ESG Economist

What can AI do to fight climate change?

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- **Artificial Intelligence can help in the fight against climate change**
- **Its computing power can be used to improve climate models, energy efficiency, waste management, water management and grid management, reduce carbon footprints, and help farming and biodiversity conservation.**
- **But in doing so it consumes a lot of energy, water and critical materials, while producing electronic waste. Moreover model outcomes could be biased if the training set was unbalanced.**
- **New efficient semiconductor architectures and cooling methods will be important contributors to bending the energy and emissions curve of AI.**
- **But choices also need to be made in how and where to use AI.**
- **So the aim is Green AI for sustainability.**

Introduction

Artificial intelligence affects our day-to-day life but its impact is not for everyone clear and transparent. Artificial Intelligence can have a substantial impact on sustainability. In this report we focus on what Artificial intelligence can do in fighting climate change. We show the advantages of using AI for sustainability but also some of its drawbacks.

What is AI ?

Artificial Intelligence or AI is the ability of machines to simulate human intelligence processes such as the ability to reason, to discover meaning, to generalize or to learn from past experiences. AI on its own or combined with other technologies such as sensors, geolocation, robotics, can perform tasks that would otherwise require human intelligence or intervention (see more **here**). In general, AI systems work by importing large amounts of labeled training data, analyzing the data for correlations and patterns, and using these patterns to make predictions about future states (see more **here**).

Machine learning and deep learning

AI involves machine learning. Machine learning is a form of AI based on algorithms that are trained on data. An algorithm is a procedure used for solving a problem or performing a computation. There is machine learning and deep-learning. Deep-learning is a smaller, more powerful, sub-set of machine learning. It is referred to as 'deep' due to its hidden and extensive modelling architecture. Machine learning and deep-learning involve the development of AI algorithms, modeled after the decision-making processes of the human brain, that can 'learn' from available data and make increasingly more accurate classifications or predictions over time. One of the most accurate and powerful deep learning algorithms is called the Neural Network. Neural Networks are algorithms that are able to easily capture non-linear trends within vast amounts of data. Generative AI is a set of deep learning models that is able to generate, when prompted, new content or data that is similar to, but not exactly the same as, the data it was trained on. This includes text, images, music, and even video, making it capable of creative and diverse outputs that can be used for a wide range of applications, from art and design to innovation in science and technology. Large language models have deep learning algorithms that can perform a variety of natural language processing tasks.

Weak and strong AI

There are two types of AI: weak AI and strong AI. Weak AI or narrow AI (ANI) is AI that functions with limited human assistance. It focuses on performing a specific task. Weak AI is developed with the consideration that AI is and will always be a simulation of human cognitive function (see more **here**). Weak AI follows human command. It acts upon and it is bound on the rules imposed on it. Examples of weak AI are characters in a computer game that act believably within the context of the game, or Apple Siri. Weak AI drives most of the AI that surrounds us today.

Strong AI is a theoretical form of AI that replicates human functions such as reasoning, planning and problem solving. This can be either artificial general intelligence (AGI) or artificial super intelligence (ASI). AGI would be capable of performing cognitive abilities that humans have without any human intervention. Artificial superintelligence (ASI) is a hypothetical software-based AI with intelligence beyond human intelligence. It would be self-aware and intelligent enough to surpass the cognitive abilities of humans.

Green AI, Sustainable AI and AI for Sustainability

Artificial Intelligence can be used to help our enormous quest to decarbonize the world. There are several forms of AI related to sustainability: Green AI, Sustainable AI, Eco-friendly AI, and AI for Sustainability. Sustainable AI, Green AI or Eco-friendly AI are different labels for the same thing. They focus on developing and deploying AI technologies in a manner that minimizes their environmental impact and maximizes long-term sustainability (see more **here**). Sustainable AI focuses on changing the entire lifecycle of AI products to prioritise sustainability benefits such as ecological health or social justice amongst other things. Its aim is to improve the way we create and use AI products which involves reducing the carbon footprint of AI systems by using sustainable data sources, carbon optimised architecture and Cloud infrastructure (see more **here**). AI for Sustainability refers to the use of artificial intelligence (AI) technologies to address environmental, ecological, and social challenges and promote sustainable development. Below we focus mainly on AI for sustainability.

What can Artificial Intelligence do to help fight climate change?

