

254. HOW ARTIFICIAL INTELLIGENCE IMPACTS THE ENVIRONMENT

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This paper explores the complex environmental implications of artificial intelligence, focusing on both its significant environmental costs and its potential sustainability benefits. It highlights how AI's rapid growth drives increased energy consumption, water usage, and demand for physical infrastructure, contributing to carbon emissions and resource depletion, while also demonstrating how AI can enhance climate modeling, optimize resource management, monitor environmental changes, and support evidence-based decision-making. The study emphasizes that achieving a balance between these impacts requires responsible AI development, deployment, and regulation, ensuring that technological advancements contribute positively to environmental sustainability.

Artificial intelligence (AI) has become increasingly widespread in contemporary society, being utilized across numerous domains due to its unique computational and generative capabilities. However, this rapid development comes at the cost of substantial resource consumption, which has significant environmental implications. Data centres that house AI servers consume not only large amounts of electricity but also other resources, contributing to the overall ecological footprint of AI technologies.

According to the Digital Economy Report 2024, artificial intelligence does not directly produce environmental pollution. However, its development, deployment, and large-scale integration into digital systems significantly contribute to the environmental footprint of the digital economy. This impact is largely indirect and results from the infrastructure required to support AI systems. The key environmental challenges associated with AI include rising electricity demand, increased water consumption, and the accelerated expansion of data centre infrastructure.

One of the most critical aspects of AI's environmental impact is its carbon footprint, which is primarily linked to energy consumption. Machine learning models, especially deep learning systems, require substantial computational resources during both training and deployment phases.

The training phase involves processing large datasets through repeated iterations, which demands high-performance computing and consumes significant amounts of electricity. Empirical estimates indicate that approximately 20–40 % of total energy consumption is associated with training, while 60–70 % is attributed to inference, that is, the real-time use of trained models in applications. As AI becomes increasingly embedded in everyday digital services, including search engines, recommendation systems, and automated decision-making tools, the demand for inference is expected to grow rapidly. This shift suggests that the long-term environmental impact of AI will be driven not only by model development but also by large-scale deployment and continuous use.

Moreover, the growing complexity of AI models further intensifies energy consumption. Modern AI systems often involve billions or even trillions of parameters, requiring advanced hardware and extended computation times. As a result, even marginal improvements in model performance may come at the cost of significantly higher energy expenditure. While AI currently accounts for a relatively small share of global electricity consumption, projections indicate that its contribution may increase substantially as adoption continues to expand across industries.

Water consumption represents another important environmental concern. Data centres, which provide the physical infrastructure for AI systems, generate considerable heat due to intensive computational processes. To maintain operational stability, this heat must be dissipated through cooling systems, many of which rely on fresh water resources. For example, the training of large-scale language models such as GPT-3 has been associated with the consumption of approximately 700,000 litres of clean water.

A further dimension of AI's environmental impact concerns the spatial distribution and localisation of data centre infrastructure. The placement of such facilities is often determined by a combination of economic, climatic, and regulatory factors, including access to affordable energy, political stability, and connectivity to global data networks. Increasingly, technology companies are situating data centres in regions with abundant renewable energy resources, such as hydropower or wind energy, in an effort to reduce carbon emissions. However, this strategy may lead to uneven environmental pressures, as local ecosystems and communities bear the burden of intensified resource use, including land occupation and water extraction. In some cases, the concentration of data centres in specific regions can strain local energy grids and water supplies, potentially leading to competition with residential and agricultural needs. Therefore, the environmental sustainability of AI

infrastructure must also be evaluated in terms of its geographical footprint and its socio-environmental impacts at the regional level.

The level of water usage varies depending on factors such as geographic location, climate conditions, and cooling technologies, including air and liquid cooling systems. This creates a complex trade-off between minimizing carbon emissions and reducing water consumption, as regions with access to renewable energy sources may not always offer optimal conditions for water-efficient cooling. Consequently, the environmental impact of AI infrastructure must be assessed in a broader geographical and resource-management context.

