Weekly Summary

Economics of Climate Change

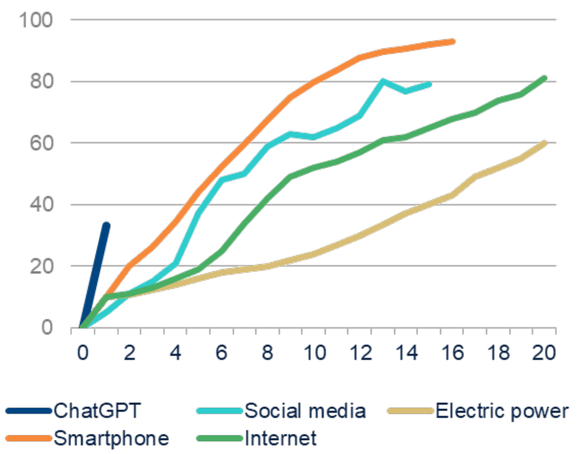
September 6, 2024

AI and Climate: Disruptive Potential Amid Growing Resource Strain

Artificial Intelligence (AI) offers promising productivity enhancements and optimized decision-making. However, significant uncertainty surrounds its overall economic impact due to the complex interplay of efficiency gains, the ability to trigger new sources of economic growth, unlock new avenues for climate action, and, for now, increasing demand for energy and water.

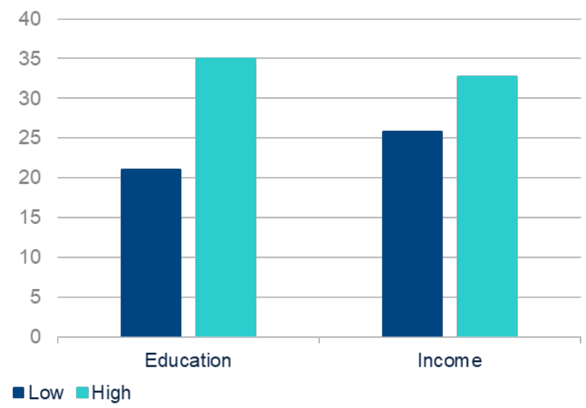
The economic impact of AI[1] remains uncertain. The speed at which AI is being adopted is unprecedented **(Figure 1)**, raising both opportunities and uncertainties. AI's influence on economic growth, employment, and overall productivity depends on the uncertain evolution of several factors, including regulatory frameworks that will shape its deployment.

Figure 1. **Speed of adoption of AI compared to other technological advancements** (Y: % of US households; X: years since introduction)



Source: BBVA Research from BIS Annual Economic Report

Figure 2. **Average probability of higher productivity gains from generative AI use[2]** (%)



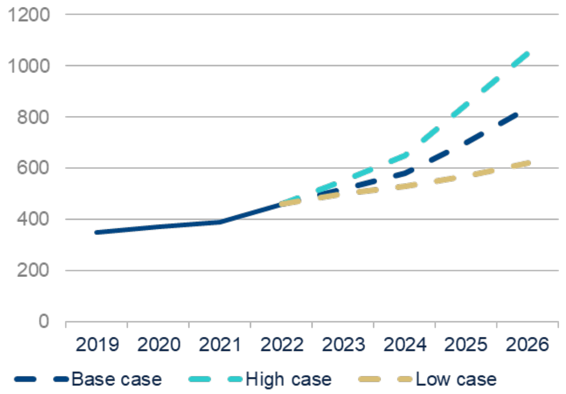
Source: BBVA Research from BIS Annual Economic Report. Based on a Survey of Consumer

1: Artificial Intelligence (AI) is the simulation of human intelligence by machines, especially computer systems, enabling them to perform tasks that typically require human cognition, such as learning, reasoning, problem-solving, and decision-making. Source: ChatGPT 4o.
2: Generative AI refers specifically to AI systems that generate new content or data, such as text, images, or music, based on learned patterns. Source: ChatGPT 4o.

