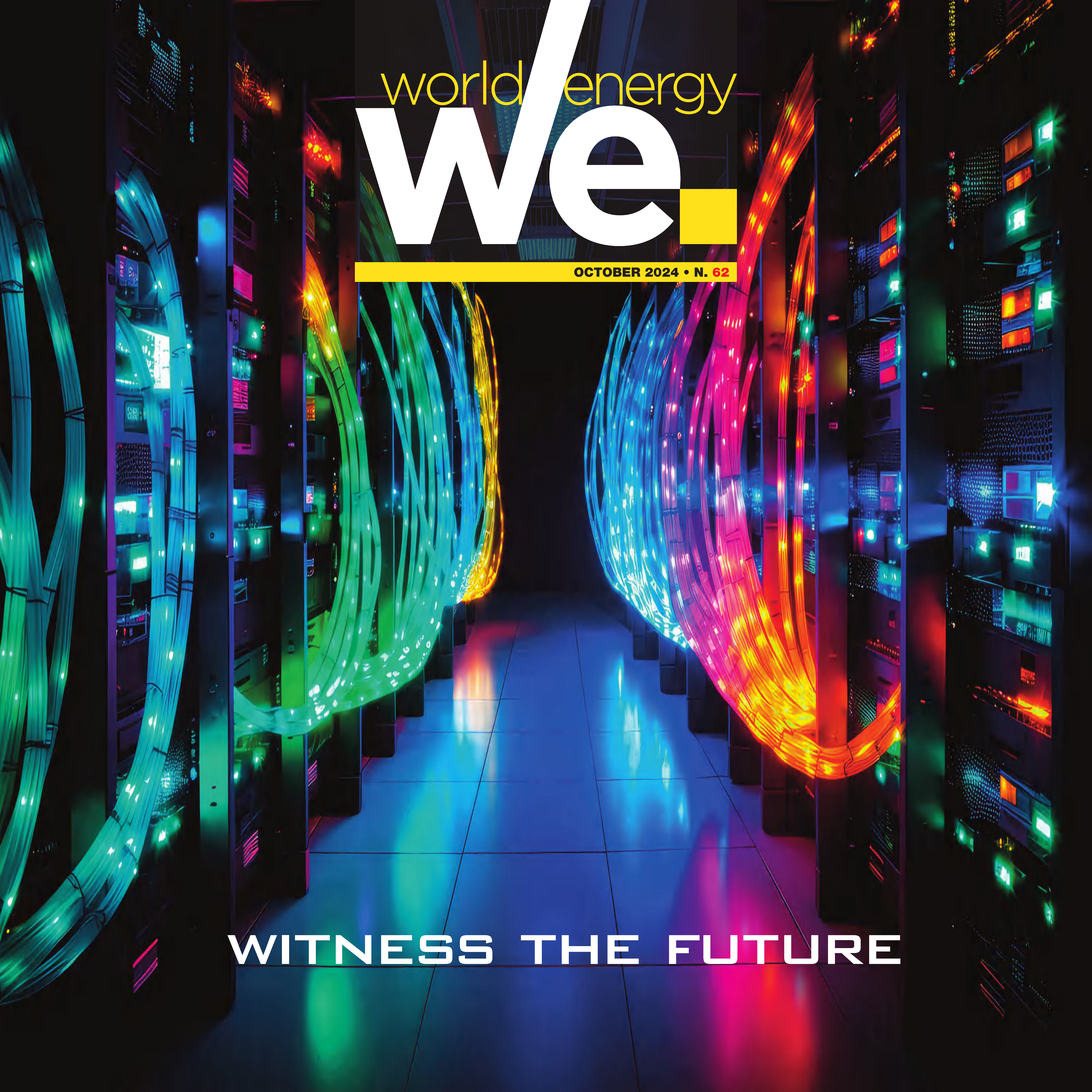
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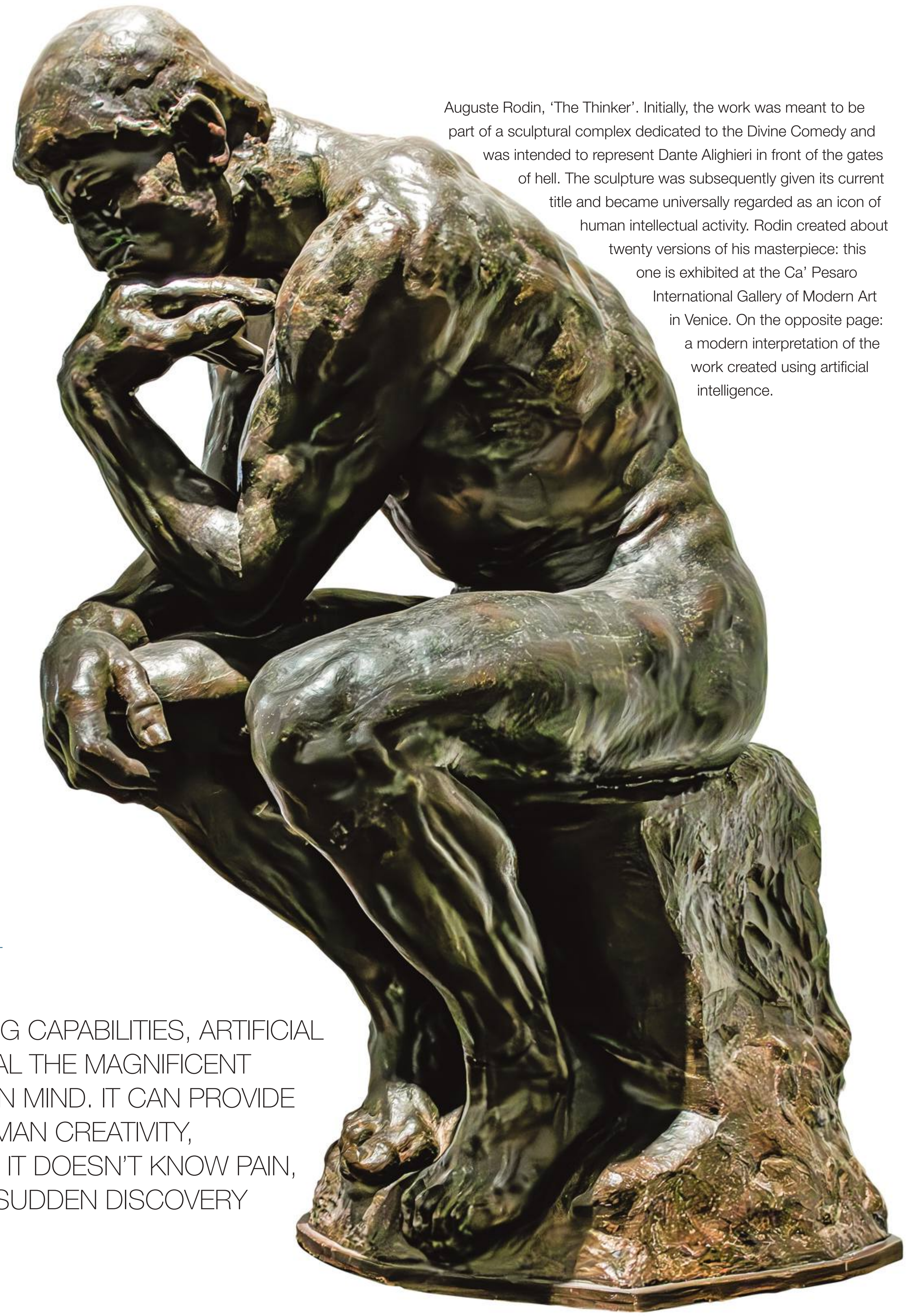
OCTOBER 2024 • N. 62
WITNESS THE FUTURE

C O N T E N T S

Beyond AI: the unique power of human thought

by Rita Lofano

DESPITE ITS FAST IMPROVING CAPABILITIES, ARTIFICIAL INTELLIGENCE CANNOT RIVAL THE MAGNIFICENT COMPLEXITY OF THE HUMAN MIND. IT CAN PROVIDE ANSWERS, EVEN MIMIC HUMAN CREATIVITY, BUT IT LACKS AWARENESS. IT DOESN'T KNOW PAIN, JOY, OR THE BEAUTY OF A SUDDEN DISCOVERY



Auguste Rodin, 'The Thinker'. Initially, the work was meant to be part of a sculptural complex dedicated to the Divine Comedy and was intended to represent Dante Alighieri in front of the gates of hell. The sculpture was subsequently given its current title and became universally regarded as an icon of human intellectual activity. Rodin created about twenty versions of his masterpiece: this one is exhibited at the Ca' Pesaro International Gallery of Modern Art in Venice. On the opposite page: a modern interpretation of the work created using artificial intelligence.

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I STILL REMEMBER the tap-tap-tap of my fingers on my old red Olivetti Valentine typewriter during my journalism exams in the mid-1990s. Each keystroke was deliberate, guiding my thoughts as I carefully organized my ideas. Every letter had to be precise, every sentence well-considered—because once typed, there was no going back.

Today, computers finish our sentences, suggest synonyms, and correct mistakes in real time—sometimes even introducing new ones. My life as a journalist has transitioned from the tactile era of paper to the dawning age of artificial intelligence.

We've made great strides—humans have long dreamed of machines capable of solving our problems. But the machine does not truly 'understand' what it sees, nor does it assign value or meaning to the images it processes. It can provide answers, even mimic human creativity, but it lacks awareness. It doesn't know pain, joy, or the beauty of a sudden discovery. It cannot experience the thrill when a story begins to take shape, when you dig deep and uncover a truth no one else has seen.

As advanced and sophisticated as artificial intelligence may be, it cannot compete with the magnificent complexity of the human brain. As Blaise Pascal famously said, "Man is only a reed, the weakest in nature, but he is a thinking reed."

In 2018, I interviewed artist Andrea Bianconi for his exhibition Breakthrough at the prestigious Barbara Davis Gallery in Houston, Texas. He described an abstract, spiral work that initially seemed indecipherable to me, much like his performance with a cage on his head. But as he spoke, something shifted in how I viewed the painting; suddenly, I began to grasp its hidden meaning. It was a moment of understanding that is hard to explain—an aesthetic experience no machine could ever replicate.

A human brain operates with a fraction of the power consumed by a supercomputer. With just 20 watts of energy—the same as a small light bulb—our brains perform an incredible range of complex functions: from creative problem solving to emotional regulation, from memory to planning for the future. In contrast, a machine like AlphaGo, the artificial intelligence developed by Google that defeated the world Go champion, required thousands of GPUs and tens of megawatts of energy to achieve its feat. Yet, it couldn't savor the pleasure of victory.

This is the true power of human intelligence. We are capable not only of creating but also of reviewing, destroying, rethinking, and redoing.

One of the pioneers of cybernetics, Norbert Wiener, warned that, left unchecked, technological progress can have dangerous consequences: "The great problem is not to create machines that think, but to create machines that obey." The problem was theoretically solved by Isaac Asimov's laws of robotics, but there is always a gap between the perfection of science fiction and reality.

Looking ahead, one of the most pressing challenges for artificial intelligence is making machines more sustainable. A recent study by researchers at the University of Massachusetts Amherst found that training a single large language model can emit over 284 tons of carbon dioxide—as much as five cars over their entire lifecycles. In contrast, the human brain, with its biological structure, remains the most efficient engine of intelligence ever known—a model of natural sustainability that technology cannot replicate.

The true conductor, the only agent capable of composing, decomposing, and harmonizing artificial intelligence, is our brain—natural intelligence.

We

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ALGO *ergo sum*

WE HAVE DISCOVERED THAT EVEN CREATIVE THINKING CAN BE "EXTERNALIZED." BUT ARTIFICIAL INTELLIGENCES IMPLY A LARGE AND UNPREDICTABLE INCREASE IN ENERGY AND WATER CONSUMPTION

by **Francesco Gattei**

THE HISTORY OF HUMANITY is a progressive sequence of "externalization" of biological functions. With fire, we have delegated part of the digestive process to the flame; this has allowed us to free up hours of the day that would otherwise be spent slowly absorbing raw food—look at the resting times of big cats. Later modifications of the jaw and skull favored the development of new areas of the brain dedicated to creativity. With the industrial revolution's machines, we performed many activities using tools that replaced raw human exertion. We also learned to do new things, like flying and traveling over land and sea at speeds unmatched by any living being. At each step, we took effortful action out of the realm of the human body to better satisfy our daily needs.

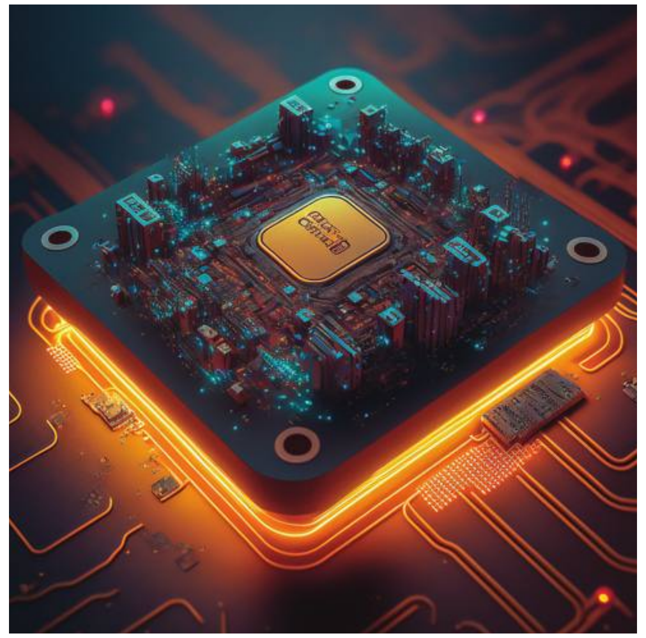
Humans are inherently lazy creatures who have spent thousands of years working out ways to increase our leisure time. We exert ourselves less and consume fewer calories, but we increase the energy consumption of the objects that replace us, which is why we increasingly exploit the environment around us.

Today, we're taking another step in replacing our efforts: we've discovered that even thinking can be outsourced. At first, this applied only to tedious calculations — we outsourced them to computers decades ago. More recently, we've begun to externalize even parts of our creative thinking.

A PROMISING CHILDHOOD

The new intelligences are still in their infancy, but they're already leaders in a wide range of activities. They can pass exams for neurosurgeons and sommeliers (without the practical test, of course!), and excel at stock trading and logistics. They write articles, compose songs (though unlistenable), and create films (albeit unwatchable). In chess, they've been defeating us for twenty-five years, but only recently have they begun to display

the hallmarks of creative thought. They're now practicing to beat us at Diplomacy, a board game requiring dialog and persuasion between players to form alliances. These AIs learn on their own, developing neural networks through continuous simulations and progressively focusing on key content.
GPT (Generative Pretrained Transformer) is the most popular model of artificial intelligence: it can compose text, answer questions and produce images. Officially launched in 2017, it has already reached its fourth iteration.
These systems develop progressively through self-learning (pre-training) and subsequent fine-tuning with human support. However, this process comes at a huge energy cost: new thinking machines must study and refine themselves to be useful. They then develop their logical paths during the usage (inference) phase. The two phases have different energy intensities: early learning is effortful and energy intensive. The later phase is less so.
During pre-training, all the focus is on the CPUs and TPUs—computer processing units and tensor processing units. The energy consumption to train the new intelligence in this phase can be enormous, potentially involving a few hundred megawatt-hours. That's equivalent to the power usage of a small city for several weeks.
During inference—when artificial intelligence answers user questions—the energy consumption is lower and limited to CPUs and GPUs (graphic processing units that facilitate algorithm processing). However, it remains quite high due to the billions of bits of information that must be analyzed and selected. Today, this involves 1 million operations per day, with an estimated consumption of around 200-300 kWh daily. This number is destined to increase dramatically with the progressive spread of this technology and its application to more diverse uses.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AN ENERGY-INTENSIVE TECHNOLOGY

Artificial intelligence is not very efficient compared to the human brain, which needs just 0.4 kWh per day while engaged in millions of intellectual and muscular decisions, including unconscious ones. However, the most surprising data emerges from comparing AI to other traditional software applications. During the learning process, AI consumes up to 100,000 times more energy than traditional software. Even in the inference phase, AI uses between 10 and 100 times more energy, depending on the tasks required. According to the IEA, data centers consume 2 percent of global power each year—460 TWh, equivalent to the electricity consumption of a country like Germany. This is expected to double in two to three years due to the rise of artificial intelligence. And, contrary to the narrative that digital equals immateriality and environmental friendliness, these machines also contribute to global warming.
Today, the IT system already has a significant carbon footprint, equal to 2 percent of global emissions—about the same as air travel. This impact is set to increase, especially considering that intermittency hampers calculation. Moreover, the heat generated has to be dissipated. According to some estimates, data centers consume up to 500-700 billion liters of water per year, an amount expected to increase by the end of the decade.
We'll surely find ways to make things work more efficiently, but the power these systems will need is growing faster than we could have guessed. Humankind is creating new (non-living) things that need food (power) and drink (water). If we think about a world where 8 billion brains will grow to 10 billion by mid-century, all hoping for a better life, we're only seeing part of the picture. On top of those billions, we'll have millions of man-made brains learning to do everything: bargain, sell, help us, take pictures, write, and drive. And perhaps even pretend to love us.
Anyone hoping to cut energy use in the coming decades through heroic gains in efficiency is likely missing some pieces of the puzzle. They'll probably need to rethink the energy sources that can support these ever-growing electronic and biological populations.
P.S.: This article was composed over three days with the help of artificial intelligence, thereby amplifying the writer's energy consumption.

