI for decarbonisation innovation in the UK.

AI has been proven to improve the sustainability efforts of the sectors in scope. More can be done to forge newfound collaboration with leading AI innovators, and to update legacy systems and business models to improve growth and agility for adopters and innovators alike.

These considerations respond to the findings of this report, and provide stakeholders, from government and other public sector funders to innovators and investors, with knowledge to drive the AI for decarbonisation ecosystem forwards.

Cross-sector collaboration and knowledge sharing

Provide further investment opportunities to develop scalable solutions through collaborations between promising AI startups and SMEs, academics, and large industry partners.

AI innovation for decarbonisation and sustainability is often undertaken by small companies that require further investment to scale and expand beyond a single sector focus area. Interviews undertaken for this report flagged the reliance on sector knowledge to drive new AI solutions for solving challenges. Open Climate Fix, for example, was born to respond to a need, and based on expertise in the energy sector. The same can be said for Carbon Re, which has in-house academic experts from the built environment sector who feed their specialist knowledge into the solutions being built.

These examples from two pioneering startups indicate the interdependence of expertise – sectoral knowledge to influence AI solution development, and AI knowledge in sector-based companies – to improve adoption readiness and implementation.

Companies interviewed highlighted the urgent need for opportunities to scale promising and value-driven startups that can have significant impact and lead new solutions forward. We recommend further government and industry joint investment and private investment in a range of challenge-led R&D and innovation projects for AI for decarbonisation, with the goal of de-risking and encouraging collaboration, along with stimulating new proof of concepts (POCs), use cases, products, and services.

This will also feed into future ADViCE deliverables, ensuring cross-sector pollination to share successes, challenges and opportunities for future development – identifying the gaps and developing new interventions in areas of maximum impact in balance across the economy, society and environment.

Focus on decarbonisation impact

Ensure AI funding in these sectors targets applications that will directly drive decarbonisation, not just efficiency and cost reduction.

It could be easy to assume that because a sector has a major drive to decarbonise, any AI applications in that sector should be credited as driving decarbonisation. However, AI adoption and decarbonisation are obviously not the same thing, and progress towards decarbonisation should not be assessed by the scale of AI adoption alone in any business or sector.

For example, data-ready business units and organisational functions (for example, HR and customer services) have already established foundations for the adoption and innovation of AI, in line with business goals such as improving operational efficiency and reducing costs. As a result, this is where AI has typically been applied to date across multiple sectors.

Therefore, for AI to accelerate the decarbonisation of key physical engineering sectors and business units and use cases in the UK economy (those that often have a higher carbon footprint), funding needs to be specifically targeted at AI adoption that explicitly helps to solve key decarbonisation challenges. Where new funding (private or public) is being offered for AI development in these

sectors, we recommend that significant weighting is applied to the expected decarbonisation impact when assessing opportunities.

Funding providers should ensure that the AI applications either directly deliver reduced emissions, or effectively address major systemic blockers to decarbonisation. As effectively illustrated by Streams 2 and 3 of this programme, the priority should be the robustness of how clearly and plausibly the route to significant decarbonisation impact has been defined, rather than relying on numeric estimates.

Responsible adoption and building trust

De-risk, encourage and drive greater collaboration between AI for decarbonisation initiatives with responsible and open AI activities both in the UK and globally.

This should include funding for ADViCE to work with organisations such as Responsible AI UK to provide toolkits for SMEs and roadmaps for the sectors in scope to consider the responsible adoption of AI technologies in their application for decarbonisation.

To ensure that AI can be readily adopted across sectors, initiatives to develop trust in AI systems must be considered. Large datasets across sectors associated with the increase in smart services and systems must be matched with security solutions to reduce potential vulnerabilities. Data accessibility should also be a core consideration, with mechanisms that enable companies to access open data sets that enable them to build better solutions that meet sector needs. This is in line with emerging goals around cyber-physical infrastructure, and the concept of digital critical national infrastructure that can provide access to data for innovation and decarbonisation.

Enabling corporate agility and skills pipelines across the UK

Develop a skills pipeline and support business preparation for cross-sector AI innovation for net zero and decarbonisation.