In addition to energy and water requirements, the development of AI technologies depends heavily on physical computing infrastructure. This includes servers, graphics processing units (GPUs), storage devices, and networking systems. The production of these components involves the extraction of raw materials, including rare earth elements and other metals, as well as energy-intensive manufacturing processes and global logistics. As demand for AI continues to grow, the need for such hardware is expected to increase significantly. This expansion not only intensifies resource consumption but also contributes to environmental degradation associated with mining activities and industrial production. Furthermore, the rapid pace of technological advancement leads to frequent hardware upgrades, resulting in increasing volumes of electronic waste, which poses additional environmental and disposal challenges [1].

The environmental implications of AI are closely connected to the broader expansion of data centres, which are essential for supporting digital infrastructure. Data centres are specialized facilities designed to house computing equipment, maintain stable operating conditions, and ensure continuous data processing and storage. Due to their intensive energy requirements, they have become major electricity consumers within the global economy. In 2022, global data centre electricity consumption reached approximately 460 TWh, and projections suggest that this figure may exceed 1000 TWh by 2026. Such levels of energy consumption are comparable to those of entire nations, highlighting the scale of the issue. In addition, AI-driven services are significantly more energy-intensive than traditional digital operations.

For example, a single AI-based query may consume up to ten times more electricity than a conventional web search. Given that billions of such queries are processed daily, the widespread integration of AI into digital platforms may substantially increase global electricity demand and further strain energy systems [2].

At the same time, it is important to acknowledge that artificial intelligence also offers substantial opportunities for addressing environmental challenges. AI technologies can improve the accuracy of climate models, enabling more precise predictions of environmental changes and facilitating more effective mitigation strategies. In the field of environmental monitoring, AI can process large volumes of data collected from satellites, sensors, and other observation systems, allowing real-time analysis of environmental conditions.

A notable example is the World Environment Situation Room (WESR), developed by the United Nations Environment Programme. This platform integrates diverse environmental datasets and provides near real-time information on key indicators such as atmospheric carbon dioxide levels, glacier mass changes, and sea-level rise. By enhancing data accessibility and visualisation, such systems support evidence-based decision-making and improve the ability of policymakers, researchers, and international organisations to respond to environmental challenges [3].

Furthermore, AI can contribute to more efficient resource management across various sectors. For instance, it can optimize energy consumption in industrial processes, improve the efficiency of transportation systems, and support sustainable urban planning. AI-driven solutions can also assist in waste management, biodiversity conservation, and the monitoring of deforestation and pollution. These applications demonstrate that, despite its environmental costs, AI has the potential to play a significant role in promoting sustainability and supporting global environmental goals.

In conclusion, the relationship between artificial intelligence and environmental sustainability is inherently complex and multifaceted. On the one hand, the rapid expansion of AI technologies leads to increased energy consumption, water usage, and demand for physical infrastructure, thereby intensifying environmental impact. On the other hand, AI provides powerful tools for addressing environmental challenges, improving resource efficiency, and supporting informed decision-making. Consequently, the overall environmental impact of AI will depend on how these technologies are developed, implemented, and regulated, as well as on the extent to which sustainability principles are integrated into the design and operation of digital systems. A balanced and responsible approach to AI development will be essential to ensure that its benefits outweigh its environmental costs.

Moreover, fostering collaboration between governments, industry, and the scientific community will be crucial for mitigating AI's environmental footprint. Establishing standards for energy-efficient hardware, promoting the use of renewable energy in data centres, and encouraging transparent reporting on AI-related resource consumption can help align technological growth with environmental sustainability goals. By

integrating environmental considerations into AI research, deployment, and policy frameworks, societies can harness the transformative potential of AI while minimizing its ecological impact, ultimately contributing to a more sustainable and resilient future.

References:

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