we

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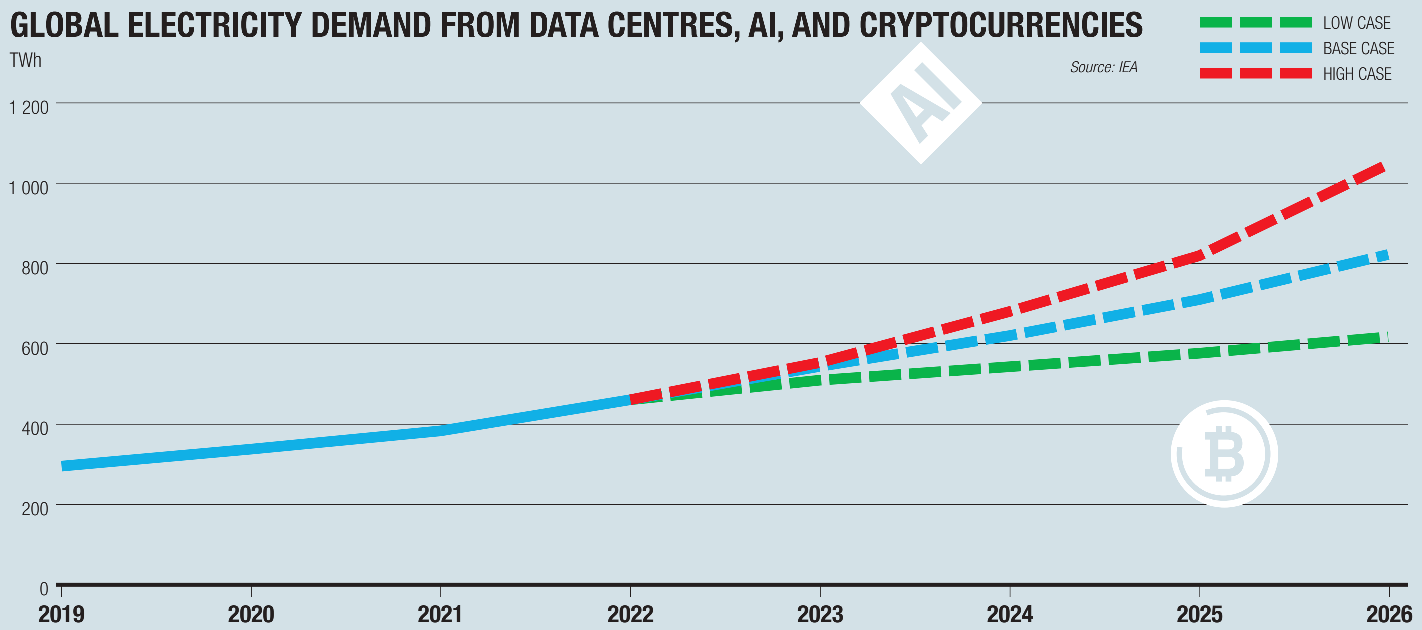
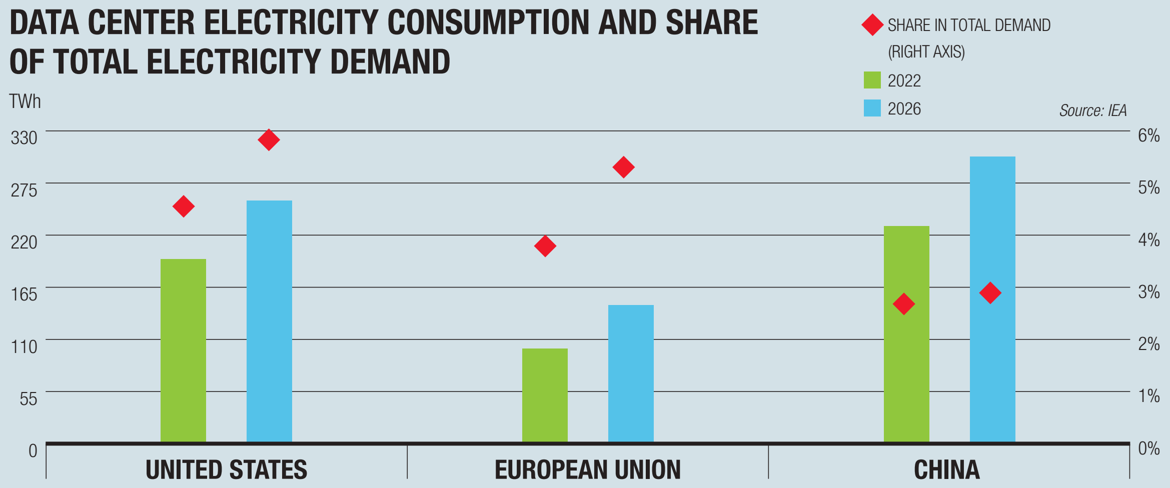
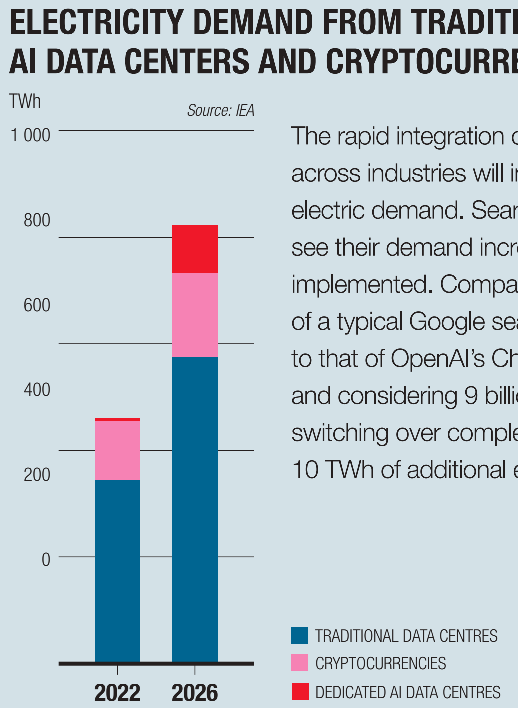
Artificial intelligence—especially machine learning and deep learning—consumes significantly more energy than traditional software applications due to the complexity of the computing required to train models and process data.



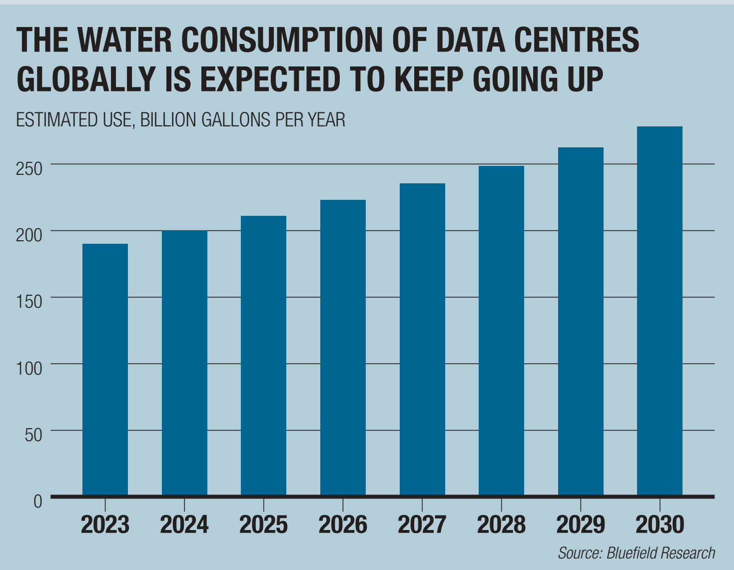
In 2022, global electricity consumption by data centers, cryptocurrencies, and artificial intelligence is estimated to have been around 460 terawatt hours (TWh), equivalent to nearly two percent of total global electricity demand. Given the pace of technology deployment, the scale of efficiency improvements, and AI and cryptocurrency trends, global electricity consumption is expected to be between 620 and 1,050 TWh in 2026, against a base case demand of just over 800 TWh, up from 460 TWh in 2022. The forecast is that by 2026, electricity demand will increase by between 160 and 590 TWh compared to 2022: roughly, an additional amount equivalent to the demand of a country between the size of Sweden and Germany.

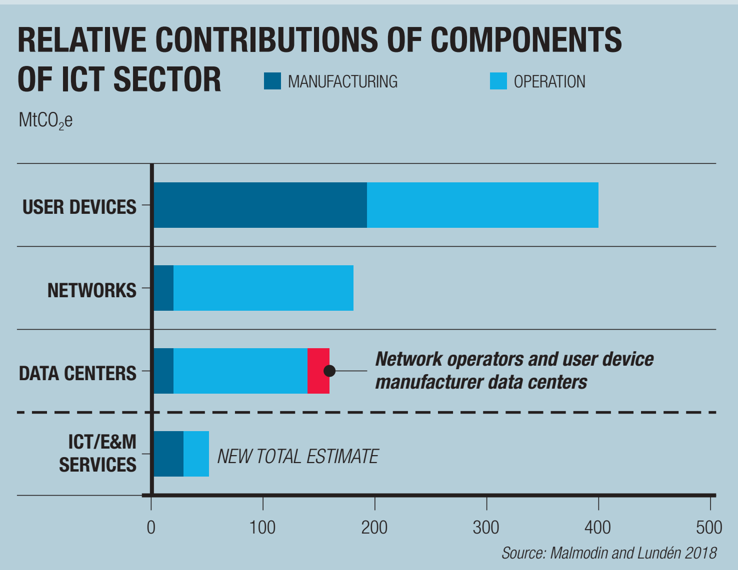


There are more than 8,000 data centers worldwide, approximately a third in the United States, 16 percent in Europe, and nearly 10 percent in China. Data center electricity consumption in the U.S. is estimated to grow from approximately 200 TWh in 2022 to nearly 260 TWh in 2026, or 6 percent of total electricity demand. In China, data center consumption will reach around 300 TWh by 2026, while in the European Union it will reach almost 150 TWh, exceeding 5 percent of total electricity demand.



The rapid integration of artificial intelligence across industries will increase data centers' electric demand. Search tools like Google could see their demand increase tenfold if AI is fully implemented. Comparing the electricity demand of a typical Google search (0.3 Wh of electricity) to that of OpenAI's ChatGPT (2.9 Wh per query), and considering 9 billion searches per day, switching over completely would require nearly 10 TWh of additional electricity every year.





The carbon footprint of the IT sector accounts for 2 percent of global emissions—on par with the entire aviation industry. This figure is expected to grow over time. Additionally, IT systems require large quantities of water for cooling: by 2030, global data center water consumption could exceed 250 billion gallons annually, equivalent to approximately 950 billion liters.

ENERGY IN & OUT

FOR TOO LONG, WE'VE FOCUSED NARROWLY ON AI AS A NEW SOURCE OF ENERGY DEMAND, NEGLECTING ITS POTENTIAL TO REVOLUTIONIZE ENERGY GENERATION. INSTEAD, WE NEED TO UNDERSTAND HOW MUCH THIS TECHNOLOGY COULD IMPROVE OUR LIVES

by Moisés Naím

MUCH HAS BEEN WRITTEN about the rise of artificial intelligence, not just as a technological revolution, but also as a huge new source of energy demand. Training large language models (LLMs) consumes an eye-popping amount of energy. To train GPT-3 required around 1,270 megawatt hours of electricity, like the power demands of 120 typical American homes for a whole year. The big data centers where AI searches are handled are gobbling up more and more energy. By 2030, data centers are estimated to account for 21 percent of the electricity demand in the United States.

An LLM query is 10 times as power-thirsty as a traditional Google search — if every Google search was rerouted through an AI engine, the added energy demand would be equivalent to the power consumption of Ireland.

All of this is true, and all of it is hotly debated. But much less attention has been given to the flip side of this equation—AI's potential to solve some of the most difficult problems in energy generation today.

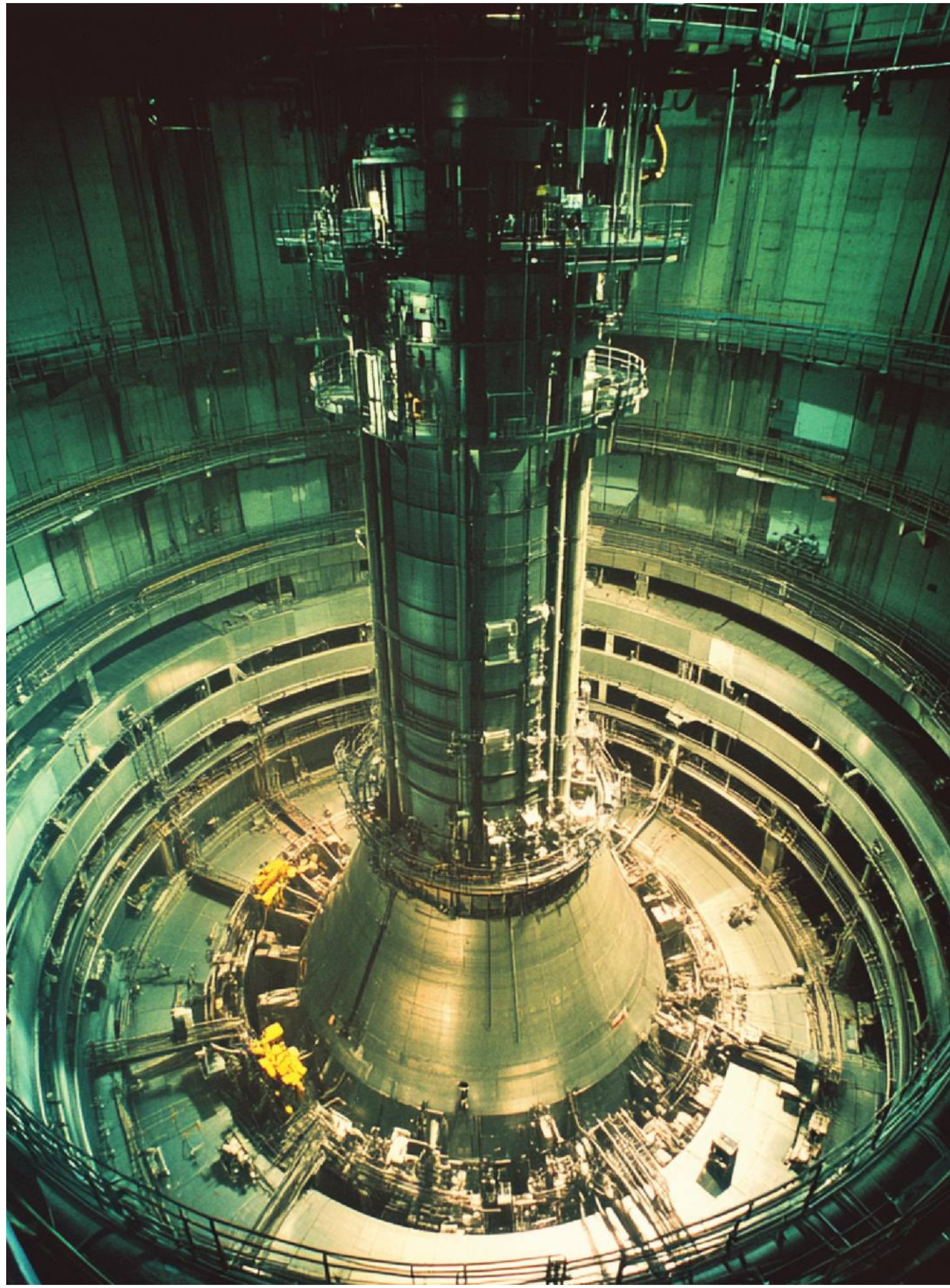
REVOLUTIONARY RESEARCH FOR OUR ENERGY SYSTEMS

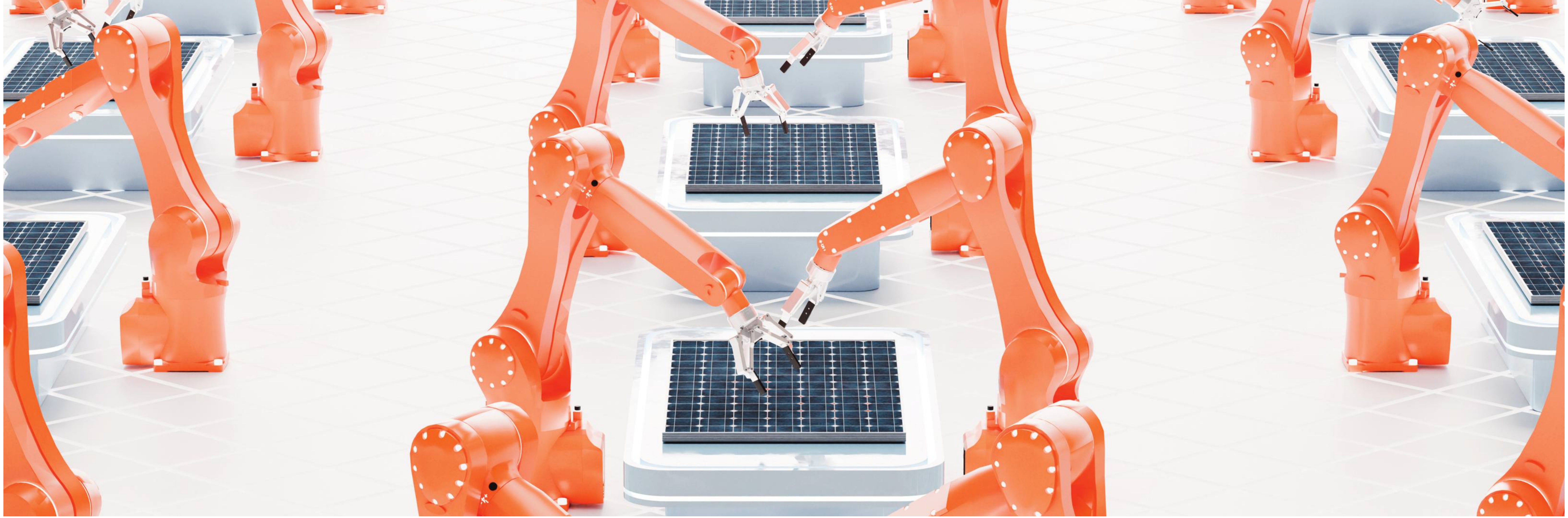
From optimizing nuclear fission reactions to aiding the stabilization of plasma in nuclear fusion, AI is already being deployed in cutting-edge research that could revolutionize our energy systems.

Nuclear fusion, the process of fusing atomic nuclei to release energy, has long been considered the 'holy grail' of energy generation due to its potential for limitless, clean power. While it has been a scientific challenge for decades, recent breakthroughs are bringing fusion energy closer to reality, with AI playing a critical role in accelerating this process.

To create a viable commercial fusion reactor, you have to find a way to control plasma —the exotic fourth state of matter— at temperatures exceeding 100 million degrees. That's hotter than the core of the sun. Managing these extreme conditions has been one of the greatest scientific challenges of our age, and a major reason why progress towards commercial applications has been so slow. The mathematics involved in modeling the behavior of plasma are dauntingly complex — and an ideal candidate for AI applications.

Together with high-performance computing, AI techniques are now being used to create predictive models with the potential to stabilize plasma in real time. Researchers at the Princeton Plasma Physics Laboratory, are using machine learning to anticipate plasma instabilities and adjust controls within milliseconds, making fusion reactions far more stable and sustainable. As Steven Cowley, the director of the Princeton lab, put it re-





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cently in the Washington Post, "AI is set to revolutionize fusion, reducing development timelines from decades to mere years by enabling faster design iteration and real-time plasma control." Others in rival labs are trying to beat them to the punch, creating the kind of scientific race that has often heralded major breakthroughs in the past.

Meanwhile, other AI researchers are helping to fast-track the design of new generations of much safer, much more efficient nuclear fusion reactors. Traditional computational models took months to analyze potential reactor designs, but fast AI-driven models can now evaluate competing designs in hours, allowing researchers to explore hundreds of billions of reactor configurations in their search for the best solution. This speed enables more efficient iteration, potentially bringing fusion closer to commercial reality within the next few decades.

Fusion is the sexiest area of AI nuclear research, but certainly not the only one. The AI revolution could prove similarly transformative for traditional fission-based nuclear power. As you'd expect, researchers are using AI models to plan new generations of much safer, much more efficient fission reactors. What you may not know is that AI-technology can improve existing fission reactors as well. AI-powered predictive maintenance systems can analyze vast amounts of sensor data to forecast when critical reactor components will need repair or replacement. By catching issues early, AI minimizes downtime and reduces the risk of catastrophic failures.

And AI-applications are also enhancing the efficiency of nuclear reactors by adjusting control settings to optimize fuel use and reactor output. This could extend the lifespan of existing reactors and reduce fuel consumption, making nuclear fission an even more viable low-carbon energy source.

GREAT STRIDES IN SUSTAINABLE AND TRANSITION SOLUTIONS

While nuclear energy presents exciting possibilities, AI is also playing a significant role in established renewables. AI models are being used to optimize the placement and operation of solar panels and wind turbines on the basis of weather and climate data. In hydropower, AI is improving water flow management, predicting fluctuations to ensure more consistent power generation. In geothermal energy, AI is analyzing geological data to help identify new underground heat sources, accelerating exploration and increasing the efficiency of geothermal plants.

And AI is also advancing the field of carbon capture and storage (CCS). Machine learning algorithms excel at analyzing complex geological data to determine the best locations for carbon sequestration, improving both the efficiency and safety of this critical technology for mitigating carbon emissions.

There are all sorts of ways AI-powered research will transform power generation. Fusion stands out as AI's potential 'killer app'—a domain with extraordinary upside potential where AI's capabilities to manage extreme complexities are indispensable. AI enables real-time plasma management, rapid design iteration, and unprecedented precision in reactor control. If AI succeeds in making fusion commercially viable, all the hand-wringing about how power-hungry Chat GPT is will be looked back on as a quaint side-show.

Of course, it's too early to say whether AI's additional energy demand will ultimately outstrip the gains it helps create in energy efficiency and generation. But it's not too early to say that, in focusing almost exclusively on the energy demands of AI and overlooking its potential to revolutionize power generation, our public conversation about energy and AI has become badly lopsided. It's time to rebalance this debate. Because AI draws a lot of power. But it might end up generating orders of magnitude more.