There are several ways AI can help fight climate change. Below there is an overview of the most important ways how AI can do this.

Energy efficiency

AI can help improve energy efficiency in buildings and industries by predicting the energy usage patterns and optimizing energy consumption. AI can also identify inefficiencies and provide insights for optimizing energy usage in buildings, manufacturing processes, and transportation systems. AI is able to do this by analysing massive datasets from energy consumption patterns. It's possible to install sensors that continually measure the temperature and humidity in different rooms. Combined with data about the outdoor temperature and how much energy is supplied for heating and ventilation, a pattern gradually emerges of how the weather and energy use affect indoor conditions. The AI-system can also incorporate data about the forecasted weather to adjust the heating and ventilation. So AI can heat a building in the most optimal way with optimal comfort for those inside the building.

Enhancing energy grid management

AI can help create smarter energy grids by analysing data from sensors, meters, and other devices. Smart meters produce and send several thousand times more data points to utilities than their analogue predecessors. New devices for monitoring grid power flows funnel more than an order of magnitude more data to operators than the technologies they are replacing. And the global fleet of wind turbines is estimated to produce more than 400 billion data points per year (see more **here**).

Predictive analytics also aid in facilitating a better grid management. Here are ways that AI is already changing how grid operators do their work. The power grid system is often described as the most complex machine ever built. Because the grid is so vast, it is impossible for any one person to fully grasp everything happening within it at a given moment, let alone predict what will happen later. Every day these computers run complex mathematical calculations that predict how much electricity will be needed the next day and try to come up with the most cost-effective way to dispatch that energy. Machine learning models can do these calculations much faster. In addition, several utility companies have already begun integrating

AI into critical operations, particularly inspecting and managing physical infrastructure such as transmission lines and transformers. This is spotting disasters before they hit (see more **here**).

Reduce carbon footprint

AI can measure greenhouse gas emissions and fill the gaps in data, identify areas of improvement and reduce their carbon footprints for companies. For example optimizing inventory, delivery and schedules of employees. Inventory optimization is important to ensure you have enough stock while also meeting customer demand. At the same time, you want to reduce the carbon footprint associated with moving and storing stock. AI helps address this problem by combining aspects like demand forecasting, last–mile delivery, and routing optimization. Schedule optimization is like inventory management but addresses the challenge of ensuring that you have the appropriate alignment of talent (see **here**).

Smart waste management

There are many possible ways to use AI in waste management. One of the most significant applications of AI in solid waste management is in the automation of waste sorting. AI-powered robots and machines equipped with sensors, cameras, and machine learning algorithms can identify, sort, and separate different types of waste materials more accurately and rapidly than manual sorting. This not only increases the efficiency of recycling processes but also reduces the risk of contamination. Indeed, researchers are working to develop smart waste management systems for the collection, identification and characterization of organic materials in non-recyclable waste (see more **here**). This system would use hyperspectral cameras and not digital cameras. Digital cameras can only visualize three colour bands of light — red, green and blue. Hyperspectral cameras, however, can visualize many more bands from across the electromagnetic spectrum, resulting in images that showcase chemical characteristics that would otherwise be invisible (see more **here**). Non-recyclable waste items are also analysed to determine their physical, chemical, thermal and biological properties, including moisture, density, particle size and distribution, surface area, crystallinity, calorific value and more. This information will help the system to further differentiate items as they're scanned.

Furthermore, AI robots can disassembly or assist in dissembling various challenging-to-dispose complex electronics and other items. Moreover AI can analyse data on waste generation patterns, traffic conditions, and other relevant factors to optimize collection routes. This not only saves time and fuel but also reduces the carbon footprint of waste collection vehicles. Finally AI-driven predictive analytics can forecast waste generation trends, helping municipalities and waste management companies to plan resources and strategies more effectively (see more **here**). Finally AI can make significant impact in monitoring waste levels in containers and reporting when they need to be emptied.

Precision agriculture or Smart Farming

Precision agriculture integrates AI and data-driven technologies to optimise farming operations and resource utilisation and has the potential to improve water efficiency, a critical aspect of agriculture sustainability. So the plants or animals precisely get the treatment they need, determined with great accuracy thanks to the latest technology. AI can aid in sustainable agriculture practices by analysing soil data, predicting crop yields, and identifying pest and disease outbreaks. It optimizes the use of resources like water, fertilizers, and pesticides. By analyzing data from sensors, satellites, and drones, farmers can make data-driven decisions to reduce waste, increase yields, and minimize sustainability impact. AI-driven predictive analytics can help farmers forecast crop water requirements and plan their irrigation strategies more effectively.

