mirova
Investing in sustainability

AI & Climate Change

Opportunities and challenges for a sustainable future

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Today, it is clear that artificial intelligence will become a world changing technology, boosting innovation and productivity across every sector of the economy. Microsoft's Vice Chairman and President, Brad Smith, has stated that "In many ways, artificial intelligence is the electricity of our age". AI is seeing rapid adoption, driven by massive investments into data centers and AI infrastructure by the technology giants and the emergence of GenAI services like OpenAI's ChatGPT. AI also promises to make significant contributions to accelerate the transition to a greener economy. But this technological revolution is still in its early days and already represents a significant immediate risk for the Earth's resources. As demand for AI continues to grow, the energy intensity and carbon footprint of the data centers that support this technology also increase. In light of these challenges, how can sustainable investors effectively navigate and engage with the transformative theme of AI while addressing its environmental impact?

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Summary

01 The Rapid Rise of Artificial Intelligence

Artificial Intelligence (AI) is a branch of computer science that aims to create machines and software that can perform tasks that typically require human intelligence. This encompasses a range of capabilities, including language understanding, image recognition, problem-solving, and decision-making. The technology is experiencing rapid global adoption, thanks to advancements in computing, AI hardware, and algorithms that has made it easier, cheaper and faster to run AI models. Additionally, the explosion of data availability provides AI models with a wealth of information to learn from, enhancing their performance and allowing to train complex and specialised models.

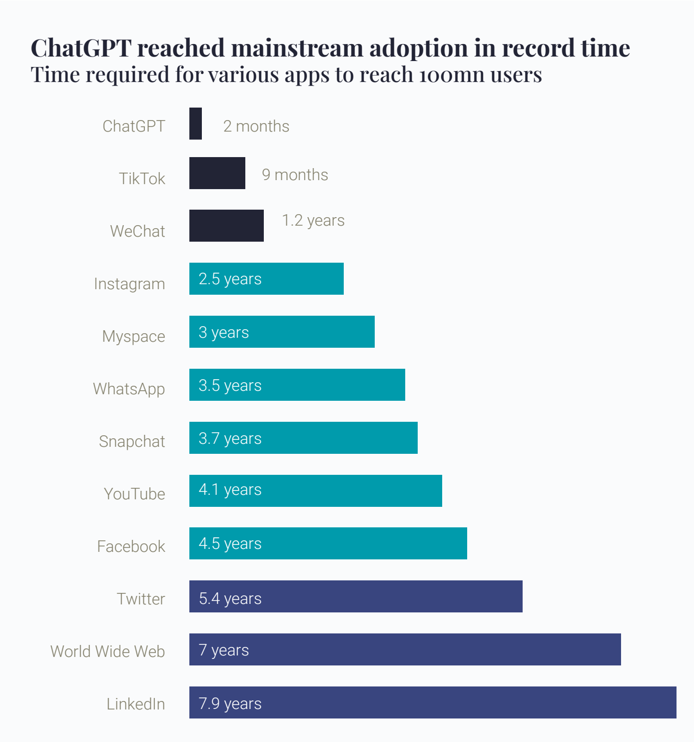
AI is more than a technological innovation; it represents a profound shift that will transform the economic landscape, impacting production, decision-making, employment, productivity, governance, and international relations.

Hervé Guez
Deputy General Manager
Listed Assets BU Head

AI is adopted at the fastest pace of any technology in history

AI is being adopted by corporates and individuals at the fastest pace of any technology in history. OpenAI's ChatGPT, has reached 100m users in record time, only 2 months after launching in November 2022, and now boasts 180m users with 23% of US adults [1] and 92% of Fortune 500 companies [2] reportedly using the service. AI solutions and the foundation models that power them have advanced rapidly in just the past 18 months. Over the next 5-10 years, AI should transform the global economy with significant efficiency and productivity gains, as well as our lives.

1 Source: Pew Research Center
2 Source: OpenAI



Source: Visual Capitalist, Bank of America

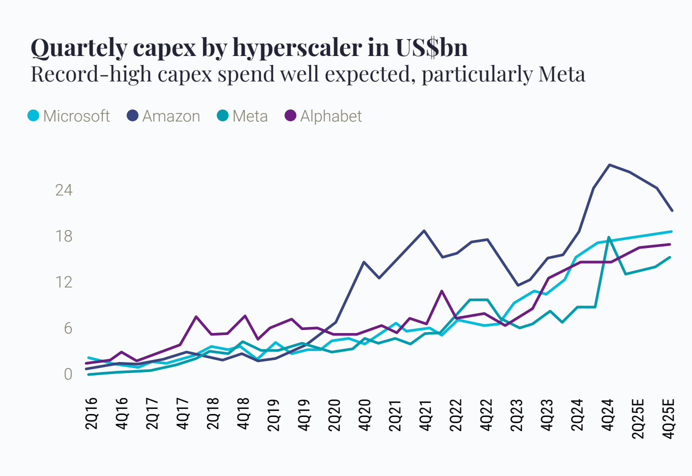
AI already permeates virtually all aspects of our lives, revolutionizing industries and transforming the way we work, live and interact. While we are still in the early stages of developing AI solutions, a wide array of potential use cases is already emerging in sectors such as healthcare (AI powered diagnostic tools), manufacturing (automation, predictive maintenance), retail (optimized supply chains and personalized shopping), finance (fraud detection), home (virtual assistants and smart devices), education (personalized learning and automation) and many others. Software companies are enhancing their offering by creating generative AI applications for business and consumer use cases, accelerating the adoption of the technology. The potential from agentic[3] and physical AI[4] will only expand the use cases and proliferate AI throughout society.

The AI ecosystem is vast and expanding quickly

The AI infrastructure layer includes hardware and cloud infrastructure necessary to store and process vast amounts of data to train AI models and run real time inference tasks.

- **AI hardware** forms the backbone of AI computation, providing specialized chips designed with the processing power needed for both training and inference tasks: Nvidia is the undisputed leader here with its Hooper and Blackwell GPUs[5]. Several contenders such as AMD and most Big Tech companies are offering or developing their own AI chips. TSMC, as the leading semiconductor foundry and with its unique CoWoS[6] advanced packaging technology, is critical to manufacturing AI chips. This hardware is paired with a software layer (such as Nvidia's CUDA[7]) with pre-built libraries to help developers of AI models.
- **Cloud Service Providers** (CSPs): Hyperscalers (such as Amazon Web Services, Google Cloud, Microsoft Azure) enable businesses to rent hardware and software for AI as a service, allowing them to store data and utilize AI tools without investing in their own GPUs, infrastructure, and data centers.
- **Infrastructure**: AI data centers need specialized hardware, networking equipment, cooling systems, and robust energy infrastructure to handle the growing computational demands of AI. This necessitates significant investments in energy infrastructure, including power generation, transmission, distribution, and backup power solutions. Additionally, effective power management solutions are essential to ensure reliable power availability and stability.