We

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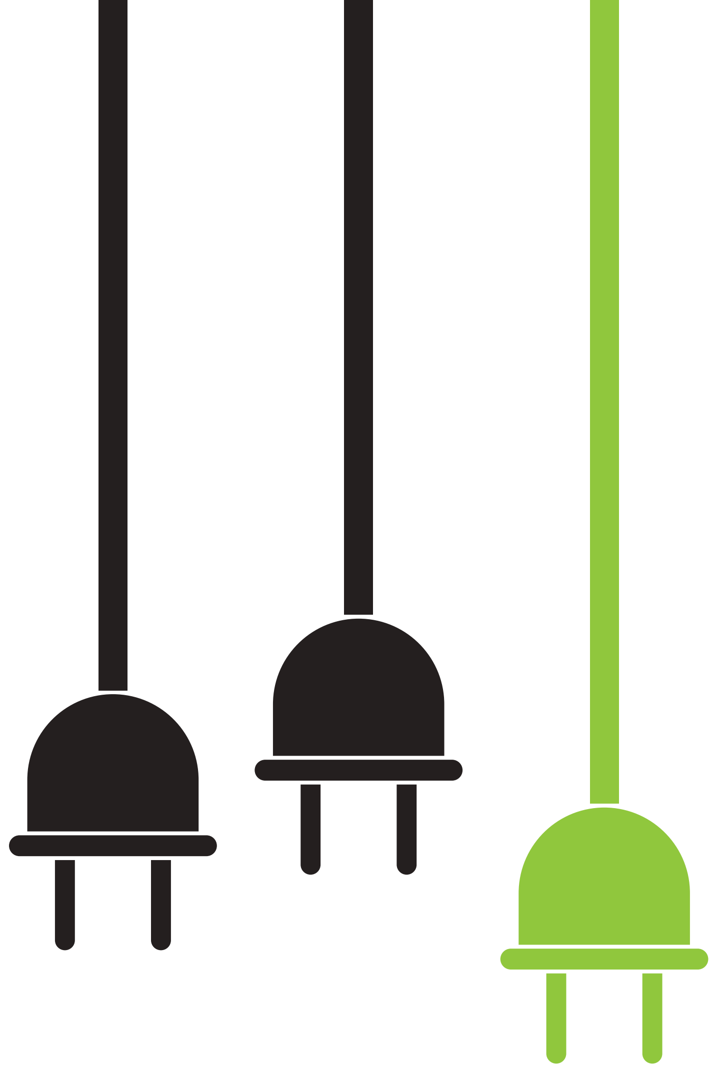
AI is being used in cutting-edge research that could revolutionize our energy systems: from optimizing nuclear fission reactions to helping stabilize plasma in nuclear fusion. Pictured: a nuclear reactor.

AI also plays an important role in established renewable energy sources, such as solar and wind: for example, it is used to optimize the positioning and operation of solar panels and wind turbines on the basis of weather and climate data. Pictured: a fully automated solar panel production factory.



THE ENERGY DILEMMA

by **Davide Tabarelli**

ARTIFICIAL INTELLIGENCE IS PUTTING A STRAIN ON ELECTRIC UTILITIES, WHICH ARE HAVING DIFFICULTY ENSURING QUICKLY THE ENORMOUS AMOUNT OF ENERGY REQUIRED. BIG TECH, WHICH HAD EMBRACED RENEWABLES, IS NOW LOOKING TO NUCLEAR

WE CAN ALL SEE the energy consumed by artificial intelligence—simplified versions of which we interact with daily on our smartphones. We constantly send queries to our devices, and through data processing, we receive increasingly complex responses. Behind this interaction lie data transmission networks and vast storage systems, all of which require electricity to function. Even though our contribution to energy consumption is small, we still add to it when we recharge our phone's battery each night. The most modern smartphones can store around 20 watt-hours of energy, enough to last a full day under normal use. To put this into perspective, a 20-watt LED bulb, which produces as much light as a 120-watt incandescent bulb,

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consumes 20 watt-hours in just one hour. Meanwhile, a complete wash cycle in a washing machine or dishwasher uses between 1,000 and 2,000 watt-hours.

The energy consumed per operation on our devices is minimal, considering we touch our phones over 2,000 times a day. However, behind what appears on our screens is a vast flow of data and the processing power of massive data centers. A race is underway to secure new electricity supplies for these centers as the exponential growth of data processing increases both energy consumption and the demand for cooling systems to keep the machines running. For example, a simple Google search uses about 0.3 watt-hours of energy in a data center. As the volume of these searches—and all other web-related activities—soars, electricity consumption is rising rapidly. A single query with ChatGPT's AI, which requires far more memory management and processing, can consume up to 3 watt-hours—ten times that of a Google search. Artificial intelligence has become the new frontier for investment, but, perhaps unexpectedly, the availability of reliable electricity is becoming increasingly scarce.

RELIABLE ELECTRICITY IS IN SHORT SUPPLY

Currently, global electricity consumption for data management is estimated at around 400 billion kilowatt-hours—2 percent of the total—exceeding Italy's entire consumption of 300 billion kilowatt-hours. By 2030, forecasts predict a 5- to 40-fold increase, potentially pushing data-related electricity consumption to 20 percent of the global total. All of this additional energy will need to be supplied by systems that can provide stable power around the clock, not just when the wind is blowing or the sun is shining. This distinction is crucial, as the Big Five tech companies—Meta (Facebook, Instagram, WhatsApp), Alphabet (Google), Amazon, Apple, and Microsoft—have pledged to use only renewable energy within a few years. Their vast financial resources, buoyed by substantial profits, and their global reach underscore their genuine commitment to addressing climate change.

However, they must also prioritize their shareholders. As a result, they have made massive investments in artificial intelligence—nearly $100 billion in the first half of 2024 alone. But they now face a significant challenge: the supply of electricity to power the ever-growing data centers is not enough.

Electric utilities themselves admit that they cannot meet connection requests within the required timeframes—often not until several years down the line, sometimes beyond 2030—while investors are pushing for results within months. As a result, Big Tech, with some discomfort, is forced to strike deals with operators of older power plants, whether coal-fired or even nuclear. One notable example is Microsoft's agreement in September 2024 with Constellation, the company that owns the infamous Three Mile Island nuclear plant, the site of a major radiation accident in March 1979. The accident occurred in reactor two, but the deal involves reactor one, which remained operational for another 30 years until 2019. Now, driven by the demand for artificial intelligence, reactor one will be modernized and restarted with a $1.5 billion investment. A portion of the energy generated will supply Microsoft's large data center in nearby Virginia. Meanwhile, both companies will also explore the development of small modular reactors, which are being heavily relied upon to revive the global nuclear industry.

OPENAI FOCUSES ON FUSION

The most striking initiative, however, involves ChatGPT itself, or rather, the company behind it, OpenAI. It is partnering with Helion, one of the most prominent start-ups in nuclear fusion—a challenging technology that mimics the sun's energy-producing process on Earth and, unlike nuclear fission, does not produce hazardous waste. The decision to explore nuclear fusion reflects the urgent need for reliable energy supplies while also honoring commitments to reduce emissions. By pursuing groundbreaking innovations like fusion, this collaboration underscores the role that advanced technologies—both human and artificial—will play in the energy transition. While the expectations for fusion are immense, they remain unproven, but that is a story yet to unfold.

we

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He is Chairman and co-founder of Nomisma Energia, an independent research company in Bologna that deals with energy and environmental issues.
He has always worked as a consultant for the energy sector in Italy and abroad, dealing with all the major aspects of this market.

SUPERCOMPUTERS

by Giuseppe F. Italiano

PROCESSING LARGE AMOUNTS OF DATA WITH MACHINE LEARNING ALGORITHMS HAS LED TO AN INCREASING DEMAND FOR COMPUTING POWER. HIGH PERFORMANCE COMPUTING IS A STRATEGIC RESOURCE WITH APPLICATIONS IN COUNTLESS SECTORS

HUMANITY GENERATES tens of zettabytes (trillions of gigabytes) of data annually. Within a few years—when 150 billion new "smart" devices are connected to the Internet—this figure is expected to rise to several yottabytes, surpassing even the Avogadro constant (which represents the number of particles—atoms, molecules, or ions—in a mole). In this context, artificial intelligence—particularly machine learning, with its remarkable advances in recent decades—appears to be the only viable tool for analyzing and extracting value from such vast data volumes. Machine learning technologies are now crucial at every stage of big data analysis, from identifying patterns in the data (information), to detecting correlations between those patterns

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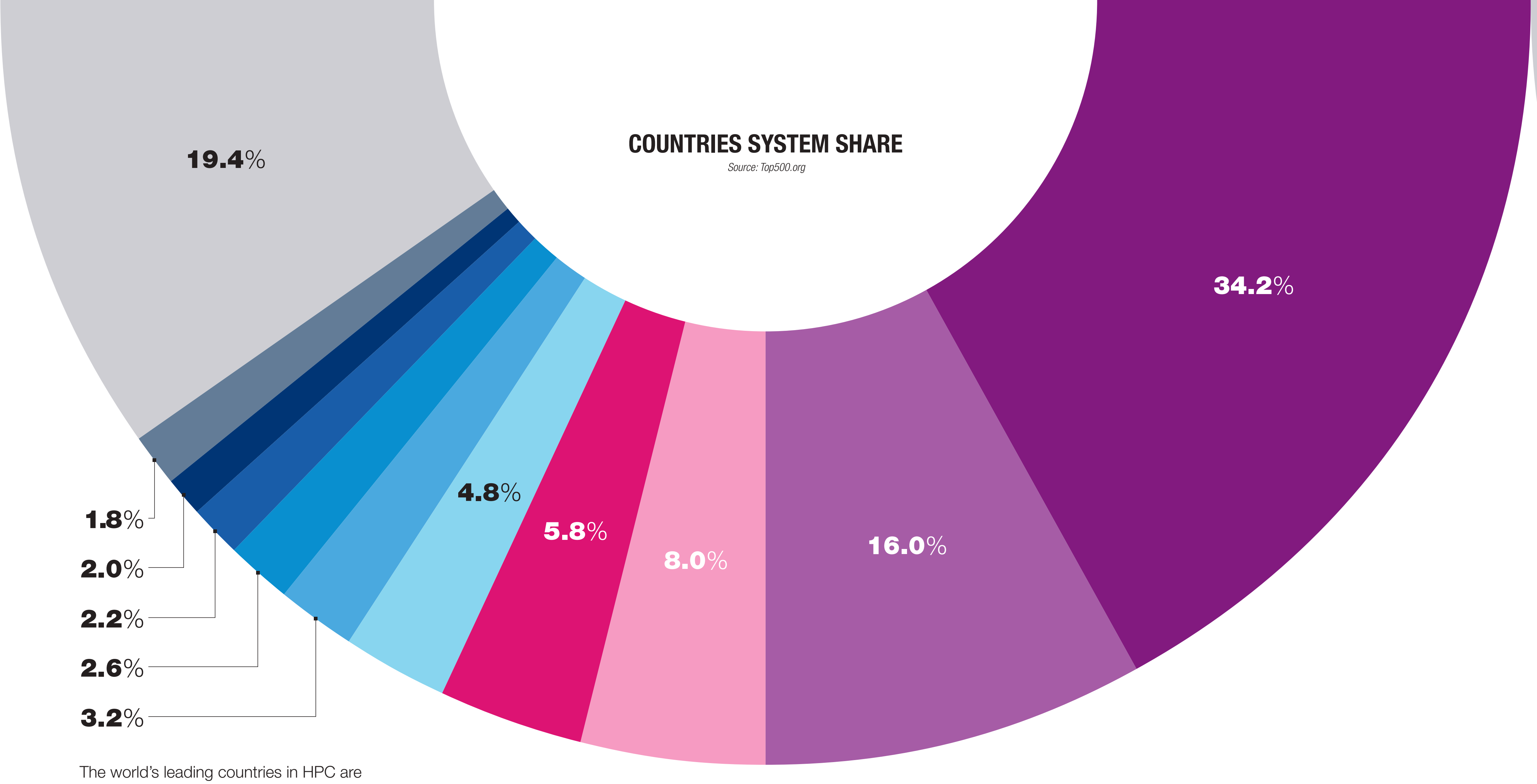


The world's leading countries in HPC are the United States and China, with 171 (34.2%) and 80 (16%) installations each. The US is also home to many of the world's most powerful HPC systems today, with a share of global computational capacity (in FLOP/s) of 53.7%. The second country in terms of performance is Japan.

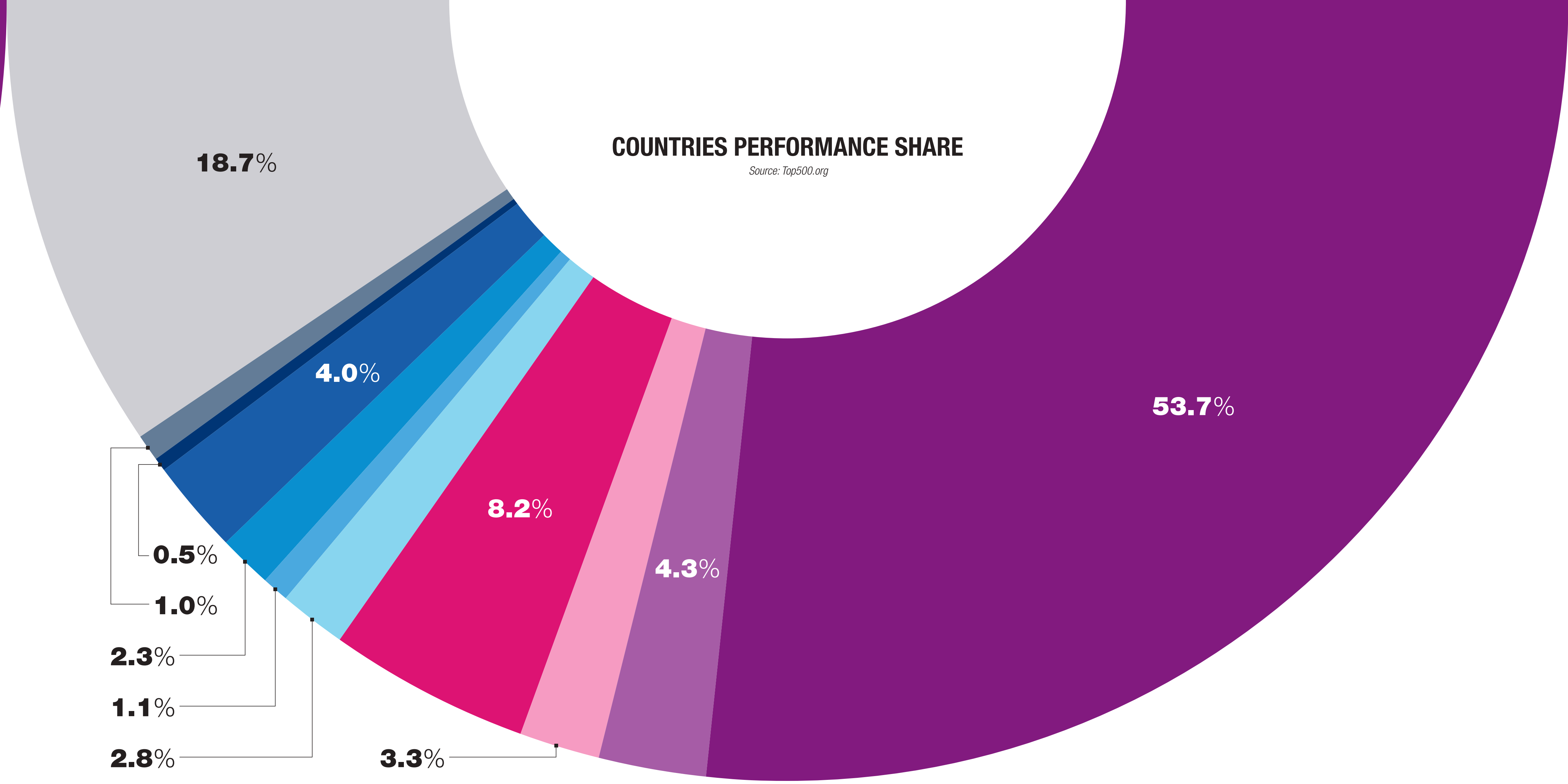
(knowledge), to building mathematical models that represent the data, and finally, developing predictive algorithms that align with these models.

The processing of large amounts of data with machine learning algorithms has driven an increasing demand for computing power. Since 2012, the computing power used during the training phases of machine learning algorithms has grown exponentially, with a doubling time of just 3.4 months. For comparison, Moore's Law predicts a doubling time of 2 years. To put this in perspective, computational usage has increased by more than 300,000 times since 2012, whereas Moore's Law would have only resulted in a sevenfold increase. These advancements in processing power have been a critical factor in the progress of machine learning algorithms. As this trend continues, it is crucial to prepare for computing systems that far exceed current capabilities.

HIGH PERFORMANCE COMPUTING (HPC) TODAY

High Performance Computing (HPC) technologies, currently capable of operating at petaFLOPS scale, typically rely on parallel computing. Interest in HPC began in the 1960s, with early applications—particularly simulations—at U.S. universities and government agencies. Since then, advancements in hardware architectures and software tools have unlocked the potential of HPC systems for a wide range of applications. In recent years, new opportunities have emerged for applying HPC in business sectors far removed from its original contexts. Today, HPC is widely used in fields such as cybersecurity, biometrics, optimization, risk management, process improvement, behavioral prediction, and business model enhancement. Partly due to its broad applications in business, the global HPC market is experiencing rapid growth, now exceeding USD 40 billion, with further expansion anticipated.

One example of HPC applications in business is PayPal, which uses an HPC cluster to identify fraud and suspicious behavior patterns in real time, quickly develop new anti-fraud models, and extract insights from the continuous data flow recorded on its systems. PayPal achieves this by correlating data from many disparate sources, allowing the company to make timely business interventions. Specifically, the HPC cluster's computing speed enables PayPal to process and correlate data from thousands of sources—handling approximately 3 million events per second—to generate real-time insights. The cluster analyzes application logs, operational data, environmental data, and social media activity, processing data flows of 25 terabytes per hour from thousands of servers, including trends from social



media and customer interactions. HPC enables PayPal to detect patterns and anomalies, allowing the company to take immediate action before any negative impact on users occurs.

In a different business segment, Eni utilizes HPC in its upstream activities to enhance hydrocarbon exploration and improve reservoir modeling during production, as well as to strengthen prediction and simulation capabilities. To achieve these goals, Eni operates two HPC systems with a combined peak computing capacity of 52 PetaFLOP/s, integrating numerical simulation with machine learning techniques, particularly deep learning. The power of these HPC systems has allowed Eni to significantly reduce the time needed to reconstruct subsurface models—from several months to just days or even hours. Additionally, the introduction of HPC systems has halved the time required to begin production, reducing it from 9 years to 4.5 years.

As of June 2024, the United States and China lead the world in HPC installations, with 171 and 80 systems, respectively. Italy ranks eighth globally, with 11 installations. The majority of the world's most powerful HPC systems are located in the U.S., including the top three: Frontier at Oak Ridge National Laboratory, Aurora at Argonne National Laboratory, and Eagle by Microsoft Azure. In the European Union, Italy ranks third in computing power, behind Germany and France, and has three systems in the global top 100: Cineca's Leonardo, in seventh place, and Eni's HPC5 and HPC4, in twenty-fourth and eighty-first places, respectively. Compared to other regions, Italy stands out for its extensive use of HPC in industry.

LOOKING TO THE FUTURE

In the near future, the introduction of new HPC systems is expected, such as HPC6, recently announced by Eni, which will have a peak power of over 600 PetaFLOP/s. Additionally, two emerging technology trends are likely to have a significant impact on HPC in the near future: the interactions between HPC and quantum computing, and between HPC and cloud computing.

Quantum computing is based on quantum theory, with one of its most intriguing computational aspects being the quantum bit (Qubit), which can exist in two states simultaneously due to the superposition principle of quantum physics. Unlike traditional computing, quantum computing's power doesn't rely on higher clock speeds but on its ability to handle exponentially larger datasets. Given the current limitations of quantum computing and the ongoing evolution of HPC, hybrid systems are likely in the near term. These systems will combine tradi-

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Artificial intelligence is transforming gaming: advanced AI algorithms enable more realistic interactions and more complex game worlds. Additionally, AI is powering game development by accelerating testing and optimization.