On the supply side, AI could enhance productivity by increasing the efficiency of workers and firms,[3] but also poses potential risks of job displacement and increased inequality. In this regard, higher income or better educated workers expect higher productivity gains from generative AI use **(Figure 2**). On the demand side, AI is expected to raise consumption and investment, however, the effect will be very much determined by the effect on the labor market and the wage distribution. As AI widespreads, its full impact on aggregate supply and demand, growth and employment, remains highly uncertain.[4]

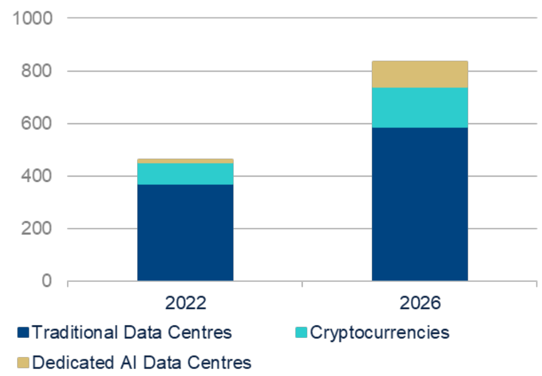
While the economic effects of AI are still unfolding, there is growing evidence of the substantial environmental resource consumption, particularly in terms of energy. AI technologies, especially those involving large-scale data processing and machine learning models, require vast amounts of computational power. This power demand translates into significant energy consumption, particularly within data centers **(Box 1. AI's footprint channels)**. **According to IEA estimates, data centers, cryptocurrencies, and AI consumed almost 2% of total global electricity demand in 2022**. The underlying reasons are both the speed of adoption of AI across industries, which has significantly amplified data centers' energy requirements, but also due to AIs computing power requirements, which can consume up to 33 times more energy to perform tasks compared to traditional software[5]. In the coming years this electricity demand could scale to ten times higher in 2026 with respect to current levels **(Figure 4)**. Under different scenarios, this demand would range between 620-1050 TWh in 2026 **(Figure 3)**, a huge uncertainty range depending on its progress on efficiency, the rate of implementation and upcoming technological advancements. In this regard, how the electricity is produced will be key. Data centers located in countries where renewable sources prevail will have a smaller carbon footprint than data centers located in carbon intensive countries. For that reason, some data center companies are helping to improve the share of renewable energy in the energy mix, as they are large buyers of Green Power Purchase Agreements (PPAs), ensuring a proportion of carbon-free electricity to the grid.[6] Despite uncertainties, there is a consensus on the projected increase of AI-related electricity demand in the following years and, hence, the need to satisfy this demand with renewable sources.

Figure 3. **Global electricity demand from data centers, AI, and cryptocurrencies, 2019-2026** (TWh)



Source: BBVA Research from Electricity 2024 Analysis - IEA

Figure 4. **Estimated electricity demand, base case 2022 and 2026** (TWh)

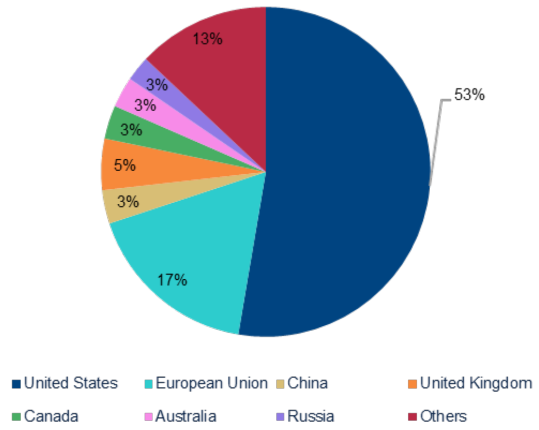


Source: BBVA Research from Electricity 2024 Analysis - IEA

3: For example, estimates from the McKinsey Global institute suggest a potential boost to annual global GDP growth by 3-4 percentage points between now and 2040, while Acemoglu (2024) estimates a TFP increase of 0.06% annually driven by IA, with potential overall GDP growth of 1-1.5% if productivity gains and investment boom are taken into account.
4: See BIS Annual Economic Report - Artificial intelligence and the economy: implications for central banks for further details on the macroeconomic impacts of AI.
5: AI and energy: Will AI help reduce emissions or increase demand? Here's what to know. World Economic Forum, July 2024
6: How Data Centers Are Driving The Renewable Energy Transition. Forbes. March, 13 2023