3 Agentic AI refers to artificial intelligence systems that possess the ability to act autonomously and make decisions based on their understanding of the environment, goals, and available information.
4 Physical AI refers to artificial intelligence systems that are embodied in physical forms, such as robots or smart devices, enabling them to interact with and manipulate the physical world.
5 GPUs stands for Graphics Processing Units. GPUs are specialized electronic circuits designed to speed up the creation of images and video
6 CoWos stands for Chip-on-Wafer-on-Substrate. Developed by TSMC, the platform provides best-in-class package technology for ultra-high performance computing applications.
7 CUDA stands for Compute Unified Device Architecture. Developed by NVIDIA, the platform provides a development environment for creating high-performance, GPU-accelerated applications.

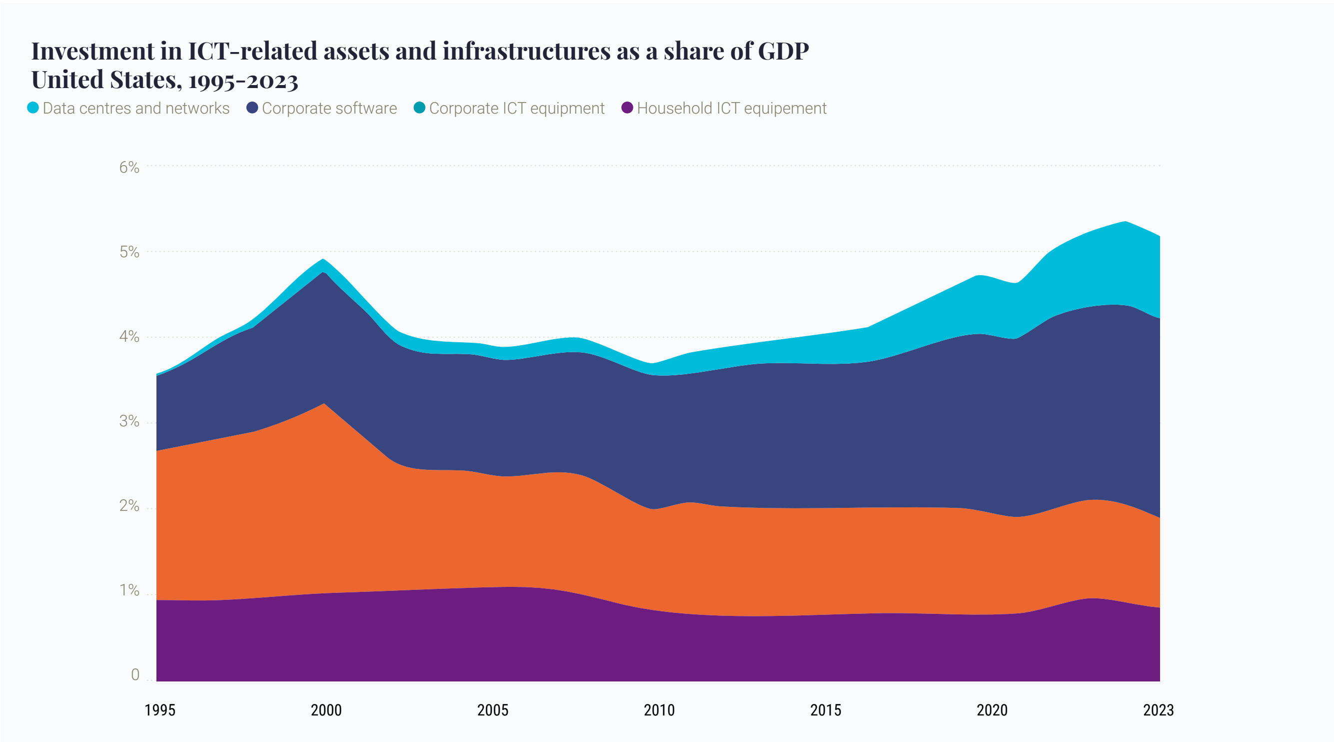


Source: Bank of America, companies - Microsoft data adjusted for CY basis

> Information and Communication Technology (ICT) investment has grown to around 5.5% of US GDP in recent years, higher than at any other time since the 2000 dotcom bubble.
>
> International Energy Agency (IEA) CC by 4.0

AI infrastructure is seeing unprecedented levels of investments and developments driven by technology giants like Alphabet, Meta, Microsoft and Amazon who are quickly expanding their capital expenditures (each estimated between USD40-75bn for 2024) into servers and data centers to meet demand for generative AI, large language models and cloud services. In 2024, total spend from these hyperscalers could reach around USD240bn (according to Jefferies, more than a fifth of total S&P500 capex), a significant increase from USD148bn in 2023. These investments are expected to continue to accelerate near term with the combined capex of tech giants reaching around USD300bn in 2025 with a focus on data centers equipped with high performance GPUs (like the new Nvidia Blackwell chips), their own custom silicon development and energy infrastructure to support AI workloads. In 2025, Microsoft alone is on track to invest approximately USD80bn to buildout AI-enabled datacenters to train AI models and deploy AI and cloud-based applications around the world.

Source: Bank of America & Alphabet, Meta, Microsoft and Amazon's websites



Source: IEA analysis based on data from US Bureau of Economic Analysis (2024)

- **Foundational models and GenAI services**: The building, testing and refining of AI models is central to creating pre trained intelligent systems such as foundational models (the leader being GPT from OpenAI) that can then be fine-tuned for various applications (natural language processing, genAI etc). The famous ChatGPT is the leader in GenAI services today.

02 AI's Environmental Potential and Risks

AI Opportunities for Climate and Nature

The use of AI is rapidly transforming various sectors and its vast potential, — when combined with expertise and knowledge from diverse domains — **could accelerate the transition to a more sustainable economy**.

While AI is currently in its early adoption phase, we are already witnessing its potential to drive environmental use cases that could help us on our decarbonization trajectory towards net zero emissions:

- Decarbonisation of our energy systems and integrating solar and wind power into electric grids,
- Improvement of the energy efficiency of industrial operations or buildings,
- Optimization of agricultural practices to reduce emissions and increase yields
- Monitoring of GHG emissions and deforestation and forecasting climate change,

AI is also accelerating scientific progress and innovation through the development of new technologies and materials in all sectors (energy, technology, materials, transport etc), leading to better environmental solutions to reduce pollution and waste globally.

A non-exhaustive list of environmental applications of AI:

Electrifying and strengthening the grid

Smart Grids:

A software-defined grid is needed to manage the complexity of modern grids. Using AI at the edge and high-performance computing (HPC) in the data center, utilities can simulate real-time power flow on the grid, identify potential outages, and dynamically manage distributed energy resources.