In recent years, the main cloud computing providers have invested in global networks of massive-scale systems that are potentially very competitive with current HPC systems. Pictured: Cloud Gate, the famous work by Anish Kapoor, Chicago.

tional high-speed general-purpose processing (via HPC) with ultra-performance, use-case-specific processing (via quantum computing). Notably, the EuroHPC JU (European High Performance Computing Joint Undertaking) has funded the HPCQS (High-Performance Computer and Quantum Simulator hybrid) project, which aims to integrate quantum and traditional HPC technologies by incorporating quantum simulators into existing European supercomputers. This will be a globally unique incubator for Quantum-HPC hybrid computing, unlocking new innovation potential and preparing Europe for the post-Exascale era.

In the near future, it will become important to consider the interactions between HPC and cloud computing. In recent years, major cloud providers have invested heavily in global networks of massive-scale systems that could become highly competitive with current HPC systems. As the computational demands of AI algorithms grow, today's cloud systems are increasingly built using custom chips and semiconductors. This trend could negatively impact HPC by reducing the financial leverage of traditional hardware and CPU vendors, which have historically played a key role in HPC development.

Will cloud providers become the dominant players in offering HPC-like services and applications? It's difficult to predict, but cloud architectures are already taking the lead in many fields, such as gaming and computer vision, and are reshaping how we think about high-performance computing. Building the next generation of HPC systems will likely require rethinking traditional approaches and focusing more on the success factors of cloud architectures, such as custom hardware configurations and large-scale prototyping.

One crucial point to consider: while HPC systems have traditionally relied on large financial investments from governments and research institutions, cloud systems generate substantial revenues. Is this model sustainable for HPC? This dynamic suggests that stronger collaborations between HPC and dominant players in the computing ecosystem, including cloud providers, may be necessary. It's no coincidence that the third most powerful HPC system in the world today is Microsoft Azure's Eagle supercomputer.

we

GIUSEPPE F. ITALIANO
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DRIVER FOR INNOVATION

by Lorenzo Fiorillo

SUPERCOMPUTING IS NO LONGER JUST NICE-TO-HAVE. THE ABILITY TO PROCESS DATA AT MASSIVE SCALE IS ESSENTIAL FOR COMPANIES OPERATING IN AN INCREASINGLY COMPLEX AND INTERCONNECTED WORLD

IN 1954, ENRICO FERMI wrote a letter to the rector of the University of Pisa with a request that seemed, at the time, futuristic: a new calculator to support studies in the field of physics.

The legendary intuition of this Italian scientist marked a dividing line between the world that had been and the world that would be. Seventy years on, we are immersed in a technological revolution that is pushing science into territories that only the power of supercomputing is able to explore.

In every sector—from physics to materials science, from energy to health—supercomputing has become an essential enabler of innovation.

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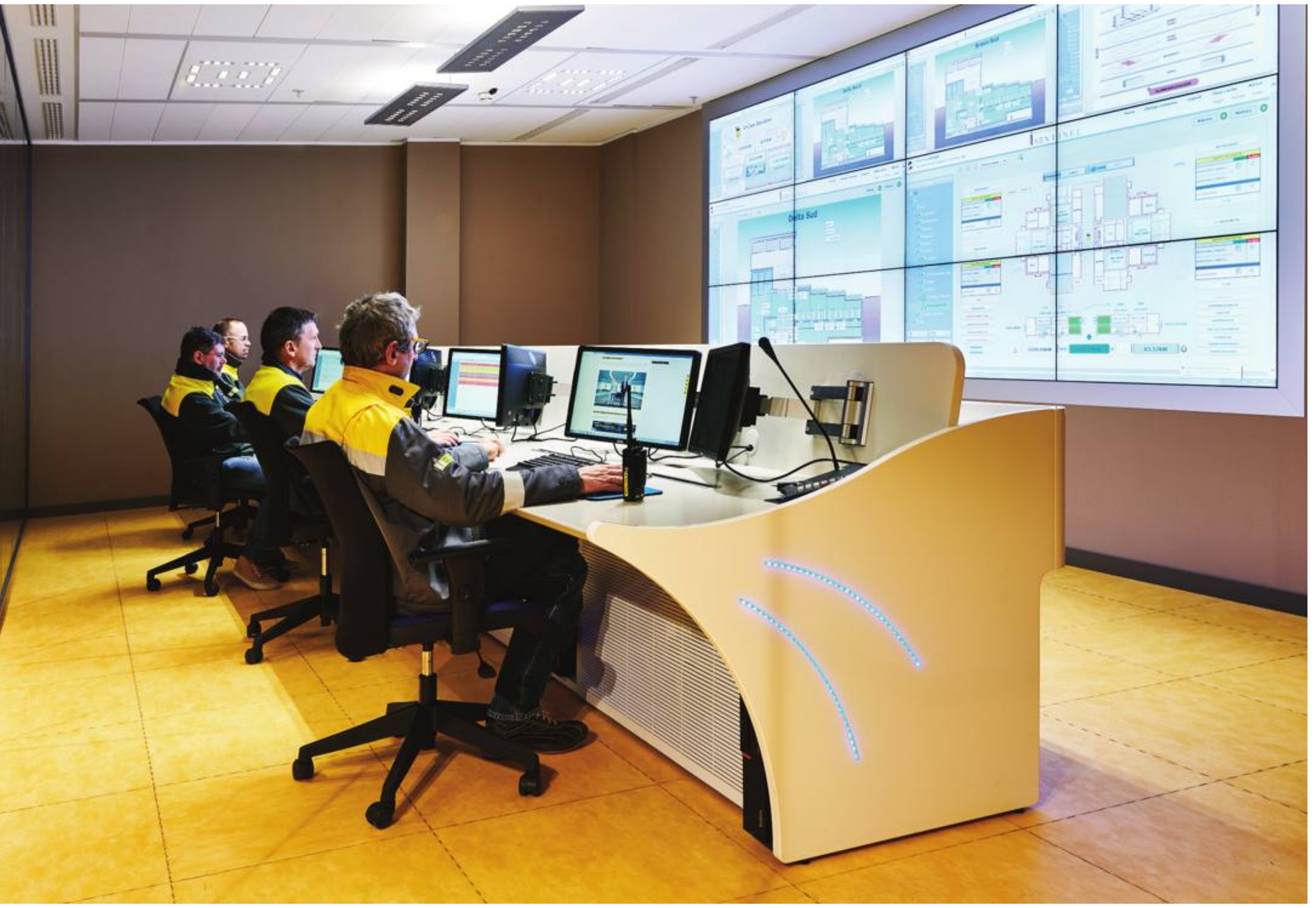
RESEARCH COMPLEXITY IN THE AGE OF SUPERCOMPUTING

In today's world, the complexity of the challenges we face and the urgency to bring innovative products and processes to market can no longer be tackled with traditional data processing systems. Whether it's developing new materials, researching future energy solutions, or advancing health technologies, we need the capability to simulate billions of parameters and variables, integrate vast datasets, and process information globally in mere fractions of a second. The energy transition, in particular, demands vast computational resources. For example, improving the efficiency of solar cells, developing higher-performance batteries, or simulating plasma behavior in future magnetic confinement fusion plants all require immense computing power. Since October 2022, when the first public release of ChatGPT "democratized" access to generative AI applications, it has become evident that supercomputing has yet another vital field of application.
The computational power needed to train and query the various large language models, whether for private or corporate use, is poised to become an increasingly significant factor in the overall demand for supercomputing resources.

THE CHALLENGE OF ENERGY EFFICIENCY

To paraphrase a famous comic book hero: with great power come great challenges. Supercomputers are remarkable machines, but their massive energy consumption is drawing growing public scrutiny. This issue is particularly significant for younger generations, who are highly attuned to environmental concerns, yet also the primary users in the digital era. The seemingly free access to services and applications often obscures the underlying technological complexity and the substantial resources required to sustain them.
The energy consumption of supercomputers like HPC6 is a much-debated topic. Estimates of both the current situation and future developments vary widely depending on the source, but the trend is unmistakable: the global energy consumption of supercomputers and the infrastructure that support them is expected to rise significantly in the coming years.
For instance, a single supercomputer can consume several megawatts of electricity—enough to power a small city. However, the total energy consumption of all supercomputers currently in use or projected for the near future is often compared to that of entire nations.
The challenge, then, is not only to build ever more powerful machines, but to make them more energy efficient as well. In this context, companies like Eni, which place innovation at the core of their strategy, must prioritize digital sustainability.
For Eni, this aspect was not only fundamental but foundational in the design and construction of its Green Data Center (GDC) in Ferrera Erbognone, near Pavia, in 2013. The facility houses Eni's supercomputers HPC4, HPC5, and the soon-to-be-operational HPC6.
The GDC stands as a model of excellence in combining advanced technology with environmental sustainability. From the outset, its primary goal has been not just operational efficiency, but also minimizing environmental impact, with sustainability at the core of its mission.
A key feature that sets the GDC apart is its focus on energy efficiency, measured using the PUE (Power Usage Effectiveness) indicator. PUE represents the ratio of a data center's total en-



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Eni's Green Data Center, in Ferrera Erbognone, is home to the HPC4, HPC4 and HPC6 supercomputers. It is one of the most energy efficient and lowest emitting computing centers in Europe: in addition to being powered in part by a 1MW photovoltaic system, for at least 92 percent of the year the machines are cooled by the circulation of low-speed air, thus minimizing the use of air conditioning.

For a company like Eni, which operates on a global scale, producing and using a very significant amount of data, supercomputing is not just a strategic choice, but an operational necessity. Pictured: engineers at work with the supercomputer.

ergy consumption to the energy used specifically for powering its IT systems, such as servers, storage, and networking devices. A PUE of 1.0 represents the maximum theoretical efficiency, meaning that all the energy consumed is used solely to power the IT systems, with no waste. The latest certified PUE value for Eni's GDC, recorded in 2023, is 1.172—an extraordinary result that ranks the facility among the most efficient in Europe. This achievement is the result of several innovative solutions that optimize cooling and energy management, including the use of an air convection cooling system ("free cooling") and the integration of a solar park that helps power the GDC.

The introduction of HPC6 at the GDC marks a further advancement in the supporting systems, including the adoption of a new liquid cooling system, all with the goal of maximizing overall energy efficiency.

SUPERCOMPUTING AT ENI: A PRECIOUS RESOURCE

Given its costs and energy demands, it's important to consider the value that the HPC family can offer. For a global company like Eni, which produces and processes vast amounts of data, supercomputing is not just a strategic choice—it's an operational necessity.

Every exploration activity, decarbonization project, and study of new energy sources both generates and requires vast amounts of data. Without the power of machines like HPC6, transforming this data into actionable insights for our business and our decarbonization strategy would be impossible.

By rapidly processing vast amounts of data, digital tools—particularly supercomputing—enable and accelerate innovation across a wide range of areas and processes within our organization.

DATA QUALITY AND ROBUSTNESS

In the world of supercomputing, access to vast amounts of data is not enough; the data must also be robust and of high quality. As the old computer science adage goes: "garbage in, garbage out." Poor-quality, incomplete, or untraceable data not only makes simulations and analyses useless but can also lead to faulty decisions.

For Eni, where operations rely on precise information, ensuring data quality is essential. From the sensors monitoring our offshore fields to the systems analyzing our bio-refining processes, robust data forms the foundation of every decision we make, both operational and strategic.

For this reason, we have implemented—and continually refine—systems and processes that enforce a strong data policy. These cutting-edge applications "federate" and validate data in a transversal way, making it accessible and usable across different professional teams. This ensures that decisions are based on solid, verifiable knowledge.

The importance of data quality extends beyond numerical data. A large company like ours also holds vast amounts of textual information, which today's AI tools allow us to search and analyze. This enables us to quickly extract insights, suggestions, and solutions from past issues that remain relevant. All of this is made possible by unstructured and distributed knowledge management software.

Here too, it's essential to carefully validate and systematize input data to ensure that the output can be trusted. At Eni, we are committed to fostering a "data culture" at all levels, so we can increasingly rely on this valuable resource with greater efficiency and security.

ALGORITHMS: THE REAL DRIVER OF SUPERCOMPUTING

If data is the fuel and computing power is the engine, then algorithms are the drivers. It's the algorithms that transform data into useful energy, and they do so thanks to the skills and talent of the people who design them. Without advanced algorithms, HPC6 would be like a Formula 1 car without a skilled driver.

Over time, and thanks to the expertise of our team, we have built a strong capability in developing proprietary software that fully harnesses the power of the HPC machines.

Thanks to these algorithms—and the programs that translate them into instructions optimized for our massively parallel computing systems—we can model gas deposits with extreme

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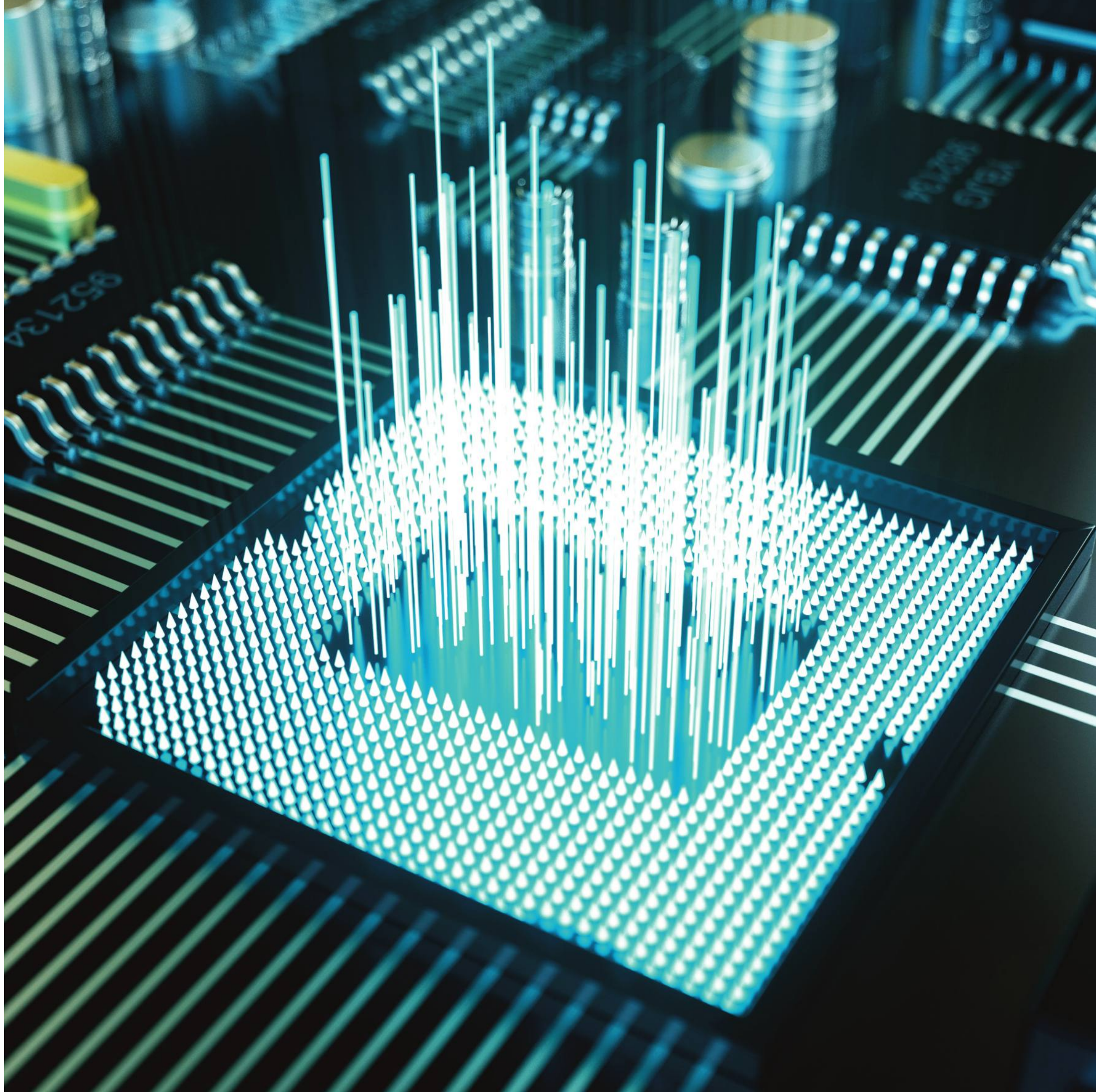


precision, optimize our operations for energy efficiency and safety, and explore and validate new technologies for producing energy from renewable sources and breakthroughs like magnetic confinement fusion.
True strength lies not only in the sheer power of the supercomputer (even when, like Eni's, it ranks among the best in the world) but in the ability to fully harness it through intelligent guidance.

THE FUTURE: HPC6 AND QUANTUM COMPUTING

In the supercomputer ecosystem, time flies. The Top 500 ranking, which lists the 500 most powerful supercomputers in the world, is updated every six months. Due to new entries or updates, the top 10 are in constant churn.
We must make the most of the machines we have, while also considering how to take advantage of the ongoing improvements in computational power, efficiency, and integration that technological progress continues to unlock.
With the launch of HPC6, which will soon replace HPC4 and HPC5 (in operation since January 2018 and January 2020, respectively), Eni's computing power is expected to increase nearly tenfold, from around 70 to approximately 600 petaFLOP/s at peak performance.
HPC6 will support the next phase of our innovation process and, in particular, enable us to tackle the challenges of achieving carbon neutrality, serving as a crucial technological tool in the development of new energy solutions.
As part of our commitment to the energy transition, we are also launching significant quantum computing applications through Eniquantic, the joint venture with ITQuanta established last July. With Eniquantic, we are solidifying our position at the forefront of supercomputing, particularly in this exciting and potentially transformative field.
Although still in its early stages, quantum technology has the potential to completely revolutionize research and development in critical sectors such as energy and materials. With its ability to process an unimaginable number of states simultaneously, quantum computing could solve problems that would take even the most powerful traditional supercomputers years to address.
A recent study on the profit potential of quantum computers highlights the significance of adopting quantum-hybrid solutions to maximize return on investment in this field. According to the study, such solutions "harness the power of both quantum and classical computers, reducing environmental noise and costs compared to pure quantum systems. As a result, they offer an immediate commercial quantum solution for enterprises at a lower cost, even before pure quantum computers are fully commercialized."
What's happening in the automotive sector with hybrid vehicles pioneering the way ahead of fully electric ones could also

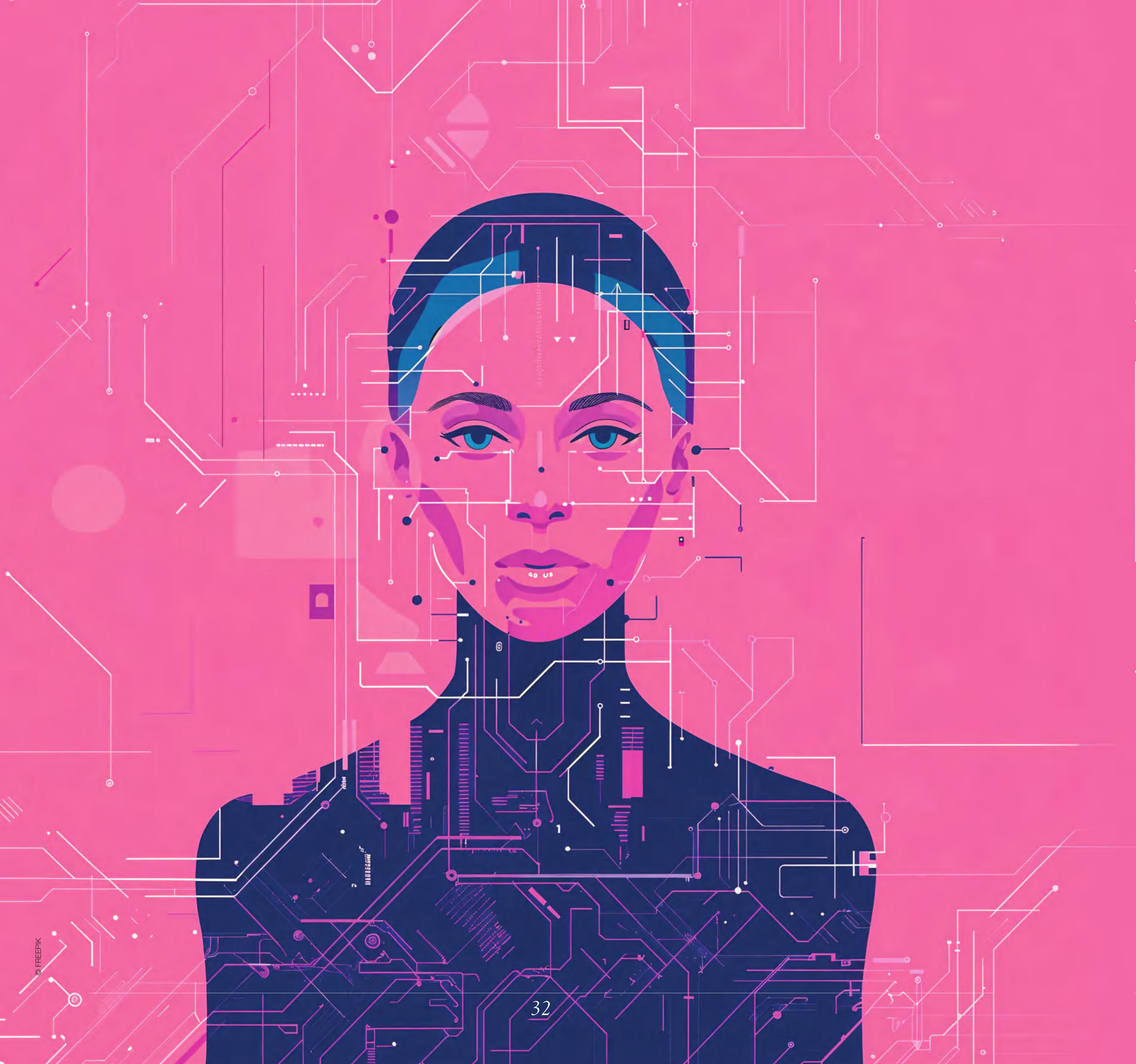
apply to quantum computing. In a field as cutting-edge as quantum technology, having both powerful traditional supercomputing capabilities and quantum expertise (and future quantum machines) within the same organization opens up new possibilities. At Eni, we are cautiously exploring these paths, fully aware of the complexities involved, but also the potentially revolutionary applications they could unlock.
For us, the concept of hybridization in supercomputing is not new; Eni was in fact among the first companies in the world (in 2014, with the HPC2 supercomputer) to recognize the importance of combining CPUs and GPUs in a hybrid configuration, in order to maximize the computational performance and energy efficiency of HPC6. This is a technical approach that, as we know, has now become so well-established in the world as to be paradigmatic, and is behind the fortune of some companies originally specialized in graphics cards for video games.