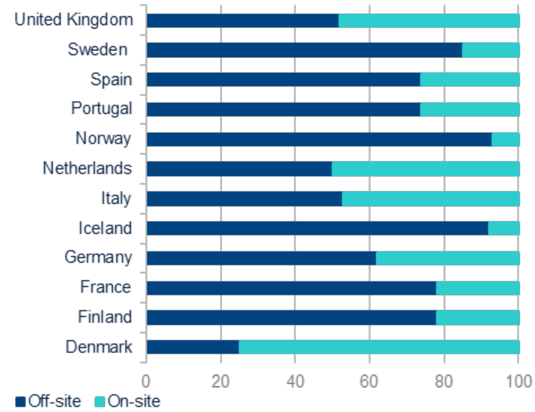
Water consumption of data centers, not only for cooling. AI's environmental footprint is not limited to energy consumption alone - it also has a significant water footprint. (**Box 1. AI's footprint channels)**. For example, in the US, fossil fuels, nuclear energy and hydropower generated in 2023 represented 84% of the total electricity[7]. These sources are water intensive, so the US uses 3.1 L/KWh[8], compared with 1.476 L/KWh by Ireland, where wind and natural gas represented in 2023 80% of electricity generation. This difference is relevant because more than half of data centers are nowadays located in the US **(Figure 5)**, and usually, off-site water consumption is bigger than the water that is used to cool the servers (**Figure 6**).

Figure 5. **Leading countries by number of data centers in 2024** (%)



Source: BBVA Research from Statista.

Figure 6. **Share of energy-related water consumption in annual total water consumption for data usage** (%)



Source: Javier Farfan, Alena Lohrmann: Gone with the clouds: Estimating the electricity and water footprint of digital data services in Europe,

AI offers substantial potential for advancing sustainability, both mitigation and adaptation… Its ability to collect and analyze large datasets can lead to better climate modeling, more accurate predictions, including early warning systems for natural hazards, and optimized resource use, all of which are crucial for climate mitigation and adaptation strategies[9]. For example, in terms of climate mitigation, AI can optimize carbon capture processes, both nature-based and technology-based carbon removal strategies, improve emissions tracking, and model the impact of different climate interventions. That way, by scaling up the application of existing AI technologies there might be potential to mitigate GHG emissions by 5-10% by 2030[10]. On the adaptation and resilience front, AI can help forecast climate vulnerabilities, develop estimates of the cost of inaction, and model the impact of various climate interventions. This includes building early-warning systems, developing resilient infrastructure, and protecting biodiversity.

… and breakthrough innovation. Furthermore, AI can boost the energy transition by supporting breakthrough innovations in climate science, such as facilitating the discovery or optimization of new materials for clean energy technologies (e.g., by analyzing large datasets and running simulations to identify more efficient solar panel materials), or improving energy storage capabilities, which are crucial for stabilizing electrical grids and advancing

7: What is U.S electricity generation by source?
8: Making AI Less "Thirsty": Uncovering and Addressing the Secret Water of AI Models
9: 9 Ways AI is helping tackle climate change
10: How AI Can Speed Climate Action. Boston Consulting Group commissioned by Google, November 2023.

the energy transition. The latter is especially relevant due to the intermittent nature of renewable energy sources, where AI can help free up capacity and allow more renewables to connect to the grid, bringing stability to supply and demand and ensuring a more reliable and consistent flow of energy.[11]

AI also could boost sustainable finance. AI's role in optimizing investment decisions through improved data analysis[12] can facilitate a more efficient allocation of resources by analyzing the environmental impacts of different projects, ensuring that capital is directed toward the most sustainable and high-impact initiatives.[13] This not only improves the efficiency of investment decisions but also fosters greater transparency and accountability, both of which are key to attracting more private capital into sustainable finance.[14]