Itron[8] leverages AI in its advanced metering infrastructure (>10m end points) to analyse energy consumption patterns and predict demand. This helps utilities manage energy loads more efficiently, integrate renewable energy sources, and reduce outages. Their AI solutions can optimize grid operations by automatically adjusting distribution based on real-time data, improving overall energy efficiency and sustainability.

Power generation optimization and predictive maintenance for Renewable Energy:

AI predicts equipment failures and optimises operations in renewable energy plants (like wind and solar), helping to maintain efficiency and reduce downtime.

As the leader in wind energy, **Vestas** uses AI to predict maintenance needs and adjust turbine settings based on weather forecasts, maximising energy output and reducing wear. AI driven optimisation ensures wind farms are more productive and reliable, contributing to a more sustainable energy supply and helping solve one of renewable energy's greatest challenge, its intermittency.

8 Source: Itron's data

Electric and Autonomous Vehicles:

AI is revolutionizing the automotive industry. AI tools are being used to optimize vehicle design, improve battery performance, and facilitate advanced driver-assistance systems (ADAS).

Dassault Systèmes'[9] 3DEXPERIENCE platform exemplifies the power of AI in automotive innovation, with 85% of electric vehicles (EVs) globally being developed and produced using their platform. It utilizes AI simulations and digital twins of vehicles to predict how designs will perform under real-world conditions. This helps streamline and accelerate the development cycles of EVs by up to 1 year.

Resource efficiency

Smart Buildings:

Building energy use is determined by a constantly changing thermal flow, dictated by occupancy and weather. Understanding these dynamics is crucial to the efficient operating of heating, ventilation and air conditioning (HVAC) systems, however this is difficult to observe directly. AI tools can help to simulate how building occupancy, structure, design and the weather interact to affect thermal flow, but also to predict how it may change.

Schneider Electric, thanks to its large installed base of sensors and its real-world AI solutions, enables reductions in electricity use and in heating energy consumption in buildings.

Digital Twins:

A Digital Twin is a virtual representation of a physical asset, system, or process that can be used to simulate, predict, and optimize performance throughout its lifecycle.

Bentley Systems is a leading company in the field of infrastructure engineering software and its tools allow its clients to reduce operational costs whilst delivering infrastructure projects (water, transportation or construction) faster and with longer asset lifespans. Some examples include its use of dashcam videos and computer vision to help detect hazards or damages immediately and improve the efficiency and cost of maintaining highways. It also provides improved asset operation and management for cell towers. The most promising use of digital twins and AI is to accelerate the industrialisation and deployment of infrastructure projects. Bentley's genAI tools will be copilots helping engineers draw designs (a big time sink) and solve problems thanks to the library of existing infra projects, allowing the reuse of existing designs instead of each project being bespoke as is the case today.

Electronic Design Automation:

It integrates to enhance design efficiency and accuracy by automating complex tasks, optimizing workflows, and enabling predictive analytics in the development of electronic systems.

Cadence[10] employs AI tools in its electronic design automation (EDA) software and IP portfolio to optimize circuit designs for energy efficiency. AI is becoming an integral part of designing electronics and is now used by all major semiconductor companies in the world. Cadence 5 AI platforms (analog, digital, verification, PCB, package and system analysis) use machine learning algorithms to analyse design parameters and suggest improvements that minimize power consumption while maximizing performance. They deliver significant productivity improvements but also delivers better results with power improvements of 5-20%.

9 Source: Dassault's data
10 Cadence's data

Precision Agriculture:

AI analyses data from sensors and drones to optimize crop yields, monitor soil health, and reduce water usage, leading to more sustainable farming practices.

Trimble provides precision agriculture solutions that leverage AI to analyse data from various sources, including sensors and drones, for smarter farming practices. Their platform enables farmers to monitor crop health and optimize inputs (like water and fertilizers), resulting in improved crop yields and reduced environmental impact.

Water Efficiency and Quality Monitoring

AI analyses data from sensors to reduce water loss and detect pollutants in water bodies, enabling faster responses to contamination.

Badger Meter employs AI and machine learning in its water metering solutions to detect leaks and monitor water usage patterns. Their smart water meters collect data that is analysed to identify anomalies, such as unexpected spikes in usage that may indicate leaks. This allows municipalities and utilities to respond quickly to water loss, optimizing water resources and promoting sustainability in water management.

Process Optimisation:

In manufacturing, AI is already used in robotics and predictive maintenance software to reduce operational downtime, maximising resource efficiency. Siemens utilizes AI in its industrial IoT solutions to monitor equipment health and predict failures before they occur. Using data from sensors (tracking indicators like temperature or movements) and machine learning algorithms, Siemens' MindSphere platform analyses operational data to optimize maintenance schedules, reducing downtime and energy waste in manufacturing processes. This leads to a more sustainable industrial operation.

Waste Management:

AI optimizes waste collection routes and recycling processes, improving efficiency, and reducing landfill waste.

Waste Management employs AI to optimise waste collection and recycling processes. The company uses AI algorithms to analyse data from GPS and sensors on collection trucks, allowing for real-time adjustments to routes based on traffic conditions and waste generation patterns. This optimization has led to reduced fuel consumption and improved service efficiency.

Adaptation

Climate Forecasting/Modelling and Extreme Weather Prediction and Preparation:

AI models are proving to be very strong at forecasting complex climate systems. They are able to do this in a fraction of the time and with at least an order of magnitude less energy used than current supercomputers.

Nvidia's Earth 2 project serves as a prime example of this. These more accurate climate models are in turn improving predictions of climate change impacts and extreme weather and aiding in the development of mitigation strategies to minimise environmental and human impact.

The identification and mitigation of specific risks will also be very powerful for insurance and reinsurance purposes.

Biodiversity Conservation:

AI analyses satellite and drone imagery to monitor wildlife populations and habitats, helping to protect endangered species.

Planet Labs operates a fleet of satellites that provide high-resolution imagery of the Earth, which is analysed using AI to monitor wildlife populations and habitats. Their data is used for conservation efforts, allowing researchers to track changes in biodiversity and habitat loss over time.

Sustainable City Design:

AI analyses urban data to enhance city planning, promoting green spaces and efficient public transportation systems to reduce carbon footprints.

Siemens uses AI to analyse urban data for smart city solutions, promoting sustainable urban planning and infrastructure development. Their smart city software solutions help cities optimize energy usage, improve public transportation systems, and enhance urban mobility.