Water management

One of the ways in which AI is being used in water management is to monitor and analyse water cycle data. This includes checking water quality, tracking water use, and identifying potential problems in water supply infrastructure. AI is also used to analyse large amounts of data in real time, enabling utilities to detect potential issues before they turn into crises. Furthermore, AI can be used to predict water demand and to optimize water supply throughout the day. This can help water utilities reduce water waste and ensure that water demand is met effectively. AI is also used to predict and mitigate potential risks associated with the water cycle. Finally, AI can also improve water supply efficiency. This includes identifying leaks, detecting pressure-related problems and optimizing water flow (see more **here**).

Biodiversity conservation

AI is becoming a powerful force in nature conservation, with applications ranging from monitoring wildlife to collecting environmental DNA. One of the remarkable applications of AI, especially the computer vision sub-field of AI, is where it helps transform indicators like population sizes and species into meaningful information. Also, AI is increasingly used in conservation decision-making and policy formulation to speed up responses to emerging threats like disease surveillance, for example. AI algorithms use existing data to develop predictive models that estimate species distribution and habitat suitability. This information is valuable for identifying areas of high conservation priority and planning conservation interventions. What is more, AI helps forecast the impacts of climate change on species and ecosystems. AI technologies can help create predictive models of future biodiversity change, based on current observations and different scenarios of human activities. These models can estimate the potential impacts of climate change, land use change, and other human activities on biodiversity and ecosystem services (see more **here**).

In addition, AI-powered technologies like sensors are used for wildlife monitoring and anti-poaching efforts. Moreover, eDNA sampling involves collecting and analysing DNA traces present in environmental samples, such as water or soil, to detect the presence of species. AI supports ecosystem restoration efforts by analysing ecological data and recommending appropriate restoration techniques. Finally, AI optimizes resource management in conservation, such as efficient deployment of park rangers, predictive maintenance of conservation equipment and intelligent monitoring of conservation projects (see more **here**).

Climate models

Global climate models projections are planetary-scale Earth simulations that are the primary source of information on future climate change. The Earth system shows chaotic dynamics which makes it difficult to predict the future based on equations. All Earth system components (atmosphere, ocean, land surface, cloud physics etc) are connected in a non-trivial way (see more **here**). Global climate models aim to represent the key physical, chemical, and biological processes of Earth's climate. Climate models are based on mathematical equations represented using a grid mesh that covers the globe: a finer grid mesh is more accurate but much more computationally expensive (see more **here**). Indeed, climate models are extremely computationally expensive and therefore require the fastest available supercomputers. However, for many types of simulations, even those supercomputers are still not powerful enough to globally resolve several important climate processes. Machine learning techniques have the potential to make climate models better, faster and to reduce their high energy consumption (see more **here**). So AI can assists climate scientists in modelling and predicting climate patterns, aiding in the development of effective mitigation and adaptation strategies (see **here**). AI can help address climate change by examining data on greenhouse gas emissions, weather patterns, and other environmental factors. AI positively drives environmental outcomes through its ability to analyse large-scale interconnected databases to develop coordinated actions aimed at environmental preservation.