As AI grows the requirement for adopter companies to develop new skills, it also replaces the need for other skills. This requires agility, and a drive to renew business models and ways of working within companies. It also requires agility around legacy systems and ensuring that machinery, tools, and systems can be used in conjunction with new technologies, finding ways to solve any challenges that are presented.

A key consideration here could be for the UK Government and industry to establish and invest in a range of skills leadership training initiatives related to the use of AI for decarbonisation. This can include leading edge data science skills, but most importantly should seek to upskill business leaders on the opportunity for using AI for decarbonisation, how to overcome technical and business barriers, and how to become more data ready. This could be aligned to activities and support being offered through the BridgeAI programme from Innovate UK, for example.

Enabling place-based opportunities

Most high-growth AI startups and scaleups in the UK are based in London, as already shown in this report when assessing the location of AI companies innovating to drive new decarbonisation solutions. For AI innovation to be harnessed as a UK strength, and for greater success to be achieved, support for the adoption of AI into companies and sectors that underpin economies outside of London and the Greater South East is critical.

The government has laid out plans to "support the transition to an AI-enabled economy, capturing the benefits of AI innovation in the UK, and ensuring AI technologies benefit all sectors and regions" through supporting commercialisation, understanding factors that influence the decisions to adopt AI into organisations, as well as leveraging demand for AI and markets for new services. In partnership with Innovate UK, the government has also launched the Local Industrial Decarbonisation Plans (LIDP) competition, offering grants to industrial manufacturers around the UK to decarbonise, reduce emissions and avoid carbon leakage. LIDP specifically supports the advancement of place-based decarbonisation plans and encourages further collaboration and partnerships. AI should be seen as an important enabler of local and place-based ambitions, and AI companies around the UK should be encouraged to innovate and deliver solutions that support such plans.

Further investment in place-based opportunities to drive AI for decarbonisation innovation will enable accessible opportunities that extend beyond current clusters and build bridges with the existing AI ecosystem. While established industrial clusters have access to key decarbonisation challenges such as carbon capture and hydrogen, these networks are unlikely to provide national uptake and adoption. This is because technologies remain commercially unavailable due to poor data availability, and due to the high number of SMEs with limited capital and capacity to engage with the complexities of implementing new technologies. Innovation outside UK cities should also be considered to engage with dispersed industrial domains.[75]

The Institute for the Future of Work emphasises the need for AI adoption for firms across the country to be balanced with a focus on the design, development and deployment of technology, and the impact on work, demand for skills and the creation of new jobs.[76] Readiness levels around AI should be improved across the country to drive economic growth and make adoption opportunities viable across all parts of the UK. At the same time, programmes similar to BridgeAI should be encouraged to help to pivot existing AI startups into new sectors that have a high carbon footprint – de-risking the building of new products and services to meet the needs of these sectors and fostering connections with key physical engineering areas of the economy that have low levels of data availability and skills.

By upskilling AI supply and demand there will be greater balance and scalability of decarbonisation solutions to solve challenges across multiple domains.

"Variations in innovation readiness across UK regions significantly alter the relationship between technology adoption and work outcomes."[77]

Institute for the Future of Work (2023)

Cross-technology decarbonisation exploration

In the context of the UK's cyber-physical infrastructure vision, further investment from the UK Government and industry in cross-technology adoption and use case exploration for decarbonisation.