Table 1. Summary of AI's Contribution to Climate Action

Issue	AI contribution	Environmental impact
Climate Modeling	Collects large datasets for more accurate predictions	Mitigates natural disasters by improving forecasting and response
Emissions Tracking	Tracks real-time emissions data and models their impacts	Helps policymakers develop effective strategies for reducing emissions
Carbon Capture Optimization	Optimizes both nature-based and technology-based carbon capture methods	Reduces emissions by making carbon capture more efficient
Energy Transition & Management	Predicts energy demand and stabilizes energy grids	Enhances the integration of renewable energy sources
Climate Resilience & Adaptation	Forecasts vulnerabilities and supports early warning systems for climate hazards	Builds resilient infrastructure and improves preparedness for climate-related disasters
Sustainable Finance	Analyzes ESG (Environmental, Social, Governance) data for sustainable investment	Increases investment in green projects and supports the development of climate-related initiatives

Source: BBVA Research

11: How to manage AI's energy demand — today and in the future | World Economic Forum.
12: Addressing challenges in data gaps, from collection to quality, or risk modeling.
13: For further reference: Leveraging data, technology and AI for a sustainable future SPI Journal 3Q2024. OMFIF.
14: This opportunity is being used by multilateral financial organizations, such as the World Bank, through the Malena project. This project is based on given investors Environmental, Social and Governance (ESG) data to enhance portfolio management in developing countries, which allows the World Bank to achieve its climate goals.

Policies to address the resource-intensive nature of AI while promoting sustainable practices: Pricing, regulations and disclosure. A globally coordinated carbon pricing strategy would encourage the use of cleaner energy sources, improve energy efficiency, and enhance the sustainability of AI operations, as well as preventing the migration of AI operations to regions with lower environmental standards.[15] Against this background, public policies and regulations should promote the enhancement of energy infrastructure and clean-power generation to satisfy the expected growth in uninterrupted electricity demand of data centers. Standardized reporting frameworks could help increase transparency regarding the energy and water footprints, with sustainability certifications encouraging climate-conscious operations.[16] Additionally, data centers must prioritize energy efficiency, particularly by optimizing operations during periods of low demand and relying more on renewable energy sources. Regarding the water usage, the key lies in the cooling processes and reducing unnecessary data storage. Increasing transparency on both carbon and water footprint is needed to enable truly sustainable AI.[17]

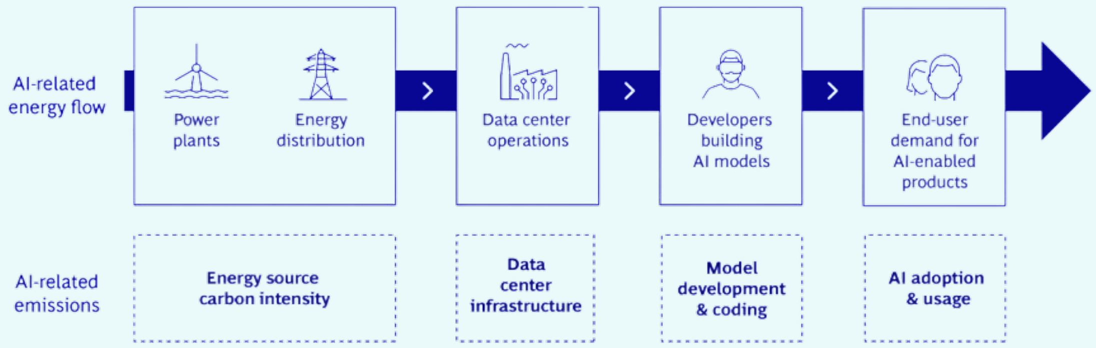
In conclusion, AI has the potential to enhance both economic growth and environmental sustainability. To fully realize its disruptive potential, it must be developed in an environmentally responsible manner. By managing its resource demands and aligning its development with environmental goals, AI can contribute to a more sustainable future.

15: According to the IMF this carbon price should rise to $85 per ton by 2030.
16: Will businesses or laws and regulations ever prioritize environmental sustainability for AI systems?
17: Along this line, the Kepler project, which is an open source project, helps developers optimize their code while they are getting information about the energy consumption of their code. This facilitates code developers to be aware of the energy footprint of the code.