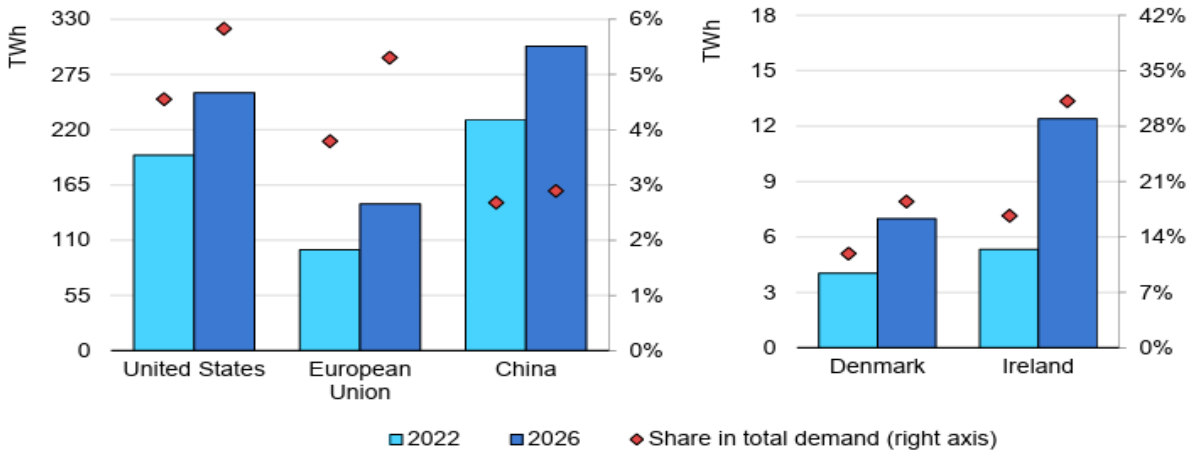
What are the drawbacks of using AI for sustainability

As indicated above AI can do a lot of good things in fighting climate change but it also has serious drawbacks related to climate. First, the development and use of AI technologies can contribute to electronic waste, which can have harmful environmental impacts. To minimize e-waste, it is crucial to design AI hardware and components for durability, repairability, and recycling.

Second, AI systems can perpetuate bias and discrimination if they are trained on biased or incomplete data. This can have negative social and environmental impacts by perpetuating inequalities and contributing to environmental injustice. More specifically, AI models are stronger when working with what data scientists refer to as ‘’balanced datasets.’ In simpler terms, a model’s capacity to predict an event largely depends on the data it been trained with. When predicting climate change, we are currently experiencing climate data which we have previously not seen before or rarely (for example wildfires, typhoons, extreme temperatures), making it difficult for AI technology to predict something it hasn’t learnt how to predict yet.

Estimated data centre electricity consumption and its share in total electricity demand in selected regions

Includes traditional data centres and dedicated AI data centres, excludes consumption from cryptocurrencies and data transmission networks.



Sources: IEA, Data Centres and Data Transmission Networks; Lawrence Berkeley National Laboratory, United Stated Data Center Energy Usage Report; Ireland Central Statistics Office, Data Centres Metered Electricity Consumption 2022; Danish Energy Agency, Denmark's Energy and Climate Outlook 2018; China's State Council, Green data centres in focus; European Commission, Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market; Joule (2023), Alex de Vries, The growing energy footprint of artificial intelligence; and Crypto Carbon Ratings Institute, Indices.

Last but not least, the IT infrastructure including AI systems in data centres use a lot of energy (see graphs above) and water. The bigger the large language model (LLM), the more energy used in training it. Large language models have deep learning algorithms that can perform a variety of natural language processing tasks. A LLM with 110m parameters emitted 0.64 tonnes of C02 in the training phase. In contrast, another LLM, with 75b parameters had a training footprint of 550 tonnes. 60%–90% of emissions are generated by inferencing, running the model on live data. In response, researchers are creating smaller models and optimizing the trade-offs between training speed and energy consumption (see more **here**). In Singapore there is growing concern over the increasing power consumption and widening carbon footprint of its data centre industry. A typical 20MW data centre on the island consumes the same amount of electricity a day as around 60,000 households (see more **here**). In regions with higher outdoor temperature there needs to be more cooling of the systems via energy or water. Globally, the carbon footprint for data centres is estimated at more than 2% of global carbon emissions. This number is expected to rise to 3.2 per cent by 2025 and 14 per cent by 2040 (see **here**). Next to the large energy consumption, data centers also use a substantial amount of water for cooling the systems.

Conclusion

As indicated above AI can do a lot of good things in fighting climate change. Its computing power can be used to improve climate models, enhance energy efficiency, waste management, water management and grid management, reduce carbon footprint, help farming and biodiversity conservation. But in doing so it consumes a lot of energy, water and critical materials, while also producing electronic waste. Moreover the model outcome could be biased if the training set was unbalanced. On the one hand new efficient semiconductor architectures and cooling methods will be important contributors to bending the energy and emissions curve of AI. On the other hand choices need to be made in how and where to use AI. A model with less parameters uses less energy and good be enough for certain applications. The goal thus is Green AI for sustainability.

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