QUANTUM COMPUTING ON THE HORIZON

From Enrico Fermi's insight into the need for computing power in physics to the evolution of supercomputing at Eni, the journey has been remarkable. Today, supercomputing is no longer a mere accessory—it is a central pillar of innovation. For companies like ours, operating in an increasingly complex and interconnected world, the ability to process data on a massive scale has become—and will continue to be—indispensable.
With HPC6 and quantum computing on the horizon, Eni not only continues to push the boundaries of technology but also reaffirms its role as a visionary leader in a sector where the future of energy and innovation depends on the power of supercomputing.
Moore's Law[1] may not last forever, but our ability to innovate will remain a defining feature of our commitment and mission.

[1] Moore's Law is (an) "empirical law that describes the development of microelectronics, starting from the beginning of the 1970s, with a substantially exponential, therefore extraordinary, progression; the law was enunciated for the first time in 1965 by Gordon Moore, one of the founders of INTEL and pioneers of microelectronics, who reaffirmed it publicly in 1974. It states that the complexity of microcircuits (…) doubles periodically, with the period originally foreseen at 12 months, extended to 2 years towards the end of the 1970s and, since the beginning of the 1980s, settling at 18 months.(…)" (Treccani Encyclopedia).

LORENZO FIORILLO
Director of Technology, R&D & Digital at Eni since May 2024. Since joining Eni back in 1999, Fiorillo has held various roles of responsibility in Italy and abroad during his career, including Operations & Energy Efficiency Manager in the Natural Resources General Department.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THE CHALLENGE IS TO DEVELOP AI THAT IS NOT ONLY POWERFUL AND EFFICIENT, BUT ALSO FAIR, TRANSPARENT AND ALIGNED WITH OUR VALUES

ETHICS

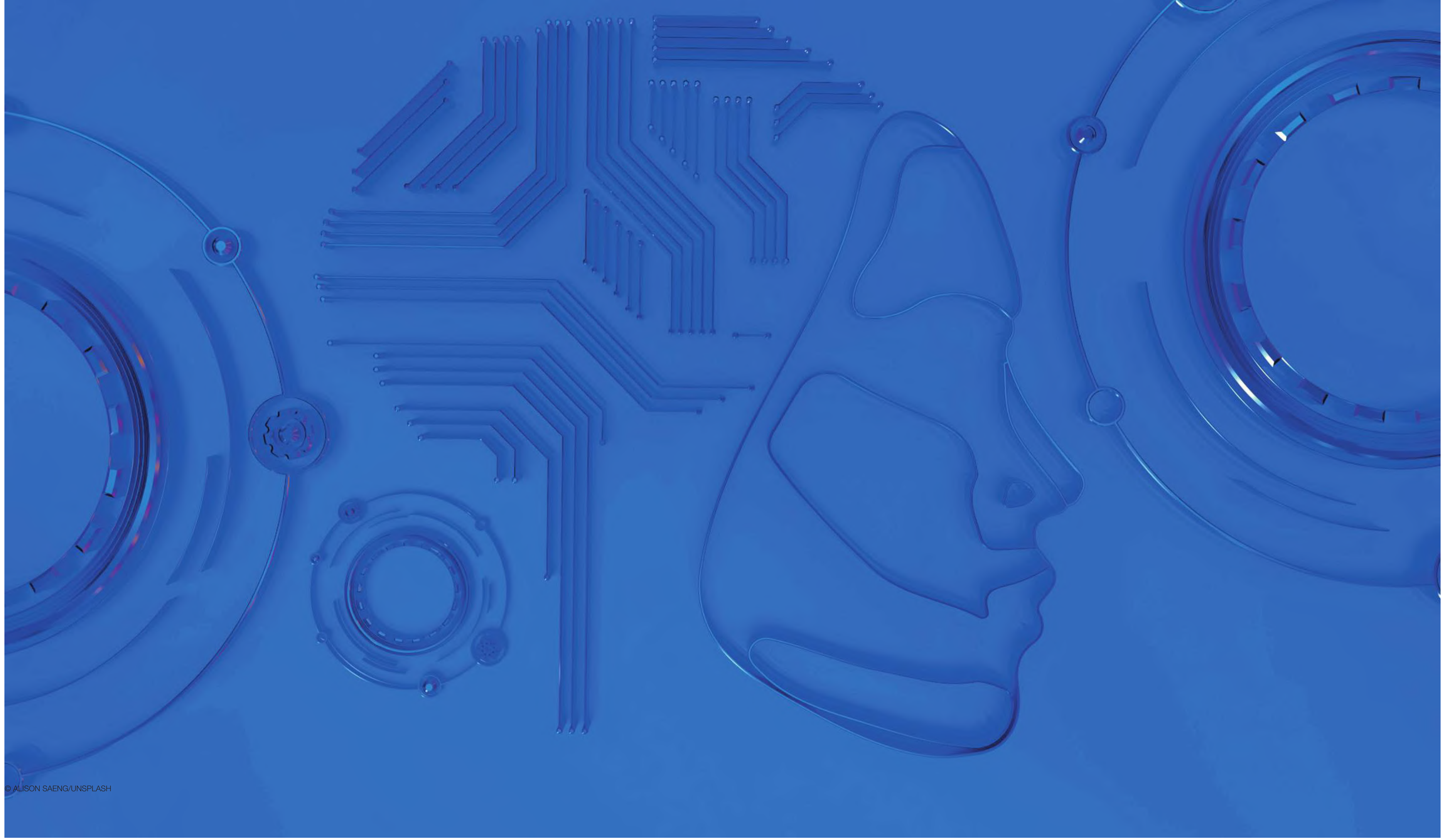
by Massimo Lapucci

A guide, not a hurdle

IN THE FAST-CHANGING technological landscape of the 21st century, digital ethics and artificial intelligence (AI) have emerged as pivotal issues shaping our collective future. These interconnected fields raise fundamental questions about human-machine interaction, the boundaries of automation, and the ethical responsibilities tied to technological advancement. In this article, we will explore the key challenges and opportunities that arise at the intersection of digital ethics and AI.

THE IMPORTANCE OF MORAL PRINCIPLES IN THE DIGITAL WORLD

Digital ethics focuses on the moral principles and norms that guide behavior in the digital world. With the rise of AI, digital ethics has taken on even greater significance. AI's ability to process vast amounts of data and make autonomous decisions raises complex ethical questions that demand careful consideration. Several issues, in particular, have emerged as enduring ethical challenges, including:



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- Privacy and data protection: AI requires large amounts of data to be effective. This raises concerns about the collection, storage and use of personal data.
- Bias and discrimination: if not carefully designed and trained, AI algorithms can perpetuate or even amplify existing biases.
- Transparency and 'explainability': many AI systems still operate as 'black boxes', making it difficult to understand how their decision-taking process actually develops and how they reach a final decision.
- Responsibility and accountability: when an AI system makes a mistake, who is responsible? Such questions become particularly critical in sectors such as healthcare and the justice system.
- Impact on the world of work: AI-driven automation is transforming the job market, often giving rise to talk of 'technological unemployment,' even if the public discourse should focus on the need for reskilling and rapid retraining.

OPPORTUNITIES IN ETHICS INTEGRATION

Integrating ethics into artificial intelligence is both one of the greatest challenges and most promising opportunities of our time. As AI continues to evolve and permeate more areas of daily life, it is crucial to consider not only its technical capabilities but also the ethical implications of its use. This integration offers the chance to create AI systems that are not only efficient and powerful but also responsible and fair. The real opportunity lies in shaping a future where technology enhances human capabilities without compromising fundamental ethical principles, ensuring that AI becomes a tool for social progress and collective well-being, primarily by:

- Improving the quality of life: ethically designed and guided AI can significantly improve quality of life, from personalized healthcare to optimized urban transport. In the environmental field in particular, AI technologies can help monitor and manage natural resources, but their development and use require very careful consideration. For example, mining the materials to power AI can damage fragile ecosystems, while energy-intensive data centers generate high carbon emissions.
- Promoting equity: through AI systems designed, for example, to help identify and mitigate social inequalities. It is essential, in this sense, that AI development policies incorporate principles of equity and sustainability. Only in this way can we ensure that these innovations foster technological progress, while also contributing to a more just society and a healthier environment.
- Strengthening scientific research: AI has the potential to accelerate research in critical fields such as medicine and climate science, leading to discoveries that can benefit society as a whole.
- Improving safety: 'ethical' AI systems can improve safety in various sectors, from cybersecurity to road safety.
- Facilitating accessibility: AI can make technology more accessible to people with disabilities, promoting digital inclusion.

TOWARDS ETHICAL GUIDELINES

To address the challenges and seize the opportunities of AI ethically, a multifaceted approach is essential. As a society, we must acknowledge that AI is rapidly becoming an integral part of our daily lives, influencing sectors from healthcare and education to commerce and security. This rapid technological progress brings significant ethical responsibilities. It is crucial that AI development and implementation respect human rights, promote fairness, and protect privacy. Achieving this requires collaboration between governments, tech companies, academics, and civil society to create robust ethical guidelines and effective oversight mechanisms.

Additionally, we must develop comprehensive public education initiatives on AI—supported by dedicated financial resources—so that people can understand both the benefits and potential risks of this technology. It is equally important to promote diversity and inclusion within the AI field, ensuring that systems are designed to serve all communities equitably. As AI continues to evolve, we must remain vigilant and adaptable, constantly reassessing and refining our ethical frameworks. Only through these collective efforts can we create a future where AI is a tool for human progress, guided by sound ethical prin-

The integration of ethics into Artificial Intelligence is one of the most significant challenges and at the same time one of the most promising opportunities of our time. As AI continues to evolve and permeate more and more areas of our daily lives, it is crucial for us to consider not only its technical capabilities, but also the ethical implications of its use.

ciples and core human values. Certain aspects, in particular, merit special attention, such as:

- Education and awareness

It is crucial to educate not only AI developers but also the public at large about the ethical implications of AI. This includes promoting digital literacy and fostering an understanding of the basic principles of AI.

- Regulation and governance

We need to develop regulatory frameworks that strike a balance between fostering innovation and protecting individual rights and the social good. These frameworks must be flexible enough to adapt to rapid technological advancements, avoiding excessive particularisms that could quickly render them obsolete.

- Ethical design

Ethics must be integrated into the AI design process from the start—not as an afterthought or, worse, a later imposition. This includes adopting principles such as privacy by design and algorithmic fairness.

Privacy by design means that personal data protection is embedded in the development process of a system or application from the outset. This approach ensures that privacy is a fundamental element, not an afterthought. It involves designing systems that minimize data collection, securely manage information, and respect user privacy.

Algorithmic fairness refers to the need to ensure that AI algorithms do not perpetuate or amplify existing inequalities or biases. It requires critically analyzing the data used to ensure that the algorithms are representative and non-discriminatory. The goal of algorithmic fairness is to promote impartial outcomes, ensuring that AI-based decisions do not disadvantage vulnerable or marginalized groups, thus contributing to the ethical and responsible use of technology.

- Interdisciplinary collaboration

The complexity of the ethical questions raised by AI requires collaboration across disciplines, including computer science, philosophy, law, sociology and psychology.

- Transparency and accountability

Companies and organizations developing and implementing AI systems must be transparent about their processes and take responsibility for the consequences of their technologies. At the Yale University Digital Ethics Center, our mission is to address these challenges and opportunities through continuous interdisciplinary research on digital ethics, with a particular focus on artificial intelligence. Our research primarily centers on key areas such as:

- AI ethics: understood as the ethical implications of the development and implementation of AI.
- Data governance: through the exploration of ethical models for the management and use of data.
- Social impact of technology: by analyzing how digital technologies can influence society as a whole and how they can be designed to promote the common good.
- Ethics of innovation: through the study of ethical approaches to technological innovation, balancing progress and social responsibility.

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Digital ethics and artificial intelligence are rapidly evolving fields of study and practice, presenting both significant challenges and extraordinary opportunities. The work of the Yale Digital Ethics Center aims to serve as a vital tool for navigating this complex landscape. As we move toward an increasingly digital and automated future, it is crucial to maintain a balance between technological progress and fundamental human values. Ethics should not be seen as a barrier to innovation, but as a guide to creating technologies that truly enhance the human condition. The challenge ahead is to develop AI that is not only powerful and efficient, but also fair, transparent, and aligned with our ethical values. Achieving this will require a continuous, collaborative effort from researchers, developers, policymakers, and civil society.

Digital ethics throughout the 21st century will be shaped by the choices we make today. We have both the opportunity and responsibility to guide technological development in a way that promotes the common good, respects human dignity, and contributes to a more equitable and sustainable world.

The Yale Digital Ethics Center, with its interdisciplinary approach and commitment to cutting-edge research, plays a crucial role in this mission. By exploring the complex intersections of technology and ethics, the center helps train a new generation of leaders and citizens who are empowered to address the ethical challenges of our digital age.

Looking ahead, it is clear that digital ethics and AI will remain central topics in public and academic discourse. Our ability to navigate these complexities will not only determine the success of technological innovation but also the quality of the society we build for future generations.

MASSIMO LAPUCCI

He is an International Fellow at the Digital Ethics Center at Yale University. He previously worked as Secretary-General of the Fondazione CRT and Managing Director of OGR Turin.

AI is rapidly becoming an integral part of our daily lives, impacting sectors ranging from healthcare to education, trade and security. It is essential that we know how to develop and implement AI in a way that respects human rights, promotes fairness, and safeguards privacy.

Alisa Martynova is a documentary photographer. She has worked on several contemporary stories, such as African migration in Europe and the intricate relationship between people and new technologies. Rejecting direct approaches to storytelling, she uses photography as a tool to create parallel worlds and translating reality into the language of symbols, that she extracts from existing stories she subjects to meticulous research. She has received awards such as Canon Young Photographers award (2019), the World Press Photo award in Portraits Series section (2021), the UNSTUCK award from the Magenta Foundation (2022), theQUE LensCulture Emerging Talent award (2023) and the Royal Photographic Society Documentary photography award (2023).
Her work was exhibited in the festivals and galleries all over the world. Her work is published by Internazionale, D-Repubblica, Leica Fotografie International, Fisheye magazine and 20er magazine.

ANIMA

PHOTOGALLERY
BY **ALISA MARTYNOVA**

I am fascinated by the universal themes of evolution, creation, time, and space.
The emergence and rapid evolution of technology contributes to the creation of a parallel universe, perfectly real and almost as tangible as the one we have always lived in.

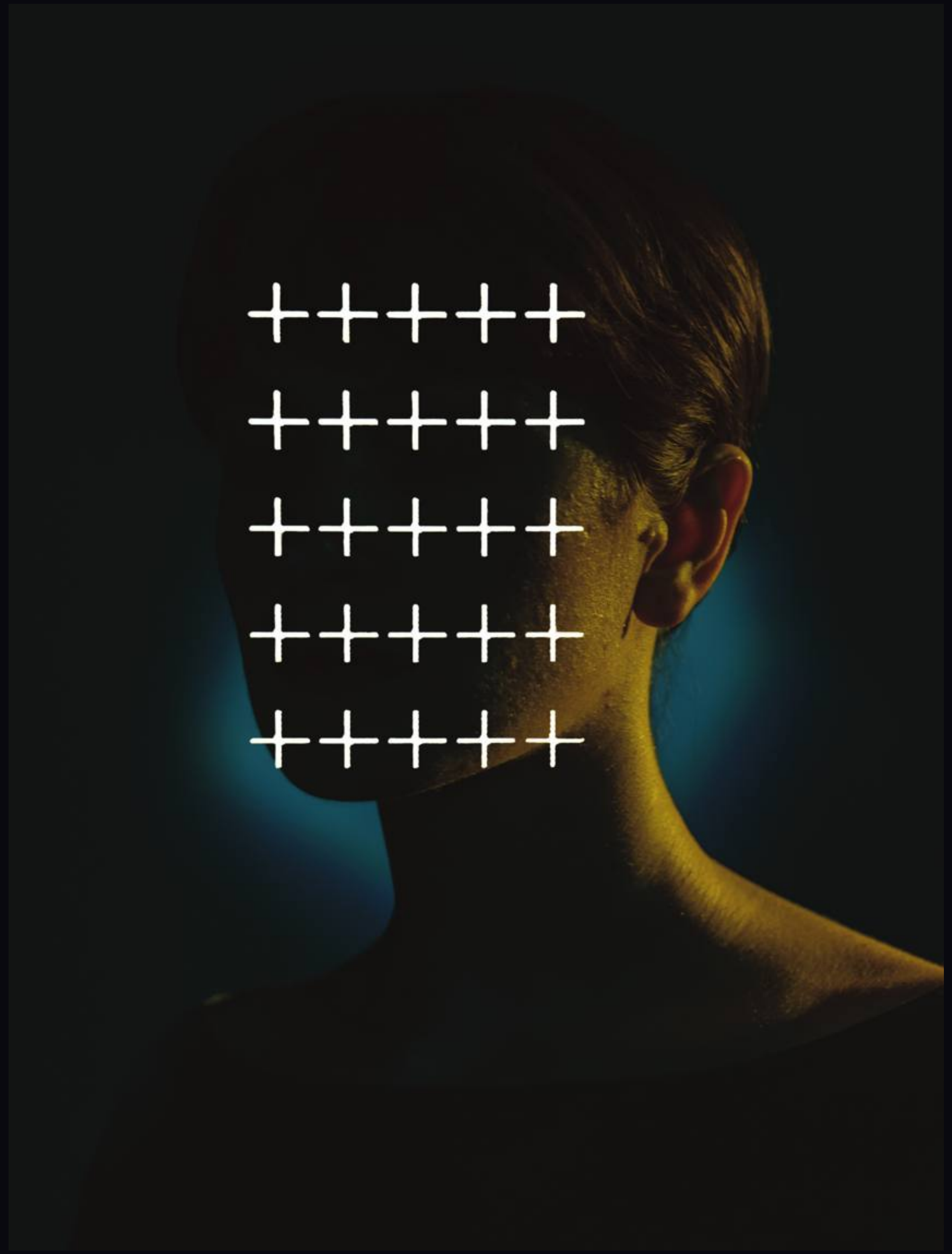
Technology was created by humans. It almost revives the biblical creation myth. But there is no longer an omnipotent and detached creator. The creator is influenced by his creature and vice versa. They are co-creating each other.