AI Environmental Impacts/Risks

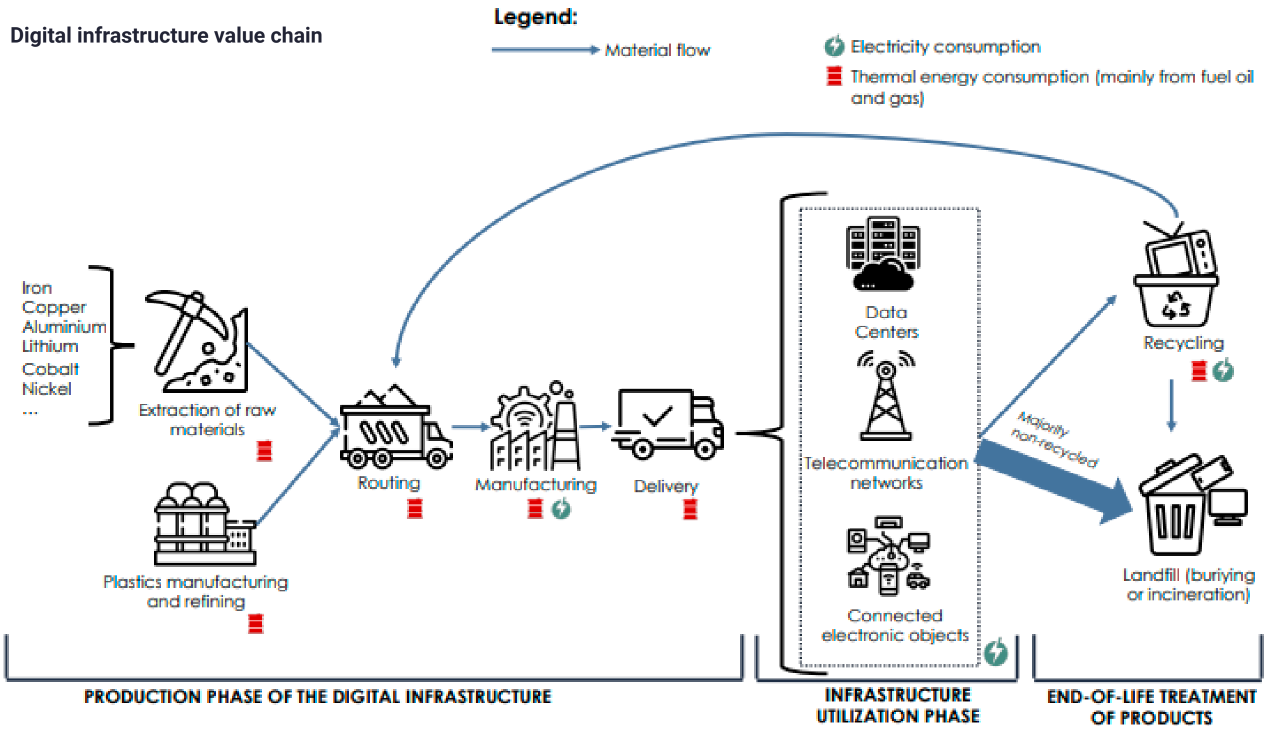
Although AI presents numerous opportunities, we must also weigh the risks that come with its adoption, particularly concerning social and environmental impacts. AI represents a significant immediate risk for the Earth's resources. As the demand for AI continues to grow, so does the carbon footprint of data centers. It is also important to recognize that AI is likely to drive climate risks throughout the ICT[11] lifecycle—encompassing mineral extraction, hardware manufacturing, and data center infrastructure. This raises critical questions about the net environmental impact of scaling up AI technologies and how asset managers should address this challenge in relation to environmental sustainability.

Against the solutions promised by AI, we must also be mindful of its climate implications:

→ AI is amplifying the ICT industry's environmental impact[12]:

In 2021, the digital economy accounted for 4% of global global greenhouse gas (GHG) emissions. While this figure is relatively low compared to other industries, it is on a rapid upward trajectory, increasing by 6% per year since 2015. The AI revolution, driven by the explosion of data availability, advancements in computing power, and innovations in machine learning and AI model architecture is one of the major trends currently contributing to the growing carbon footprint of the industry.

Digital infrastructure value chain



Source: Carbone4

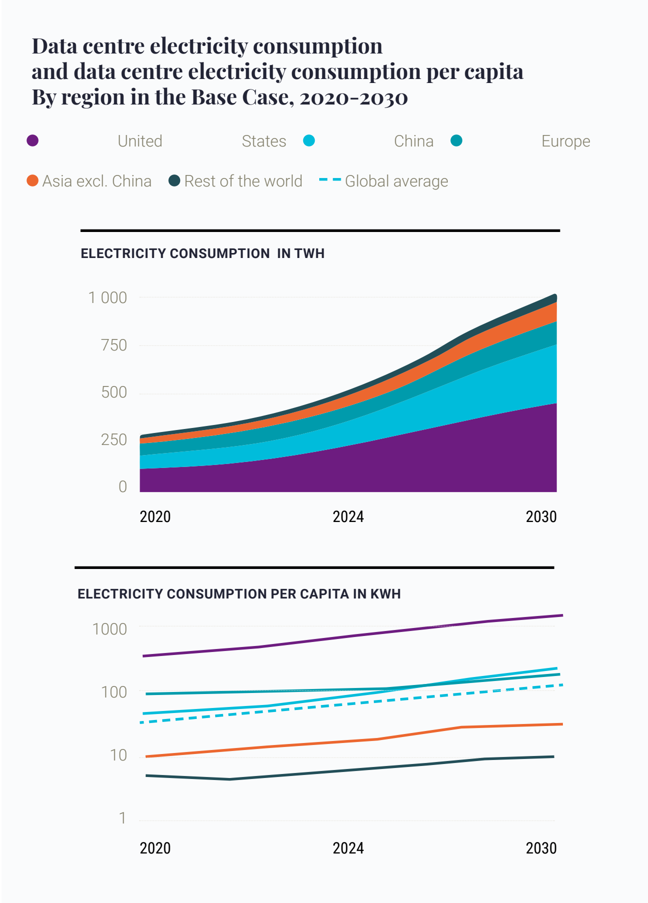
11 Information and Communication Technology
12 The Shift Project, 2021

→ AI is widely expected to increase data centers' resources consumption:

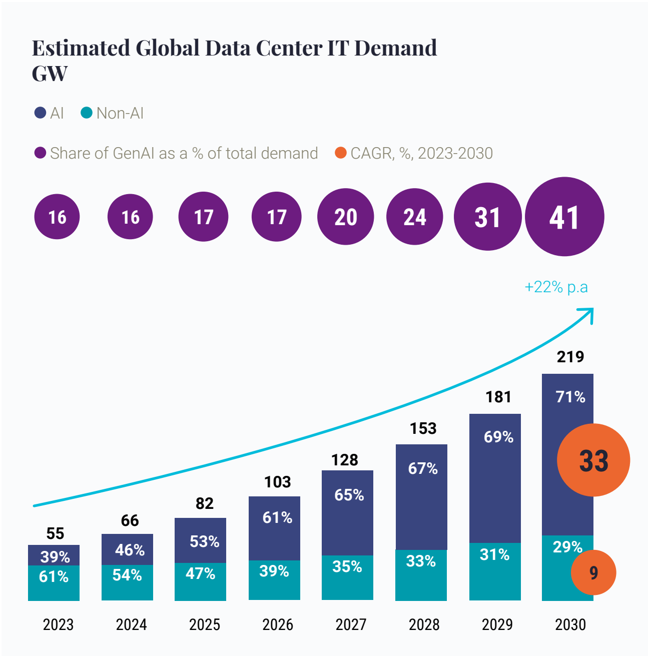
Given the central role data centers play in the lifecycle of AI — from the extraction of silicon to make the chips inside the servers to the energy used by AI-computers — their carbon footprint is key to understand the impact of AI on climate. Most of their carbon footprint is centered around their electricity consumption during various phases, including training, deployment, and storage.