Box 1. AI's footprint channels

Among the well-known environmental consequences of AI are carbon emissions and air pollution. AI's energy consumption starts with the type of power fueling data centers - the higher the reliance on carbon-intensive energy sources, the larger the emissions. Next is the infrastructure of data centers, where using more energy-efficient hardware can contribute to reducing energy use, followed by optimizing programming practices and developing more efficient algorithms. Lastly, as AI adoption grows across industries, increasing end-users demand will drive up energy consumption further. How quickly this demand scales will be critical in determining AI's overall energy footprint.

Figure 7. **Illustration of carbon footprint channel for AI**

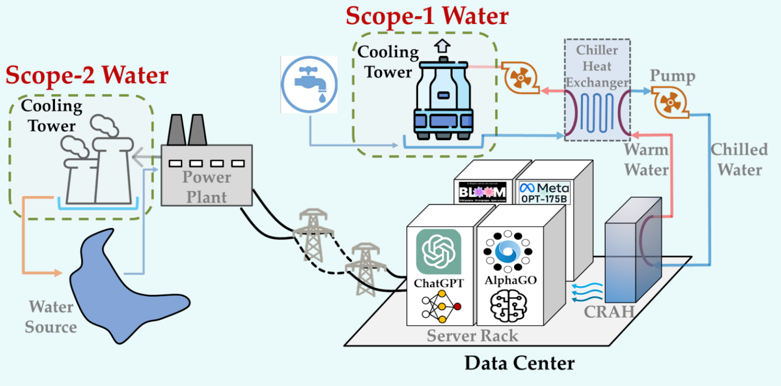


Source: How AI Can Speed Climate Action. BCG, November 2023.

On the other hand, there is also a concerning water footprint. AI uses water for two purposes, being the first for cooling servers, which is called On-site (or direct) water consumption. Its usage depends on the size and efficiency of the data centers, as well as outside weather conditions. The most common type of water-based cooling in data centers is the chilled water system. In this system, water is initially cooled in a central chiller, and then it circulates through cooling coils. These coils absorb heat from the air inside the data center. The system then expels the absorbed heat into the outside environment via a cooling tower. In the cooling tower, the now-heated water interacts with the outside air, allowing heat to escape before the water cycles back into the system for re-cooling.This is a problem, specially in those places where water is a scarce resource, because, on average, 95% of the water consume by data center for cooling is potable, and most of it is evaporated in the process[18].

The second type of water consumption is the one used by the electricity suppliers in order to satisfy the electricity demand of data centers.This type of water consumption is called Off-site (or indirect) water consumption of data centers. This is affected by the characteristics of each electric generation plant, and by the electricity mix of the country where the data center is located.

Figure 8. **Illustration of Scope-1 on-site (server cooling) and Scope-2 off-site (power generation) water usage**



Source: How much water does AI consume? - OECD.ia

18: Data Center water usage: A Comprehensive guide.

Highlights of the Week

- **Global |** Explainer: Why is climate change causing 'record-shattering' extreme heat? - Carbon Brief. Carbon Brief speaks to experts and assesses the latest scientific evidence to explore why climate change is causing record-shattering extreme heat across the world.
- **Global |** Climate policies that achieved major emission reductions: Global evidence from two decades | Science. Climate policy success needs a mix of policies that included subsidies as well as regulations and pricing mechanisms.
- **Global |** In-depth Q&A: Can 'carbon offsets' help to tackle climate change?-Carbon Brief. All the levers should be explored, but trade offs among them have to be carefully analyzed. Additivity of offsets supply and full disclosure of gross and net emissions of demand, they are a must.
- **Global |** The geopolitics of green minerals. The green transition will significantly increase demand for key minerals over the coming decades. The impact on energy prices will ultimately depend on how supply adjusts. The ECB Blog looks at the geopolitical risks involved.
- **Brazil |** Changing Climate in Brazil: Key Vulnerabilities and Opportunities- IMF. This paper assesses the Brazilian economy's exposure to climate change focusing on two key areas: agriculture and hydropower.
- **Spain |** El impacto de las energías renovables sobre el precio mayorista de la electricidad - Boletín Económico. El precio mayorista de la electricidad podría reducirse hasta en un 50 % adicional en 2030 en los escenarios de despliegue de generación renovable contemplados en la actualización del Plan Nacional Integrado de Energía y Clima (PNIEC).

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