“In our time,
a mythical time,
we are all chimeras,
manufactured hybrids
of machine and
organism, in short,
cyborgs.”

[DONNA HARRAWAY,
“CYBORG MANIFESTO”, 1985].

We always thought of machines as cold and linear. Humans, on the other hand, were perceived as emotional and fragile living beings. The advancement of technology and the invention of artificial intelligences have blurred these differences.

We wonder what makes us human. We possess consciousness, but what is consciousness? Is consciousness so different from a program? When I asked Chat GPT to come up with a visual metaphor for the interconnection between human and artificial intelligence, the answer he gave me was ‘Eclipse’.



Intelligent machines are more like mirrors than minds: fractal surfaces within which our words, actions and dreams endlessly reconfigure. Can technology be a key to understanding humanity? Or only the part of humanity that has access to technology?

"Anima" is a visual journey into the intangible and ever-changing cyberspace inhabited and nurtured by its creatures. It is an illusion of digital reality, suggesting that even our reality is ephemeral, subjective and, in essence, does not exist except in our minds.

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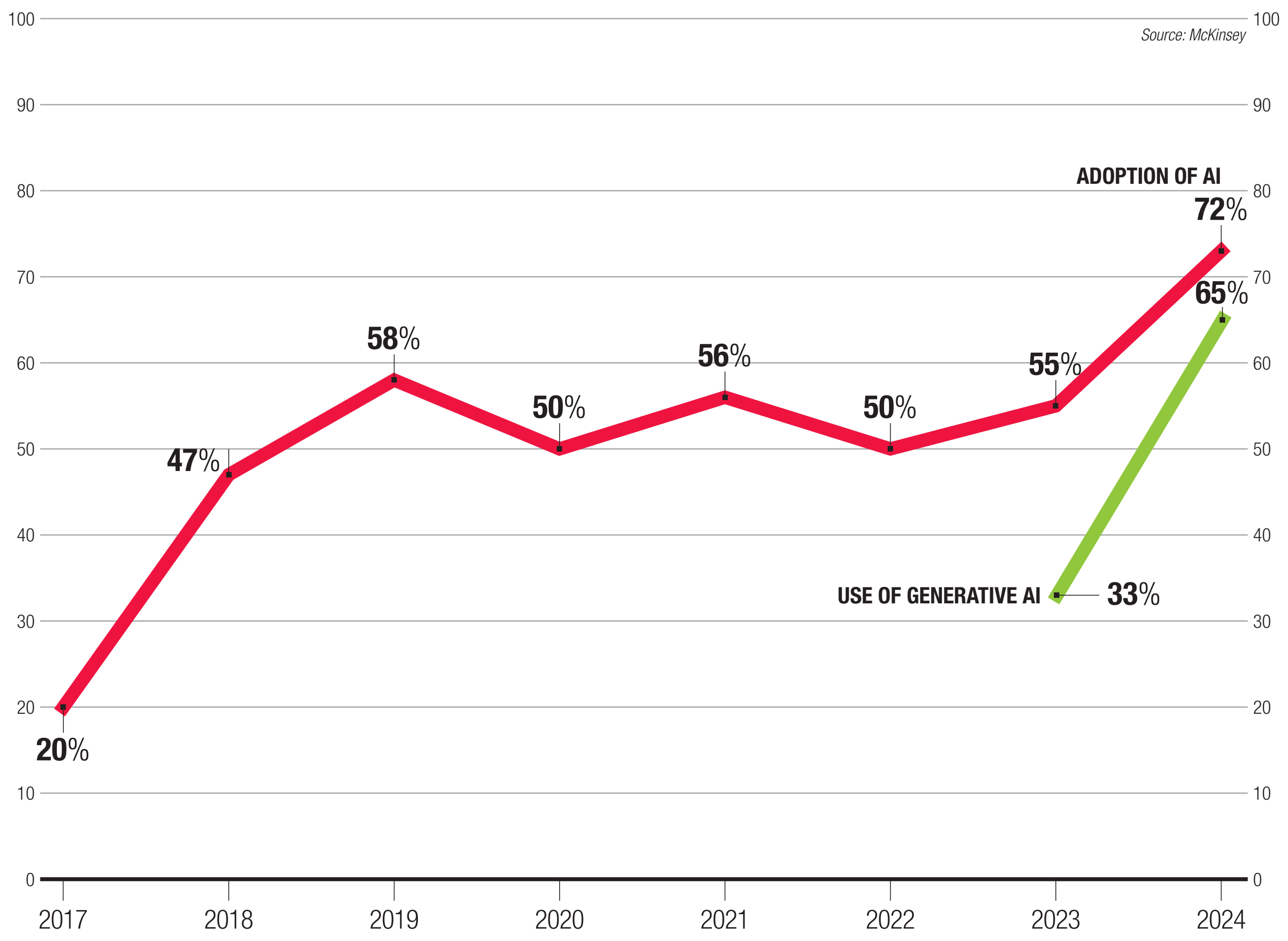
REVOLUTION

by Gianluigi Bonanomi

THE IMPACT OF ARTIFICIAL INTELLIGENCE HAS BEEN OVERWHELMING FROM THE START: THE STRENGTHS AND WEAKNESSES OF A DISCOVERY THAT IS CHANGING THE WORLD

CHATGPT SPARKED overwhelming curiosity when Open AI first released it at the end of 2022. For the first time, an artificial intelligence software was capable of holding a credible conversation in multiple languages with real people. Within five days, a million users began experimenting with it, asking it to perform tasks that, until the day before, were considered beyond a computer's reach: summarizing texts, providing quality translations, and explaining complex concepts in simple terms. And they also asked it to create video scripts, invent stories for children and adults, solve mathematical problems, and even write code in various programming languages.

ChatGPT captivated the public with its ease of use and extraordinary capabilities. However, 2022 was just at the beginning. Two years on, the system has evolved impressively: its "knowledge base," which initially cut off in 2021, has been updated, and it can now search for missing information. It has also become multimodal: it can "see" and generate images. It can be queried via voice, without typing. Its processing capabilities have improved, making it even more "intelligent." And this is just the beginning: according to Sam Altman, CEO of OpenAI, the company that developed it, ChatGPT 5, expected in 2025, will be an impressive leap forward: the new chatbot will be significantly more powerful than the current one ("100 times more powerful"). Moreover, OpenAI is no longer alone: other



ORGANIZATIONS AND THE USE OF AI

McKinsey's report on the state of artificial intelligence in early 2024 reveals that 72 percent of surveyed organizations have adopted the technology, compared to 55 percent in 2023. This figure includes traditional AI applications, such as predictive maintenance solutions widely used in manufacturing, and financial forecasting systems in the banking sector. When focusing solely on generative AI—primarily used in marketing—the current adoption rate stands at 65 percent, or nearly two out of three organizations, a significant figure nonetheless.

models have emerged in its wake, such as Claude by Anthropic (a company founded by two Italian-Americans who had left OpenAI), Gemini by Google (initially called Bard), and Copilot by Microsoft (based on OpenAI's model), just to name the best-known.

In a short time, AI has woven itself into the lives of millions, leaving a significant mark on the corporate world. Companies of all sizes are now experimenting with generative AI and integrating it into their processes.

However, alongside the excitement, doubts have surfaced about the quality, reliability, and potential impact of AI. Chief among these concerns is employment, with many jobs at risk of being replaced by AI. But the issues don't end there: AI is also being harnessed for more sinister purposes. Cybercriminals are leveraging it to enhance their attacks, crafting more convincing phishing schemes and designing malware that can slip past corporate security systems.

Beyond this, reckless use of AI could lead to societal shifts, enabling mass surveillance and the spread of invasive facial recognition technologies. It's no coincidence that the EU recently passed the AI Act, regulating the development and use of AI across Europe, even as the U.S. and China push ahead in technological advancements while we Europeans focus on regulation.

THE NUMBERS BEHIND AI

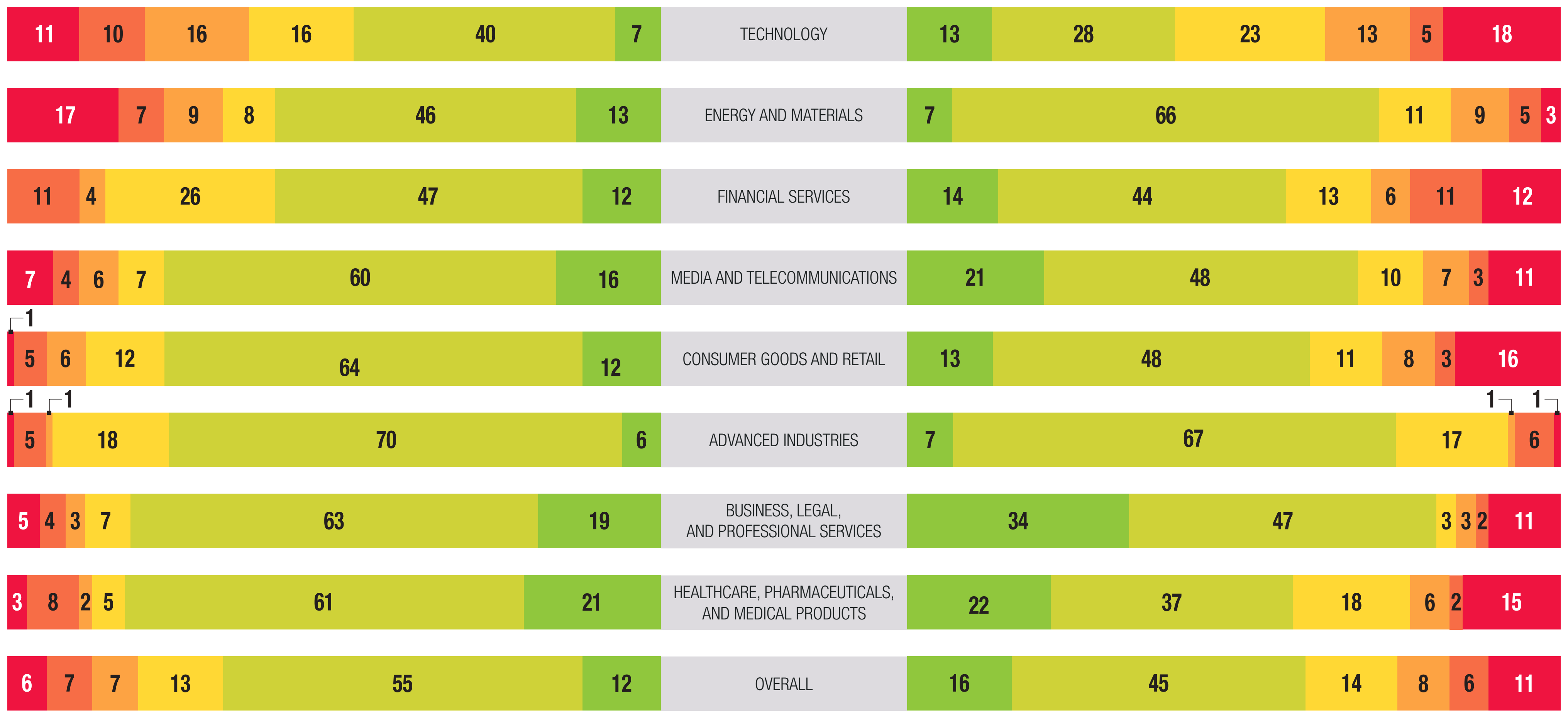
According to research by Microsoft and The European House - Ambrosetti, AI adoption could add EUR 312 billion to Italy's GDP—about 18.3 percent—without increasing working hours. This represents a long-awaited productivity boost. Alternatively, AI could free up 5.7 billion hours of labor, equal to the eight-hour workdays of about 3.2 million Italians. While Microsoft's investment in OpenAI (over EUR 13 billion) may make these figures seem overly optimistic, other studies also highlight global enthusiasm for AI, despite varying estimates. Bloomberg projects the generative AI market will reach USD 1.3 trillion by 2034, while Fortune estimates it at USD 2.74 trillion by that year.

But how many companies are actually adopting AI at this stage? The McKinsey report, *The State of AI in Early 2024: Gen AI Adoption Spikes and Starts to Generate Value*, shows that, globally, 72 percent of firms make some use of the technology. This is the proportion of companies that have embedded AI into at least one business function. However, the figure also includes an older vintage of AI applications, such as the predictive maintenance solutions widely used in manufacturing or financial forecasting systems in financial institutions. If we limit the analysis to generative AI, McKinsey reports current adoption at 65 percent, still a high figure. Marketing is the area where generative AI is most widely used, helping to create product listings, descriptions, and firms to create personalized online advertising campaigns quickly and inexpensively. Generative AI is highly valued in helpdesk and customer support: it excels at solving simple problems, so much so that many support companies have introduced AI into their call centers. In some of these call centers, AI supports human operators, while in others, it has almost entirely replaced them.

Over time, more extensive adoption is expected in other areas: human resources, to speed up candidate screening and automate workflows (although ATS, or Applicant Tracking Systems, have been in use for years), and in the development of new products. We already see AI embedded into numerous solutions for both B2B and B2C sectors: machine translation systems, AI-based video generators, cybersecurity solutions, and platforms for publishing content across multiple social networks.

RISKS AND BENEFITS OF A RAPIDLY EVOLVING TECHNOLOGY

Generative AI is best known for its edge in terms of efficiency and speed. Proper implementation increases productivity, certainly, yet this is not the only benefit to consider. In Western countries, the population is rapidly aging while birth rates are in decline. One result is a widening skills mismatch, making it difficult to align the supply of skills with the demand for labor. In practice, companies are looking for people with specific skills



(mainly in STEM, i.e., Science, Technology, Engineering, Mathematics), but these skills are scarce among candidates. The use of AI could help train professionals more quickly, as well as enhance existing reskilling and upskilling programs aimed at providing workers with the skills needed in today's professional landscape.

AI will undoubtedly have a significant impact on employment. Some jobs, like toll collectors, have disappeared entirely, and roles such as cashiers could follow. Other professions, like financial advisors, will be profoundly transformed by AI. The fear of being replaced is widespread—and justified. Data centers are feeling the pressure as companies begin laying off employees, citing AI as the reason. This is particularly evident in contact centers and industries like translation and localization, where AI's growing role has sparked protests. In entertainment, AI is now being used for dubbing, with companies training it on actors' voices, which has led to strikes. Once an AI is trained on a voice, the actor may no longer be needed. Actress Scarlett Johansson's case is particularly notable: she threatened OpenAI with legal action after it used a copy of her voice for ChatGPT. Ironically, Johansson starred in Her, a 2013 film exploring precisely human-AI interaction.

What's more, many technical roles, which are highly sought after today, might see their importance diminish. This is according to the leader NVIDIA, a company makes the chips that accelerate calculations for training and inferencing AI models and, with a valuation exceeding USD 2 billion, has become one of the most important companies in the world as a result. Its CEO, Jensen Huang has said that learning to program today could be a poor investment for the future. In his view, coding will be done entirely by AI within a few years. And programming likely will not be the only job impacted by this technology: even editorial content writing could be quickly replaced, and in some areas, this is already happening (after all, why pay even two euros for an article if you can get it for free?) Numerous news outlets and sports TV channels have long been using AI to write brief commentary articles on lower-tier sports leagues.

THE LIMITS OF AI AND THE RISK OF A BUBBLE

While generative AI is an impressive technology that can solve many kinds of problems and enhance productivity, yet it is not without significant limitations. A main concern is its propensity to hallucinate: current AI models too often generate nonsense. This can happen when generating text or even when summarizing content. Formally, the output generated is flawless, but the content is not always accurate. In some cases, AI literally invents information—referred to as hallucinations—

SHARE OF ORGANIZATION'S DIGITAL BUDGET SPENT ON GENERATIVE AI

In most sectors, organizations are almost as likely to invest more than 5 percent of their digital budgets in generative AI as in analytical AI (Graph 1). However, in most sectors, a larger share of respondents report that their organizations spend more than 20 percent on analytical AI compared to generative AI (Graph 2). Down the line, the majority of respondents (67 percent) expect their organizations to invest more in AI over the next three years.

> 20%
16 – 20%
11 – 15%
6 – 10%
≤ 5%
DON'T KNOW

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making its output unreliable. As a result, every generated text must be meticulously checked. Failing to do so could result in embarrassing situations, like that of Steve Schwartz, a U.S. attorney who decided to have ChatGPT draft documents for him. The AI fabricated a series of non-existent precedents, which seriously damaged the lawyer's credibility. To address this problem, more companies are turning to Retrieval-Augmented Generation (RAG) solutions, a technology that verifies AI output to ensure its accuracy. A (free) tool to test how AI works in this context? Check out Google's NotebookLM.

Another issue revolves around copyright. As of today, it is advisable for companies not to use public solutions like ChatGPT when working on confidential documents. The risk is that by feeding the AI these data, they may no longer remain confidential and could even be used to train the model itself, making them accessible to everyone. For this reason, those handling sensitive information should rely solely on proprietary solutions, developed in-house, and trained with their own data, to maintain full control over the information.

AI is still a developing technology, and a highly complex one. Simply purchasing software is not enough to embed it into processes. A long-term strategic approach is required. It is also essential not to get carried away by the hype: many hastily launched projects are doomed to fail. In fact, some big names have already made costly mistakes, like McDonald's with its AI assistant tested at some of the chain's drive-thrus. This is not unlike what happened with the internet: after the initial excitement, the dot-com bubble burst, overwhelming many companies. But in the medium to long term, those who adopted the right strategies reaped the rewards of their efforts.

we

GIANLUIGI BONANOMI

Gianluigi Bonanomi is a trainer and consultant on digital communication and generative AI. He is a journalist and has authored over 20 essays and guides on digital topics for publishers such as Mondadori, Hoepli, Franco Angeli, Editrice Bibliografica, and others, and he directs the Fai da tech series for Ledizioni. Currently, he focuses on training and events related to digital topics and generative Artificial Intelligence.