The data centers that power AI systems are indeed energy-intensive and contributes to significant carbon emissions. As the demand for AI grows, so does the energy consumption of these data centers, potentially offsetting the environmental benefits that AI aims to achieve. According to the latest report from the IEA[13], data centers accounted for 1.5% of the world's electricity consumption in 2024 (415 TWh) and rapid data centers growth expansion is set to more than double it by 2030 to around 945 TWh, mainly driven by rapid roll out of Generative AI (41% of expected total data centers' ITdemand by 2030 vs. 16% today[14]). However, it is worth noting that, on a global scale, data centers are expected to account for only a limited share (10%) of global electricity demand growth by 2030, according to the IEA base case, less than the share from industrial motors, air conditionning in homes and offices, or electric vehicles, making the macro impact relatively small. Yet, this demand is not uniform and places acute pressure on certain national grids. In advanced economies, data centers account for more than 20% of demand growth to 2030 and in the United States for example, data centers already account for nearly 4% of electricity demand, a figure that could rise to 9% within a decade and in Ireland, data centers now represent 21% of electricity consumption – still according to the IEA latest report.

In terms of greenhouse gas emissions, if Generative AI will very likely boost the carbon footprint of the digital sector in the years to come, it is still hard to assess in which magnitude due to many unknows, notably the pace and rate of adoption of AI by corporates and individuals, the access to clean energy, the advancement



Source: International Energy Agency CC BY 4.0 (2024)



Source: McKinsey analysis, IDC & Gartner reports, expert interviews and NVIDIA capital markets reports (2023)

13 International Energy Agency, 2024
14 McKinsey, 2024

in data centers' efficiency and the future architectures of LLMs[15]. Yet, the IAE estimate that given the electricity sources development to 2030, CO2 emissions from electricity generation for data centers should peak at c. 320 Mt CO2 by 2030 (vs c. 200 MtCO2 today), before entering a slight decline to c. 300 MtCO2 by 2035.

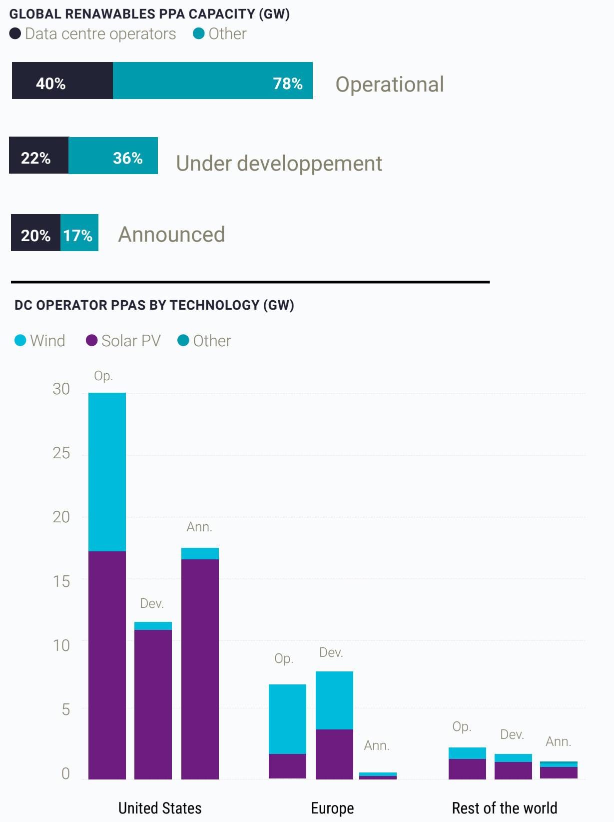
Despite the strong growth in internet traffic, data centers' energy usage growth has been more moderate thanks to efficiency gains provided by more efficient chips design and a shift away from small, regional datacenters to collocated facilities and hyperscalers, that allow to mutualize resources. However, efficiency gains of these magnitude may not be fully replicable in the medium term due to the stabilization of the market share of hyperscalers and Moore's – that indicates the doubling of computing capabilities in integrated circuit every two years – looking to be slowing down.

Moreover, we should also carefully consider the notion of efficiency gains: in the digital sector, more efficiency comes with more computing power, which drives use of this technology and in the end, higher demand and energy consumed. This concept is described as the rebound effect : this phenomenon occurs when the expected energy savings from using a more energy-efficient technology ultimately lead to an increase in usage and, consequently, higher consumption. AI follows this pattern: each new generation of GPUs and associated computing environment being more powerful, they can support larger and more complex AI models – the size of major large language models is growing ~3.5x/year with models now exceeding trillions of parameters[16]. As such, it remains uncertain if these efficiency gains will lead to real-world benefits, as they may coincide with more complex AI models that require more energy for training leading ultimately to a rebound effect in energy consumption. Therefore, reflecting on AI usage and behaviors, as well as utilizing smaller, more specialized models, can be crucial.

> Data center operators account for over 30% of active PPAs and the majority of announced PPAs
>
> International Energy Agency (IEA) CC by 4.0

Hyperscalers as Microsoft Azure, Google Cloud or AWS, are expected to drive the majority of the data center's growth and AI energy demand. As such, the impact of AI on energy consumption directly translates into the carbon footprint of major hyperscalers companies : Alphabet, Meta, and Microsoft reported 25% y/y growth in collective 2023 electricity/energy demand[17]. So far, those companies have been able to keep under wrap Scope 2 emissions thanks to the purchasing agreements of renewable energy and renewable credits. Big Tech companies are today driving the demand for green Power Purchase Agreements, which are long-term contracts in which an electricity generator sells power to a buyer at a fixed price for a specified period. . To date, nearly 120 GW of operational renewables capacity has been procured through corporate PPAs globally and technology companies operating data centres account for over 30% of this capacity.

Global renewables capacity contracted through corporate PPAs by development status, offtaker and technology



Op. = operational ; Dev. = under developpement; Ann. = announced; DC = data center; PPa = power purchase agreement. The cut-off date is February 2025. Only individual known projects are considered. Other includes bioenergy and geothermal.