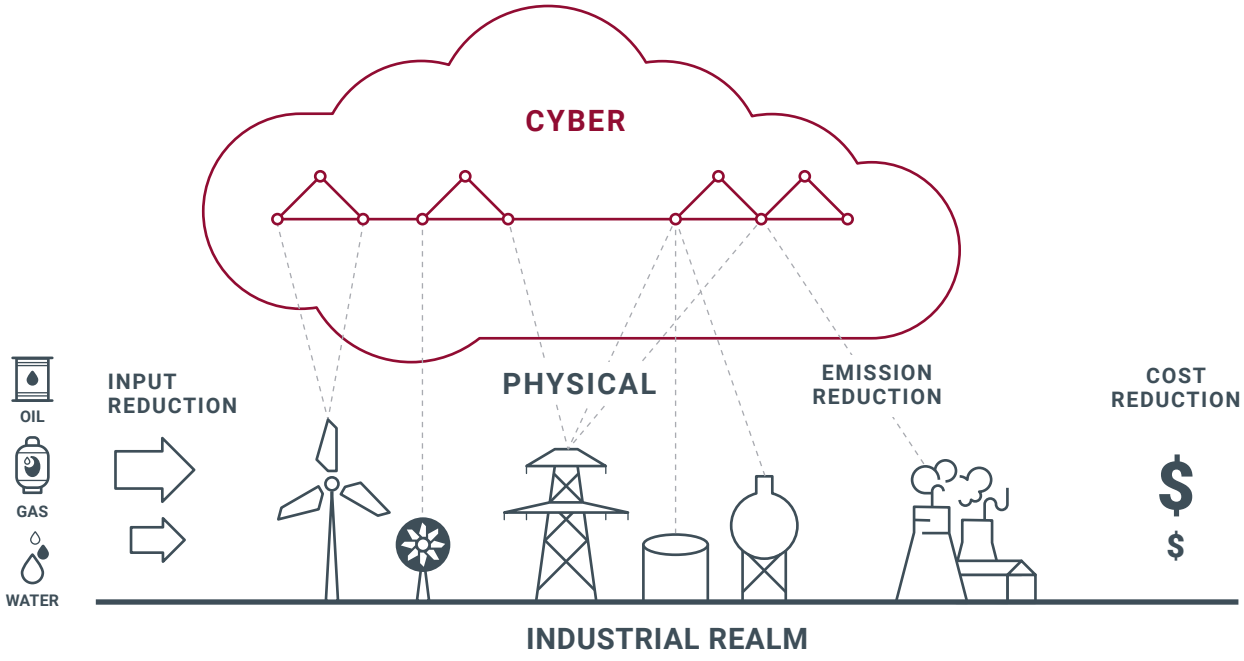
There are a number of companies and academic centres exploring cross-technology applications for decarbonisation. Where this programme focuses specifically on AI solutions, further attention and investment should be centred

upon connecting AI innovators and adopters with companies leveraging additional technological skill sets to drive further innovation, investment and growth.

In the context of further work being undertaken, for example, new capabilities are being explored in the ecosystem around building data architectures and identifying the common building blocks and principles for developing and adopting complex cyber-physical systems in the UK. The systems and data architectures being built upon can be harnessed to achieve the UK's decarbonisation ambitions, by looking at what is required to solve systemic goals through mission-focused ecosystems. In academic research, Oliver Inderwildi et al. outline key cyber-physical technologies, defined as "the orchestration of linked computers and physical systems both horizontally (within a physical system and computer respectively) and vertically (integration between a physical system and computer)"[78], that support decarbonisation across the energy system, including:

1. Big data – creating a big data-driven energy management system.
2. Machine learning – intermittent renewable and demand forecasting using data to perform tasks without being explicitly programmed
3. IoT – IoT-enabled appliances in smart homes collecting information about the real world remotely, and sharing it with other systems and devices through machine-to-machine communication
4. Advanced metering infrastructure – advanced infrastructure-based demand-side management using an integrated system of smart meters that enable two-way communication between utilities and customers
5. Edge computing – hierarchical distributed edge computing framework architecture for smart cities
6. Blockchain – encrypted ledger for peer-to-peer energy trading
7. Smart contracts – smart contract-based, decentralised transactive energy auctions
8. Semantic web – ontological knowledge management of district energy systems
9. Digital twin – predictive maintenance of offshore wind farms in cloud-based platforms

Architecture of intelligent cyber-physical system



Together, these cyber-physical solutions and capabilities will be transformational in their connection, and in the resulting shared infrastructure that allows innovation to take place and the flow of information between different parties.

AI for decarbonisation should seek to align policy goals between the Department for Energy Security & Net Zero and the Department for Science Innovation and Technology to foster collaborative goals related to AI innovation for decarbonisation. Connecting ADViCE directly to the emerging national cyber-physical infrastructure initiative funded by DSIT will be a key first step to ensuring joined-up government policy goals and initiatives in this area as they emerge.

Further considerations for policymakers

Supportive regulation to drive demand

Lack of clarity surrounding data accessibility regulations has hampered the potential of sustainable business cases and the return on investment for SMEs.[79]

The companies interviewed indicated a shift towards open-source models in order to enhance the training of AI models, ensuring more widespread availability of data.