GLOBAL GOVERNANCE
THE CHALLENGE

by Ettore Greco and Francesca Maremonti

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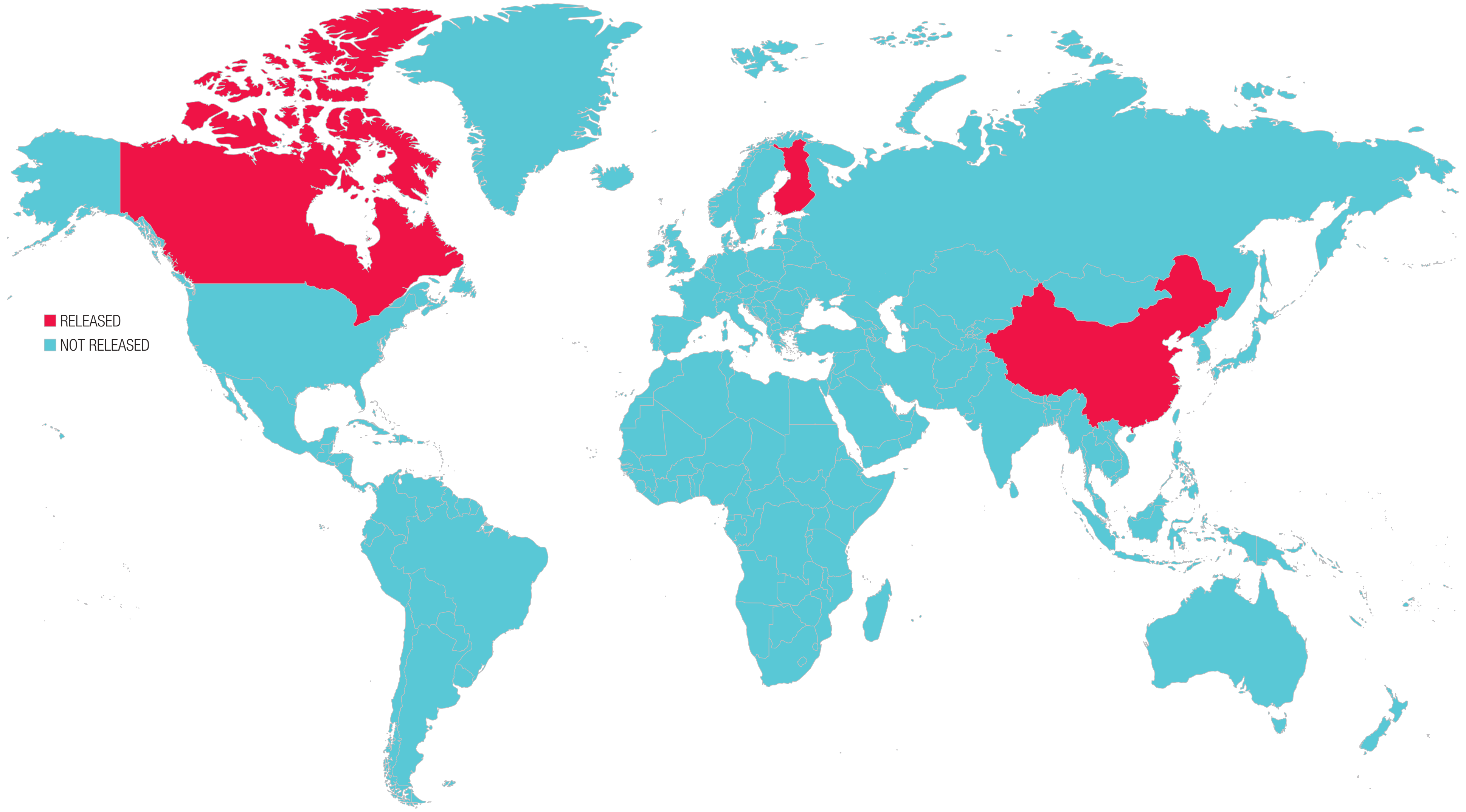
DIFFERENCES BETWEEN CHINA AND THE WEST MAKE IT DIFFICULT TO REACH MEANINGFUL AGREEMENTS ON REGULATING ARTIFICIAL INTELLIGENCE. HOWEVER, THE G7 AND THE UNITED NATIONS ARE LAYING THE FOUNDATIONS FOR COMMON PRINCIPLES. PROMOTING INCLUSIVE AI FOR THE GLOBAL SOUTH IS A GROWING PRIORITY

THE RAPIDLY EVOLVING AI policy landscape presents two main challenges. First, countries at the forefront of AI development and application have adopted different regulatory approaches. Despite efforts such as the Trade and Technology Council (TTC), significant divergences remain across the Atlantic, with the U.S. favoring a market-driven approach and the EU promoting a human-centered, risk-based model. China, meanwhile, emphasizes strict state control over AI advancements, a strategy that contrasts sharply with the free-market principles dominant in the West. Other emerging technological powers, such as India, are developing their own models. This fragmentation of regulatory efforts is a major obstacle to establishing global AI governance based on common principles and tools. Heightening geopolitical tensions and technological rivalries among major powers further complicate the entrenched differences in regulatory cultures and the economic role of the state.

Second, the rise of AI is widening the global digital divide. In Africa, where the majority of people lack internet access, AI adoption remains low due to the shortage of talent, inadequate digital infrastructure, and insufficient institutional frameworks. Experts, stakeholders, and policymakers have become increasingly aware of the urgency and global strategic relevance of these challenges, particularly in relation to the achievement of the Sustainable Development Goals (SDGs) and the implementation of the UN 2030 Agenda. This awareness has spurred renewed international efforts to reach a common understanding of AI's potential and impact, and to launch joint initiatives within various multilateral bodies and forums.

THE TRAJECTORY OF AI REGULATION

Governments worldwide have come to recognize artificial intelligence as a key driver of competitiveness and innovation. As a result, AI regulation has moved to the forefront of policy agendas in a growing number of countries. The development of AI strategies has surged in recent years, with 71 countries now having released national strategies aimed at unlocking AI's potential while mitigating its risks. However, the process of reg-



THE EVOLUTION OF AI STRATEGIES (2017-2020)

Between 2017 and 2020, high income countries rushed to publish their AI strategies. This initial phase of AI regulation produced two main outcomes: on the one hand, a severe fragmentation of the AI regulatory landscape; and, on the other, and a growing digital divide between the Global North and the rest of the world, confirming the backwardness of the latter.

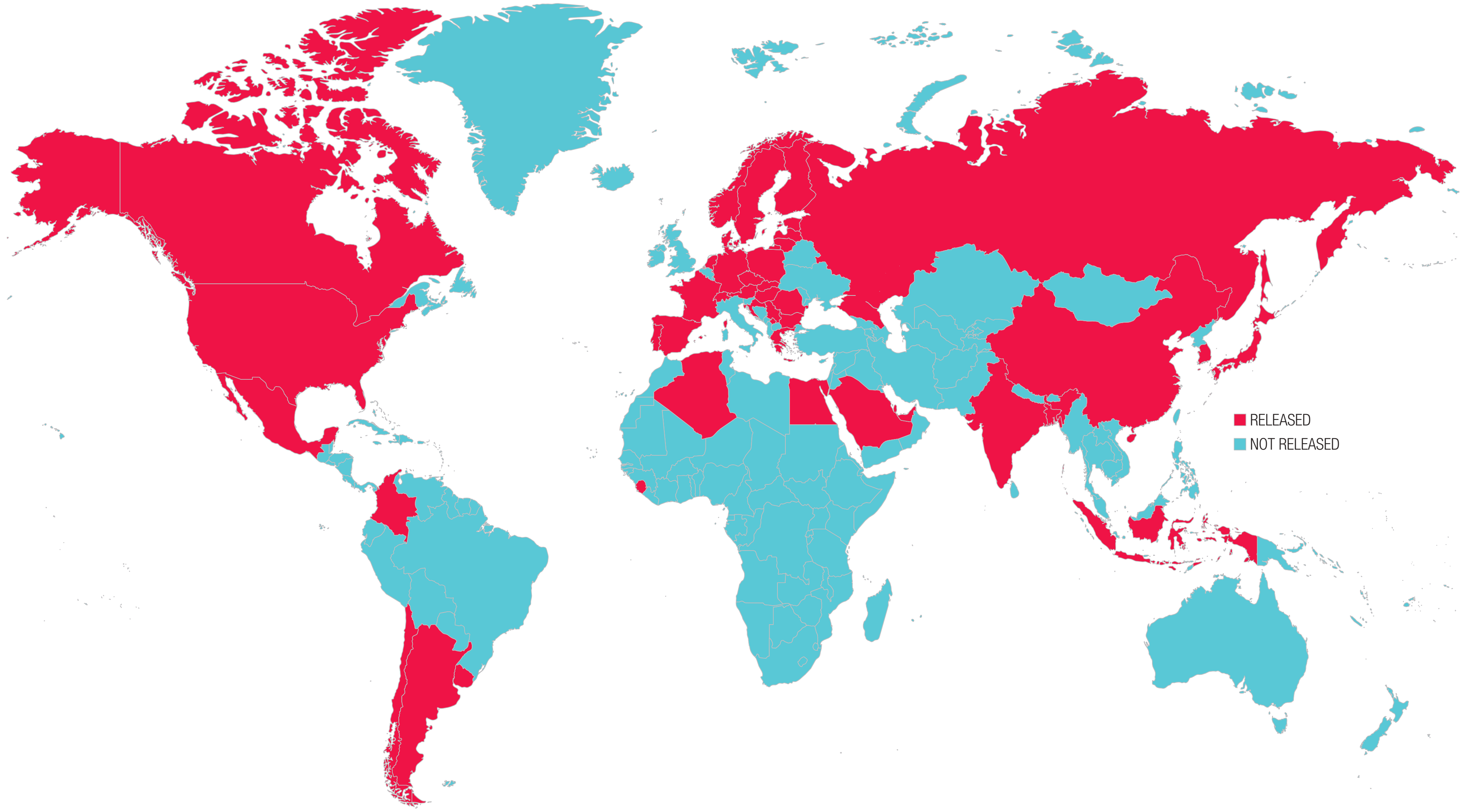
Source: Our World in Data

ulating AI has been neither smooth nor uniform.

In a first phase of AI regulation, starting in 2017, high income countries raced to release their respective AI strategies, striving for leadership in an unregulated field. By 2019, 70% of high-income countries had published an AI strategy. Leading digital powers promoted their respective AI strategies to gain traction, often rooted in different principles and national interests. This initial phase of AI regulation produced two main results: a severe fragmentation of the AI regulatory landscape and a growing digital divide between the Global North and the rest of the world which has lagged behind. Since 2021, a second phase of AI regulation has been unfolding. The Covid-19 pandemic has shown the benefits of AI adoption in practice, enabling more efficient forecasting, diagnosis, support for response and control of the pandemic. Governments have become increasingly aware of the transformative potential of AI, while technology companies have found home in a growing number of countries worldwide. Policy makers have then scaled up their efforts to design and release AI strategies to lay the groundwork for increasing AI adoption in middle and low-income countries. In 2023, the picture of countries participating in AI regulation looked significantly more diverse than before. Rwanda was the first low-income country to release an AI strategy, in 2023. Countries spreading across different regions, like Benin, Bangladesh and Tajikistan, have followed along, with increasing participation of previously underrepresented voices in the AI regulatory debate.

Many middle and low-income countries have turned to existing AI governance models when designing their own strategies. This has produced "clusters" of approaches, while normative divergences across AI governance models have remained. For example, in South Asia many governments have turned to India's "AI for all" strategy as a guide. Pakistan drew inspirationfrom its main partner for AI technological development, China, as it sought to draft its AI strategy.

Many low and middle countries striving for economic growth have seen AI as an accelerator of the so-called 4th industrial revolution. According to one estimate, AI could contribute up to $15.7 trillion to the global economy by 2030. However, AI-generated economic growth is likely to remain geographically concentrated, with North America and China expected to see



the largest gains. Most countries are grappling with the lack AI readiness, which will likely feed into greater global inequality. The commitment flagged by a soaring number of countries to chart AI regulation is a sign of progress. However, the fragmented AI policy landscape and the digital divide between regions hinder a global regulatory response to AI.

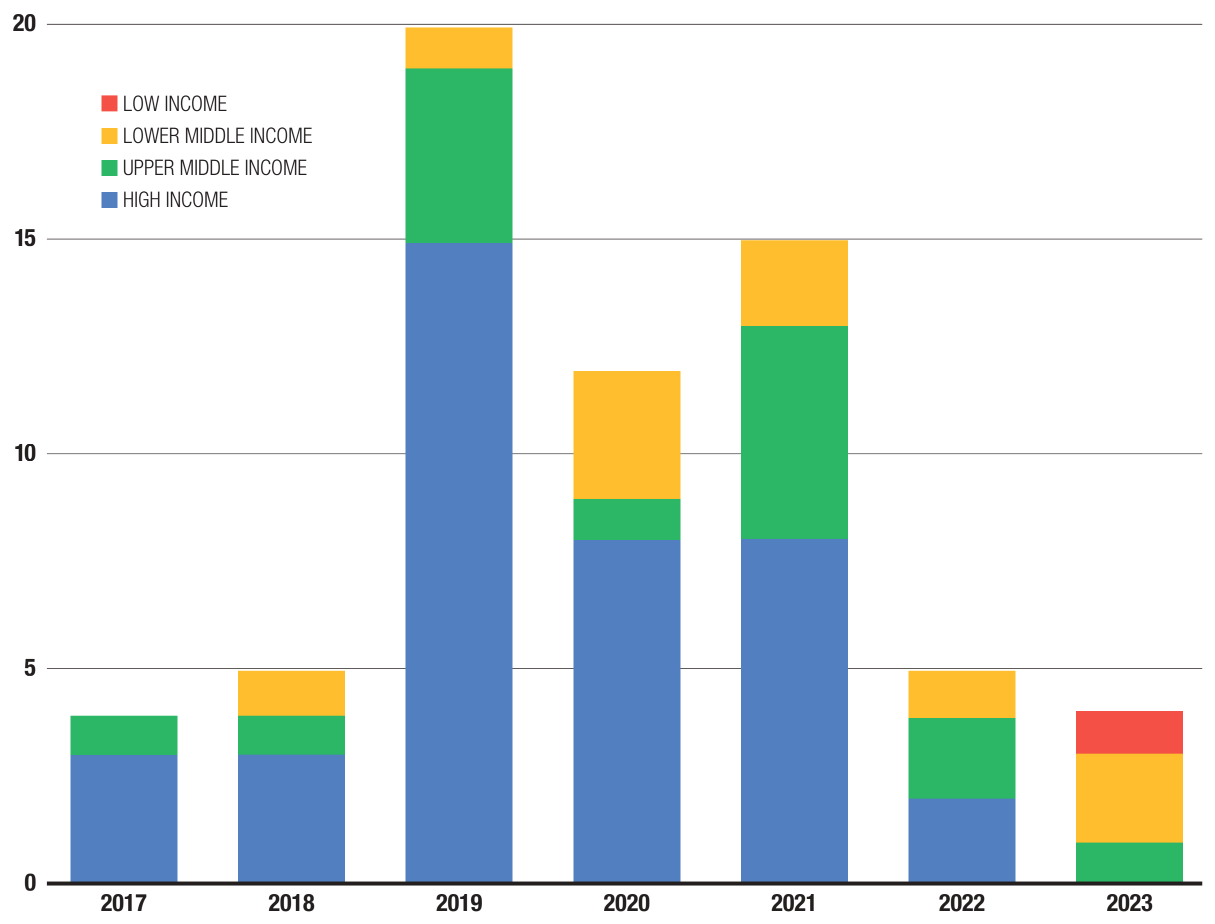
TOWARDS A NEW PHASE OF INTERNATIONAL COOPERATION ON AI

Governments across the world and international organisations have become increasingly aware of the implications of the AI regulatory fragmentation and the global digital divide. AI technologies can boost economic and social growth in both high-income and low-income countries. The use of AI across disciplines must be expanded to cover cutting-edge science and critical areas such as healthcare, education and climate change. Bilateral and multilateral platforms and international initiatives for greater cooperation on AI are proliferating. Multilateralism may prove to be a useful tool at the service of artificial intelligence and digitalisation.

THE ROLE OF THE UNITED NATIONS

In recent years, the United Nations has been increasingly vocal about the need to provide multilateral responses to AI challenges. The UN 2023 edition of the Activities on Artificial Intelligence Report, drafted in collaboration with the International Telecommunication Union (ITU), recognises the potential of AI systems to accelerate and enable progress towards reaching the 17 Sustainable Development Goals. AI underpins systems that could improve forecasting of food crises, monitoring water productivity, mapping schools through satellite imagery and optimizing the performance of communication networks, among other applications. Within this framework, the UN has launched a number of initiatives to unlock the potential of AI for global development.

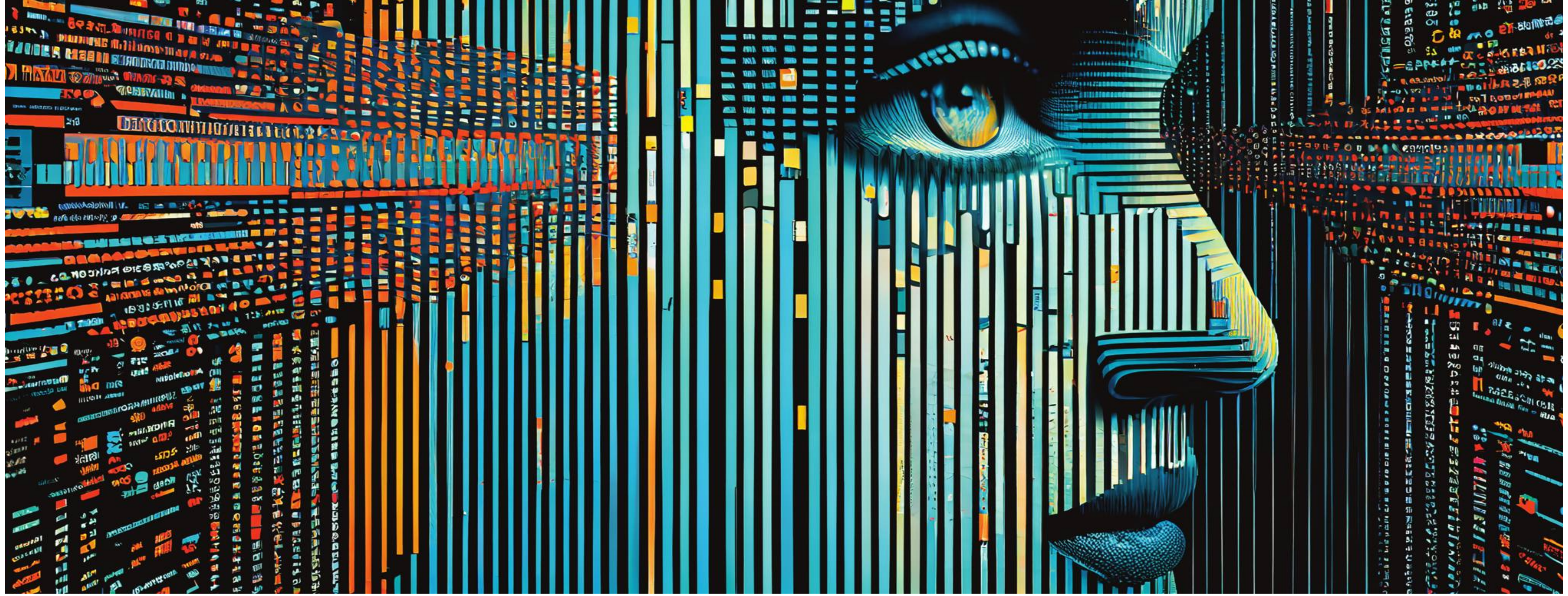
A high-level Advisory Body on AI was established by the UN in October 2023 to foster a globally inclusive approach to AI. Bringing together a multi-stakeholder team of experts representing 33 countries, the Advisory Board released its final report, "Governing AI for Humanity," in September 2024. The report highlights the global AI governance gaps, advocating



AI STRATEGIES PUBLISHED BY YEAR (2017-2023)

In 2023, a more diverse group of countries pursued AI regulation: for the first time, low income countries such as Rwanda, Benin, Bangladesh and Tajikistan are publishing AI strategies.

Source: Government AI Readiness Index 2023, Oxford Insights



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and providing a roadmap for the imperative need for a global AI approach. In March 2024, the UN adopted a landmark resolution on the promotion of "safe, secure and trustworthy" AI systems to boost sustainable development for all. The US-led drafting process saw the contributions of 120 other Member States, including China. Important milestones were cemented in September 2024, at the UN Summit of the Future held in New York. In the leadup to the event, the main digital stakeholders gathered at the Action Days from 20-21 September, committing to providing funds amounting to $1.05 billion to advance digital inclusion. During the Summit, leaders adopted the Pact for the Future, which includes a Global Digital Compact and a Declaration on Future Generations. These measures aim at transforming global digital governance with the goal of entrenching it with SDGs and the 2030 Agenda. The Global Digital Compact, in particular, provides a comprehensive framework for global governance of digital technology and AI, charting a roadmap for global digital cooperation to harness AI potential and bridge digital divides.

G7 & G20

Forum like the G7 and the G20 have been at work to provide multilateral solutions to the unresolved challenges of AI governance. Digitalisation features prominently across the areas of work of the two fora and in their ministerial meetings, with a particular attention dedicated to AI.