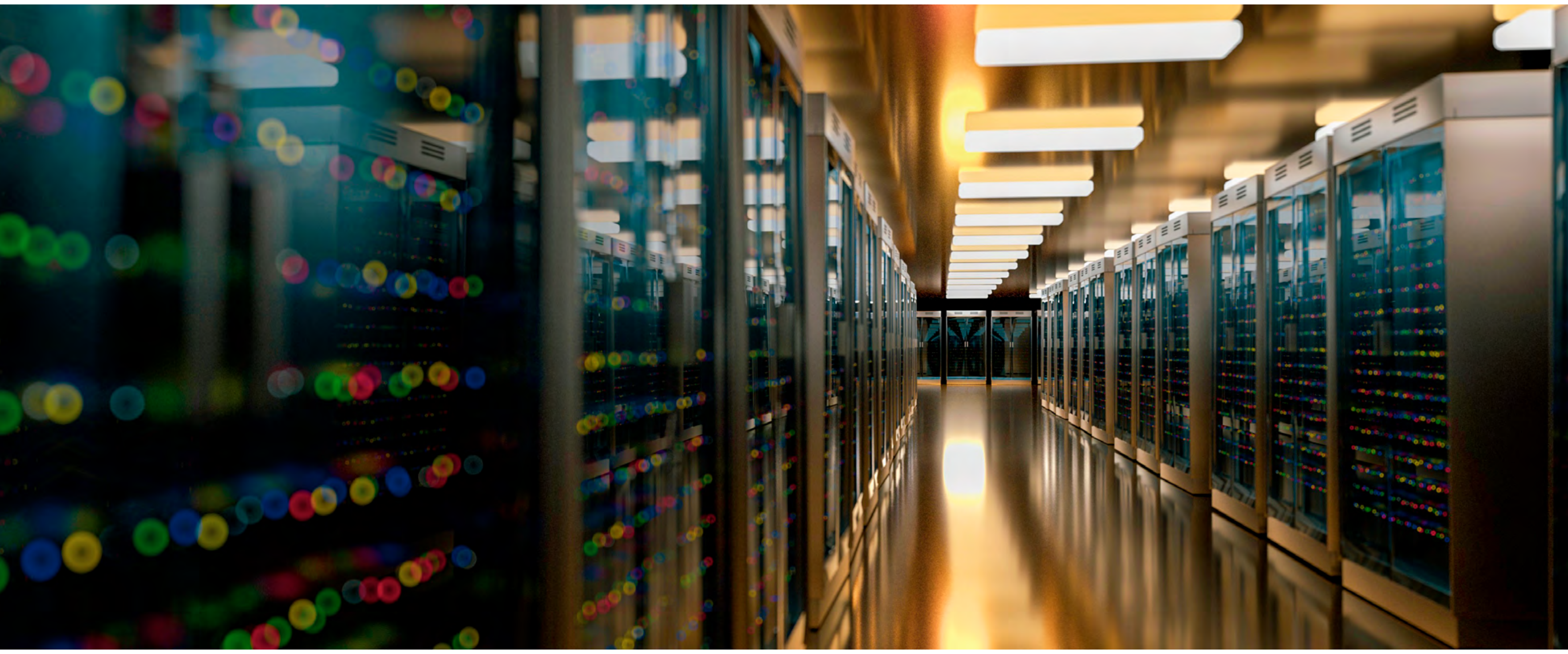
Source: IEA analysis based on data from BNEF (2025)

15 Large Language Models
16 Barclays Research, 2024
17 Barclays, 2024

As of today, renewables (primarily wind, solar PV and hydro) supply about 27% of the electricity consumed by data centers globally and are expected to be the fastest-growing source of electricity for data centres, with total generation increasing at an annual average rate of 22% between 2024 and 2030, meeting nearly 50% of the growth in data centre electricity demand. However, availability of renewable energy capacities to meet this demand is uncertain and requires significant land and battery storage duration. Additionally, the need for 24/7 energy increases the reliance of hyperscalers on the local grid, which electricity is not always green. In such settings, the strategy to build out and ensure a stable and efficient source of electricity for data centers becomes crucial. Asides renewables, electricity demand from data centers is also a significant near-term driver of growth for natural gas and coal-fired generation, through higher utilisation of existing assets and new power plants. Together, those energy sources are expected to meet over 40% of the additional electricity demand from data centers until 2030. As such, in the short term, data centers could increase demand for renewable electricity and batteries, in addition to gas power, and in the medium term, we could see the industry's leaning towards nuclear power with SMRs (Small Nuclear Reactors) entering the mix, though likely not before 2030.

These challenges already led some big technology companies to delay their Net-Zero commitments.

Data centers are also very water-intensive, requiring substantial amounts of water – both directly for cooling onsite as well as indirectly for water consumption associated with semiconductor manufacturing and energy supply. Experts anticipate that the demand for AI will propel water withdrawal to unprecedented levels, estimated between 4.2 billion and 6.6 billion cubic meters by 2027[18], a volume nearly equivalent to half of the UK's annual water consumption. In regions where water is scarce, this can lead to competition for resources, increased costs, and potential environmental degradation. As of today, in the US, 32% of existing data centers are in areas of high or extremely high water stress[19]. Emerging cooling technologies, like liquid cooling and immersion cooling, will play a crucial role in controlling the heat produced by high-density computing environments, especially as GPU racks continue to expand in size. Finally, data centers also consume water indirectly through the electricity generation needed to power data centers (traditionally thermoelectric power).



18 Gordon, C. March 2024: AI Is Accelerating the Loss of Our Scarcest Natural Resource: Water, Forbes
19 World Resource Institute, Acqueduc Water Risk Data Base

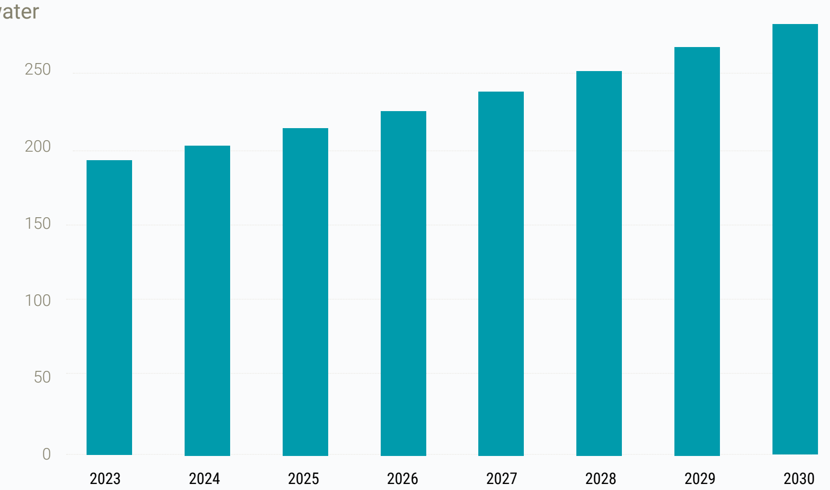
→ AI is propelling the expansion of new data center facilities[20]:

Today, there are approximately 9,000 data centers operating worldwide (33% in the US, 16% in Europe, 10% in China), with a growing number of new projects underway to fuel the development of AI. Aside from the increased electricity and grid-reliance required by data centers during their use-phase (which could be a factor of delays as many electricity grids are already under strain in many places), the construction of new data centers also indirectly contributes to the overall carbon footprint of the ICT sector through upstream carbon emissions embedded in construction materials, steel, and hardware components, including semiconductors inside GPUs, servers and racks. Microsoft's 2023 Sustainability Report received a great deal of media attention in May 2024 with total carbon footprint increased by 29% in absolute in 2023 compared to 2020. The primary driver of this rise is the increase of Scope 3 emissions, particularly upstream scope 3 from capital goods (+45% YoY). As such, hyperscalers have a great responsibility in managing data centers' location expansion in a sustainable way and use their power to drive industry action towards the decarbonization of hard-to-abate sectors (concrete, steel, hardware).

→ We should also consider value chain impacts of Materials and Infrastructure in AI:

Additionally, the necessary construction of more data centers will not only contribute to carbon emissions but also threatens biodiversity through land-use changes and increase digital pollution and waste downstream. Upstream, hardware and semiconductors production rely on a variety of minerals and materials (silicon, gallium, cobalt), which extraction, refining and waste involve high levels of pollution and water, with demand is exploding to unprecedented levels. Indeed, at the manufacturing stage, a large amount of ultra-pure water is needed for the production of microchips and semiconductors. According to the IAE, water consumption from chip manufacturing for data centres grows more than 50% from 2023 levels to around 70 billion litres in 2030.

The water consumption of data centres globally is expected to keep going up
Estimated usen billion gallons per year.
Includes water drawn from utilities and self supplied water drawn from the ground and surface water



Source: Bluefield Research (2023)

20 Source : JP Morgan, Digital Carbon: Climate, AI & the ICT value chain, April 2024.

03 Mirova's Approach to AI

Our convictions

AI's impact on the environment in the future is uncertain due to many unknows (renewable energy availability, efficiency improvements, number of data centers, consumption of the models, etc...) – as of today, there's no real consensus : AI promises to make significant contribution to developing the necessary materials, technologies and business models to accelerate the transition to a greener economy but it is undoubtedly generating adverse environmental impacts. As such, we believe that our role as Responsible Investor is to invest in AI opportunities that are real game changers for accelerating our response to climate change. However, we must also exercise utmost caution regarding their application and the potential consequences they may have on our climate and natural ecosystems.

Major opportunities we retain are the use cases of AI that increase productivity and improve results for environmental solutions:

Electrification of society: integration of renewable energy, modernising the grid, electric vehicles

Resource efficiency: smart buildings, digital twins, electronic design automation, precision agriculture, water quality and monitoring, process optimisation, waste management, sustainable materials

Adaptation: climate forecasting, extreme weather prediction, biodiversity conservation, sustainable city design

Efficiency gains in the AI value chain are crucial for reducing energy costs and supporting future environmental use cases and sustainability goals.

Efficiency gains in the AI value-chain, as advancements in semiconductors/processors, data center solutions, cooling and software are proving instrumental to drive efficiencies and mitigate AI's energy cost, while supporting future environmental use cases and sustainability goals:

Semiconductors/Chips (Nvidia): Nvidia's GPUs are at the core of AI workloads in data centers and their efficiency improvements are critical for reducing energy consumption despite larger AI models. Nvidia's latest Blackwell architecture significantly improves the number of computations per watt (by a factor of 1.7x) to make high-performance AI less energy-intensive. This new architecture can deliver up to 25x lower energy consumption for AI inference tasks on large language models (which are rapidly taking off). Yet, since 2017, the enhanced energy efficiency of AI chips—and the resulting reduction in computing costs—has resulted in a sevenfold increase in demand for AI computing, which triggers cautiousness about the net environmental gains of this solution.

Hyperscalers (Google): Google utilizes advanced computing platforms, including custom-built TPUs (Tensor Processing Units), to optimize its AI workloads. Google's use of AI to manage data center cooling has led to a reduction in energy usage for cooling by 30% on average. Overall, the company has achieved an average power usage effectiveness (PUE) of 1.1 vs 1.58 for the industry meaning its data centers use about six times less overhead energy for every unit of IT equipment power.

Data center equipment (Flex, Arista Networks): Arista offers cloud networking solutions that enhance the efficiency of data center operations thanks to reduced bottlenecks and minimising idle power consumption. Flex provides energy-efficient power distribution units (PDUs) and other data center equipment designed to optimize energy use, including its market leading power shelves embedded in data center racks. Flex has deep expertise in data center, being the only EMS player with a comprehensive offering (manufacturing and power products, addressing 80% of data center content: integrated rack, embedded power and critical power for data center), full lifecycle offering (with fulfilment and circular economy), vertical integration and broad presence globally. The company has power shelves with market leading efficiency.

Foundation models (OpenAI): Today's foundation models (like GPT4) are only getting larger and more energy intensive but companies like OpenAI are explore ways to make their models more energy efficient. The organization aims to enhance efficiency through innovative training techniques and model architectures (which would have similar AI capabilities whilst requiring less computational power for training and inference). OpenAI has also hinted at developing smaller and more efficient models which could also help reduce the energy consumption of AI.

Power management solutions (Schneider, Eaton): AI-driven power management system tailored for data centers. Schneider provides real time monitoring and automation to optimise power usage and increasing overall energy efficiency by up to 30%. Eaton's advanced uninterruptible power supply (UPS) systems protect against outages but also enhance power efficiency through load balancing and smart grid integration.

Cooling solutions (Vertiv): Cooling is one of the largest contributors to data center energy usage. Vertiv's cooling solutions can reduce cooling related energy consumption by up to 40% compared to traditional cooling systems depending on the facility, in part thanks to adaptive cooling based on real time monitoring of heat generation.

What is needed to accelerate AI applications for environmental uses:

- Skilled programmers and data engineers focused on climate mitigation
- Accessible and standardized data
- Strong policies and educational investments to better understand opportunities and risks
- Substantial resources from governments, corporations, and stakeholders

Actions needed for Companies in the AI Ecosystem to build credible decarbonization strategy:

- Invest in energy efficiency across the AI value chain to manage energy consumption growth.
- Support renewable energy generation through long-term contracts and infrastructure investments.
- Minimize environmental impact of data center operations to reduce land use and resource conflicts.

Our Engagement

As of today, Mirova is pursuing individual engagement with relevant technology companies in the AI value-chain and exploring potential new collaborative engagement with peers as well as advocacy initiatives to join on this thematic of climate and AI.