Other company suggestions highlighted the pressing need for regulatory intervention to hasten the demand for AI tools in the pursuit of decarbonisation: strengthening regulations can bring about a shift in a company's attitude to prioritising sustainability initiatives. Regulation, it was argued, should also serve as an incentive for more effective carbon taxation policies. This would not only incentivise sustainable initiatives, but also create an environment favourable to the growth of the AI market for decarbonisation, safeguarding its position as a strategic imperative for companies.

AI and carbon charter

Although this report has focussed on the innovation taking place in AI to drive decarbonisation across high-emitting sectors, the environmental footprint of AI is also a consideration for the ADViCE and the wider Net Zero Innovation portfolio.[80] While ADViCE will continue to bring together cutting-edge AI innovators with companies in these sectors, managing AI's own environmental emissions and negative impact should also be considered.

It was flagged by companies that investor support was a key enabler for incentivising environmental monitoring, as it is an established requirement for investment. The role of the investment community is therefore critical, not only for driving scale-up opportunities for promising AI companies, but also for enabling the tracking of environmental impact.

Further programme investment

The next phase of the ADViCE programme presents an opportunity to gather key players in the ecosystem, showcasing diversified AI for decarbonisation tools and solutions. This initiative could participate in breaking down silos that have traditionally separated different stakeholder groups, fostering collaboration for a sustainable industry.

There is also a broader opportunity to explore the intricacies of data assets across sectors. This involves a careful examination of ownership and accessibility, facilitating better sharing mechanisms, and improving interoperability to drive greater innovation in this space.

Discussions with companies underscored the critical need for public funding. The solutions under development are currently at the prototype stage, necessitating additional financial support to scale effectively and have a wider impact across sectors. Similarly, additional investments in skills development and training are needed to meet the growing demand for AI decarbonisation solutions, and bolstering infrastructure is essential to driving down the costs associated with decarbonisation efforts.

While this report has primarily focussed on the highest emitting sectors, the efforts toward AI adoption for decarbonisation could be extended to include more broad-ranging sectors and areas of expertise – for example, the creative industries (film/TV/screen).[81]

Appendix

Glossary of terms

Machine learning	A field of AI involving computer algorithms that can 'learn' by finding patterns in sample data. The algorithms then typically apply these findings to new data to make predictions or provide other useful outputs, such as translating text or guiding a robot in a new setting.
Natural language processing and generation	A field of AI that uses computer algorithms to analyse or synthesise human speech and text. The algorithms look for linguistic patterns in how sentences and paragraphs are constructed, and how the words, context and structure work together to create meaning. Applications include speech-to-text converters, chatbots, speech recognition, automatic translation, and sentiment analysis (identifying the mood of a piece of text).
Computer vision	A field of research that uses computers to obtain useful information from digital images or videos. Applications include object recognition (e.g. identifying animal species in photographs), facial recognition (smart passport checkers), medical imaging (spotting tumours in scans), navigation (self-driving cars) and video surveillance (monitoring crowd levels at events).
Deep learning/ neural networks	A form of machine learning that uses computational structures known as 'neural networks' to automatically recognise patterns in data and provide a suitable output, such as a prediction or evidence for a decision. Deep learning neural networks are loosely inspired by the way neurons in animal brains are organised, being composed of multiple layers of simple computational units ('neurons'), and they are suited to complex learning tasks such as picking out features in images and speech.[82]
Decarbonisation	The removal and reduction of CO2 emissions into the atmosphere.
Carbon removal	Carbon removal refers to the process of capturing and removing CO2 from the atmosphere, either through natural processes (e.g. reforestation, ocean sequestration) or through technological means (e.g. carbon capture and storage).
Carbon offset	A carbon offset is a quantifiable reduction or removal of GHG emissions from one source that is used to compensate for or offset emissions produced elsewhere. This can be done through projects such as reforestation, renewable energy development, or methane capture.
Deep reinforcement learning	Reinforcement learning (RL) is a subset of machine learning that allows an AI-driven system to learn through trial and error using feedback from its actions. This feedback is either negative or positive, signalled as punishment or reward with, of course, the aim of maximising the reward function.[83]

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