The conflicting risks and opportunities are intertwined with the broader need to decarbonise data centers and support the scaling up of renewable energy. In this context, we believe that companies within the AI value chain that have established ambitious transition plans and are taking credible actions to significantly reduce their carbon footprint are making meaningful contributions toward achieving sustainability goals.

Engagement on climate

We have identified two primary themes for engagement on climate with AI companies and the broader tech sector, as well as interconnected industries: low-carbon energy and sustainable data centers. Our goal is to promote and support the adoption of best climate practices in the sector.

Low-carbon energy:

- Investment/Partnership with Green Power providers: Track Big tech's commitments to invest in renewable power (Power Purchas Agreements, direct investments, partnerships with Utilities etc.) and sustain diverse green power supply option (physical connections and market-based transactions)
- Investment in Green Energy Storage: Encourage advancements in long-duration renewable energy storage technologies to enable 24/7 energy provision.
- Grid Upgrades: Invite hyperscalers to fund grid upgrades to support the increasing energy demands and allow reliable provision of low-carbon power.
- Monitoring Natural Gas Agreements: Some pipeline companies are negotiating with data centers to supply gas for on-site power. Keep track of natural gas supply contracts signed by hyperscalers to avoid "lock-in" effects.
- Emission Tracking: Monitor scope 1 emissions and diesel use as data centers and AI increasingly rely on backup generators. Also, assess the evolution of location-based and market-based scope 2 emissions in relation with decarbonization goals.

Sustainable data centers:

- Site selection and Layout Planning: Limit the construction of new data centers, explore the transformation of existing buildings, and select locations that minimize risks of energy conflicts or high water usage, ideally where renewable energy and natural cooling are available.
- Energy Efficiency Improvement: Enhance energy efficiency in new and existing data centers. Most hyperscalers have significantly improved their Power Usage Effectiveness (PUE), but there are still efficiency gains to be founded, notably as regard to cooling, hardware and overall architecture of data centers (compute, racks, networking). As such, continued innovation in energy efficiency as well as a reflection on AI usage and the use of smaller, less generalist AI models to handle the simplest requests or more specific uses could be an interesting way to approach this challenge.

In addition to the environmental risks associated with artificial intelligence, this technological revolution also brings forth significant ethical, social, and governance concerns.

The production of essential components, particularly semiconductors, relies heavily on the extraction of critical minerals which severely impacts human rights and communities. Moreover, automation driven by AI is reshaping the workforce, leading certain jobs to become obsolete and widening existing inequalities, with varying impacts throughout the value chain. AI also raises pressing ethical and sovereignty issues, largely due to inherent biases in model design and their applications. The lack of transparency in algorithms, combined with the concentration of AI technologies among a small number of large corporations, presents significant governance challenges. Therefore, establishing an ethical and transparent framework for AI development is essential to prevent the exacerbation of inequalities and the consolidation of technological power.

Company level:

We chose to first center our engagement efforts around Ethical AI, to promote the implementation of Responsible AI guidelines and governance structures through a dedicated targeted engagement roadmap to address the risks identified with this technology such as disinformation, exacerbating bias, threats to privacy or intellectual property rights infringement. In 2023, we engaged with two companies on this topic: Microsoft, which is exposed through its partnership with OpenAI that notably led to the development of large-language model GPT-4, and NVIDIA, which is exposed through the development of hardware needed to the accelerate the treatment of massive amounts of data and run generative AI applications. With ongoing announcements about responsible AI development, industry best practices are rapidly evolving and regulation is being structured in many jurisdictions. Another crucial risk topic linked to the growing wave of AI technologies is the increasing demand for critical minerals, making transparency essential for strong supply chains in the tech industry. Mirova, along with Boston Common Asset Management and CERES, has filed a shareholder proposal urging Nvidia to enhance its Responsible Minerals Policy and improve tracking of critical minerals, which is important for reducing environmental and social risks. Successful discussions with Nvidia have led to commitments for annual meetings to review progress and consideration of joining the Initiative for Responsible Mining Assurance (IRMA), helping Nvidia stand out in a competitive market.

Industry level:

In its Ethical AI engagement stream, Mirova recently joined the second phase of the World Benchmarking Alliance's Collective Impact Coalition for Ethical AI, which is a collaborative engagement initiative across investors set to drive progress on companies' ethical AI initiatives. In this second phase that builds on the core expectation of the initial phase of pushing Tech companies to publishing their AI principles (as of today around 50 listed companies publicly released Responsible AI frameworks), companies will be asked to demonstrate how they are implementing their published AI principles, how AI risks are reflected in their human rights impact assessments, and what governance mechanisms underpin the development, deployment, and procurement of AI technology.

As of today, collaborative initiatives around the climate impact of new technologies such as AI are just beginning to emerge. Several ongoing engagements, such as the thematic initiative on science-based targets aimed at electric power companies led by CA100+ and the Valuing Water Finance Initiative, underscore the central importance of artificial intelligence. Additionally, Mirova participated in informal exploratory discussions with investors and experts from Ceres in the technology and power sectors, focusing on the implications of renewable energy purchasing agreements by technology companies on the decarbonization potential of electric utility providers. We firmly believe that this is a critical issue that is only beginning to receive the attention it deserves, yet it will undoubtedly become a dominant focus for investors in the months and years ahead.

Advocacy level:

AI is not only analyzed as a powerful lever for economic transformation but also as a crucial tool to accelerate the transition to a more sustainable world. We believe the regulatory framework should play a role in structuring these best practices. Mirova seeks to collaborate with decision-makers, influence regulatory frameworks and strengthen the accountability of companies in the sector. In addition, we participate in various working groups and provide sponsorships to various organizations such as the Coalition for Sustainable AI and co-sponsors the "AI and Finance" working group within the One Planet Sovereign Wealth Funds network.

Finally, it should be noted that regulations surrounding artificial intelligence are being developed globally, reflecting the urgent need to address ethical, safety, and accountability concerns associated with this rapidly evolving technology; for example, the European Union has voted the AI Act to establish comprehensive guidelines for AI use, while the United States is exploring frameworks like the National AI Initiative to promote responsible AI development. Regulatory are also increasingly wary of data centres' footprint, leading countries like Ireland, Germany, Singapore, and China to implement new rules.

The EU's updated Energy Efficiency Directive requires member states to reduce energy consumption by 11.7% by 2030, with data centers over 500 kW needing to report key metrics starting September 2024. Germany's Energy Efficiency Act mandates that data centers over 100 kW source 50% of their electricity from renewables by January 2024, increasing to 100% by 2027, along with requirements for energy management systems and waste heat reduction.

Mirova has taken a proactive stance on both issues, recognizing that sustainability efforts must advance without waiting for the complete development of regulatory frameworks and that advocacy and systemic engagement is needed to reach this goal.

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