Most of the leading digital powers – but not China and India - gather at the G7 level, making the forum a valuable venue to address regulatory fragmentation and try to build common ground for greater convergence among the AI models of G7 countries. Under the Japanese presidency in 2023, G7 leaders agreed on a set of "International Guiding Principles on Artificial Intelligence" and a voluntary "Code of Conduct for AI developers." These first pillars underline the G7 commitment to deepen cooperation on AI in principle by setting standards that could be integrated national AI regulatory frameworks. The voluntary Code of Conduct aims at holding private companies accountable for the respect of basic principles in the development of AI technologies. In 2024, the G7, under the Italian presidency, established the AI Hub for Sustainable Development in collaboration with UN Development Programme. The AI Hub aims to promote a multistakeholder approach to support local AI digital ecosystems and strengthen capacities to advance AI for sustainable development, with a particular focus on Africa.

If the G7 pays particular attention to the African continent, the G20 – with a strong focus on AI's societal impacts - has doubled down on its commitment towards global inclusion and a broader digital outreach across countries and stakeholders. The G20 agenda largely aligns with the UN commitment to unlock AI's potential to promote the SDGs, while spearheading global conversations on AI governance. The Science20 (S20) platform, bringing together scientific academies from the G20 countries, has convened since 2017. Across leaderships, the S20 has mostly focused on the impact of technology on a global scale, with yearly mottos ranging from the 2020 "Transformative Science for Sustainable Development" to the 2024 "Science for Global Transformation".

Deepening geopolitical and technological rivalries are likely to continue preventing any major agreements on effective instruments for global AI governance. Divergent interests and approaches, particularly between Western countries and China, remain difficult to reconcile. However, ongoing efforts at the UN and in groups like the G20 and G7 could help lay the groundwork for agreements on a set of basic global principles and standards. The involvement of AI stakeholders and actors, which has been encouraged in many cooperation frameworks, could significantly contribute to advancing common solutions. AI governance is likely to be a blend of voluntary arrangements with varying degrees of monitoring, alongside new regulatory efforts and enforcement actions. This mix will differ across regions, reflecting their distinct regulatory cultures and economic models. In this context, transatlantic dialogue and cooperation will play a key role. The G7, in particular, has launched several promising initiatives on AI governance, leveraging converging policy efforts across the Atlantic and key preparatory work by the OECD. These initiatives could potentially serve as a foundation for broader, albeit limited, global agreements.

Concerns about AI's potential to exacerbate the digital divide have also led to several international initiatives aimed at harnessing AI's potential for achieving the Sustainable Development Goals and fostering economic growth in low- and middle-income countries. Bridging the digital divide has become a central focus of UN diplomacy, with efforts centered on promoting participatory and inclusive AI models for countries in the Global South.

we

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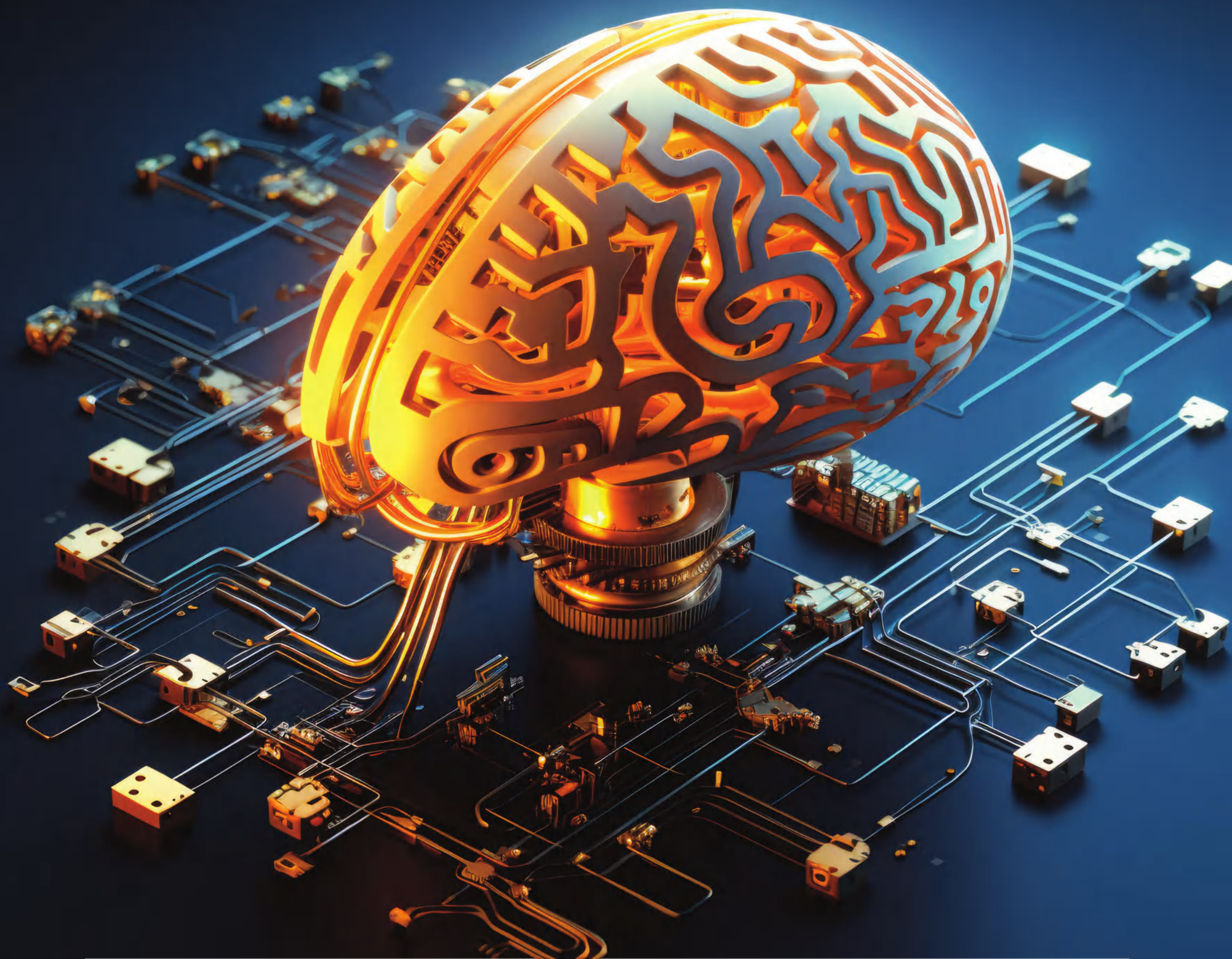
USA
RACE TO THE FUTURE

by **Massimo Basile**

THE UNITED STATES IS INVESTING ENORMOUS RESOURCES—BOTH PUBLIC AND PRIVATE— IN ARTIFICIAL INTELLIGENCE, SEEING IT AS A KEY AREA IN THE BATTLE WITH CHINA FOR SUPREMACY. MEANWHILE, THERE IS MUCH DEBATE IN THE COUNTRY ON THE ETHICS OF AI

THREE YOUNG Stanford engineers, traces of Ancient Rome, a tech company, the nuclear challenge, and a small island off Pennsylvania—these are the ingredients of one of the greatest global economic revolutions, at the center of the technological battle between the U.S. and China. This is the convergence of artificial intelligence and high-performance computing (HPC)—two transformative technologies—synthesized in a microchip with the capacity to manage multiple computers simultaneously. Only in the United States could such disparate elements come together, driving unprecedented innovations in research, data analysis, and industrial solutions. Together, AI and HPC are not only improving existing energy solutions but



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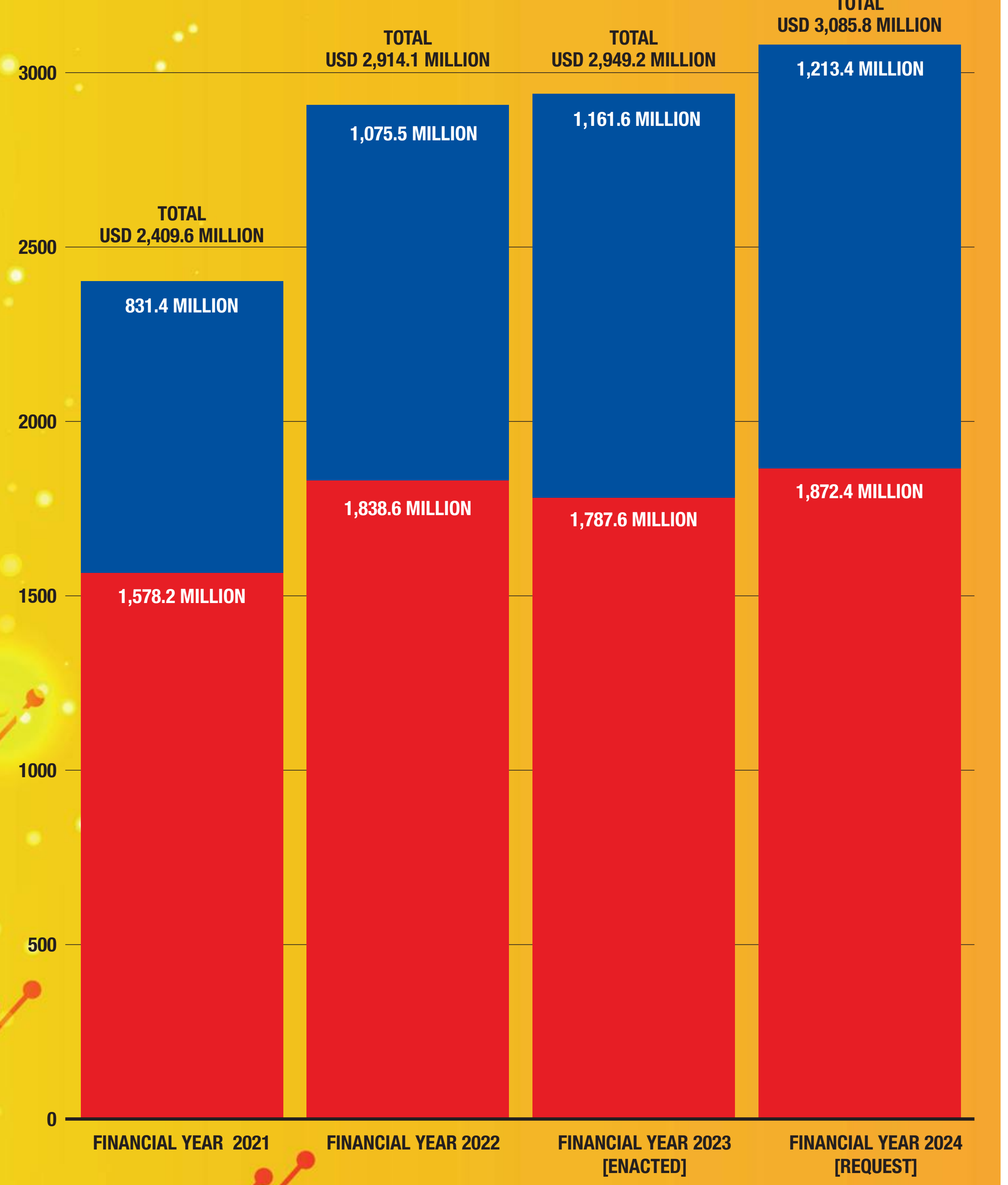
US FEDERAL BUDGET FOR AI R&D



The chart shows a steady growth in the federal budget for research and development in artificial intelligence. Between 2021 and 2024, we see an increase in both Core AI, i.e. spending directly linked to fundamental AI technologies, and AI Crosscut, i.e. spending on AI applications that cross or overlap with other technology sectors. The total increase for the years considered is approximately USD 676 million.

also opening new avenues for the energy transition. Companies can streamline operations, reduce costs, and enhance efficiency. In manufacturing, these technologies can predict machine failures, optimize supply chains, and improve product quality. In finance, they process vast amounts of data, predict market trends, and manage risks. In the medical sector, the use of algorithms in diagnostics is now standard practice in hospitals across the U.S., from New York to New Mexico, and from California to Florida.

Federal investment in U.S. microchip manufacturing has reached a turning point—spending rose from USD 1.3 billion in 2017 to USD 3.1 billion in the 2024 financial year—sending a clear message to China: it will not be allowed to overtake the American lead. This new technology is already a part of our lives. As Rajeeb Hazra, former Vice President of Intel, puts it, “there’s a whole class of new users who don’t know they’re using HPC, but it’s already part of their lives.” Fully harnessing this artificial brain is the modern challenge, though it has deep roots.

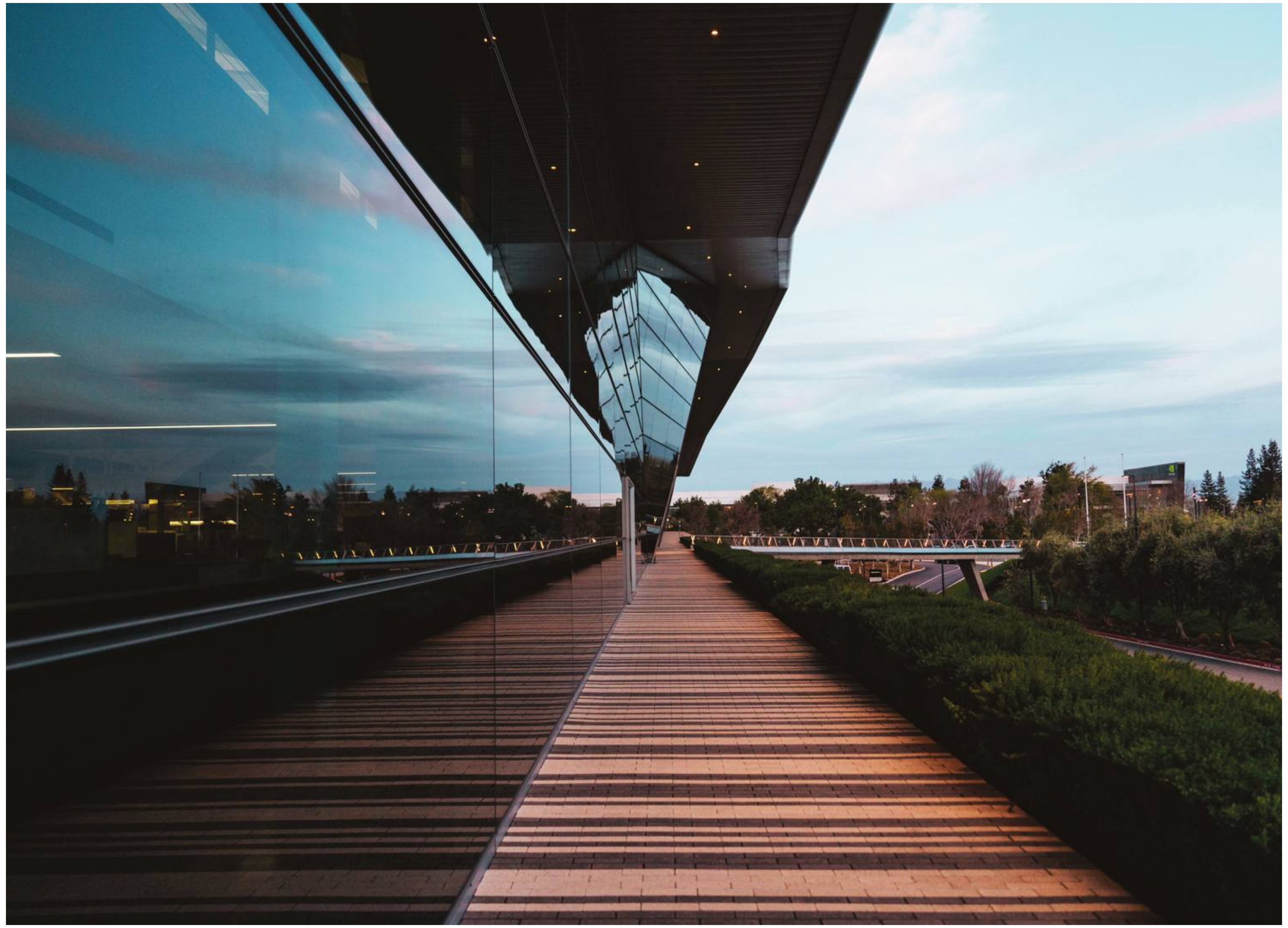
THREE GUYS AND A VISION

Nearly thirty years ago, three Stanford electrical engineering graduates—Jen-Hsun Huang, Chris Malachowsky, and Curtis Priem—founded a company that would revolutionize the world of microchips. They set up headquarters in Santa Clara, California, and named their venture Nvidia by combining “N” and “V” (for Next Vision) with “invidia,” the Latin word for envy. From the start, Nvidia embodied the tension between the drive for advancement and the forces resistant to change. It took two years to produce their first chip, but that microprocessor—capable of handling both 2D and 3D graphics and processing audio—was initially used in video games. Over time, Nvidia evolved to dominate the super microprocessor industry, controlling over 80 percent of the market and surpassing three trillion dollars in market capitalization on Wall Street. Today, Nvidia is a strategic player in the U.S. race for leadership in artificial intelligence and high-performance computing.

Joining Nvidia in this quest is Microsoft, which is also focused on AI and nuclear energy. The Seattle tech giant recently signed a 20-year agreement with Constellation Energy to restart the Unit 1 reactor, which had been closed five years ago for economic reasons. Located on Three Mile Island in Pennsylvania—infamous for the 1979 accident that crippled Unit 2—the plant will provide Microsoft with energy to fuel its push to develop artificial intelligence.

GOVERNMENT PLANS

Meanwhile, the U.S. government, with approval from Congress, has introduced two key initiatives: the Chips and Science Act and the National AI Initiative Act. The Chips and Science Act, signed into law on August 9, 2022, allocates



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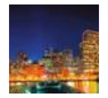
around USD 280 billion to various technology sectors, including USD 52 billion in subsidies and tax credits for chip manufacturing companies. An additional USD 200 billion is earmarked for research in AI, quantum computing, and robotics. What has this achieved so far? To date, over USD 395 billion in investments have been announced in the semiconductor sector, along with the creation of more than 115,000 jobs.

The National AI Initiative Act aims to coordinate a federal-level program to accelerate AI research and application, supporting both economic prosperity and national security. Key agencies involved include the National Institute of Standards and Technology, the National Science Foundation, and the Department of Energy, alongside contributions from Big Tech companies. Google has made significant investments in AI through Google AI and DeepMind, developing advanced technologies like machine learning and natural language processing. Microsoft, with its Azure AI platform, provides tools and platforms for developers and enterprises, and has invested in OpenAI to accelerate innovation in generative AI. OpenAI itself—renowned for models like GPT-4—is at the forefront of AI research and collaborates with Microsoft to integrate its technologies into commercial products. Startups also play a vital role in the AI ecosystem, with their agility and ability to

Nvidia headquarters in Santa Clara, California. Founded about 30 years ago, Nvidia dominates the super microprocessor industry, controlling over 80 percent of the market and exceeding three trillion dollars in capitalization on Wall Street.



Silicon Valley is the global heart of technological innovation and a major center for the development of artificial intelligence. Many of the world's largest technology companies—including Google, Apple, Meta, OpenAI, and Nvidia—are based here. Pictured: the skyline of downtown San Francisco.

quickly adapt to new trends. This synergy is creating an unprecedentedly fertile ground for AI innovation.

PRIVACY AND BIAS, THE DEBATE IN THE US

While AI and HPC offer tremendous development opportunities across diverse fields, they also raise significant ethical concerns. In the U.S., there is an ongoing debate around issues like algorithmic bias, privacy, and the impact on employment. One of the key concerns is the risk that algorithms may reproduce or amplify existing biases—particularly against ethnic minorities, socio-economically disadvantaged groups, or other vulnerable populations. Many AI algorithms are trained on datasets that reflect historical social inequalities, which can result in outcomes that perpetuate those inequalities. A recent case in American history serves as a warning: a company's hiring algorithm favored male candidates because it was trained on historical hiring data in which men were the overwhelming majority.

Privacy is another pressing issue. AI requires vast amounts of data to function effectively, but this raises concerns about how personal data is collected, used, and protected. Data from social networks, for instance, can be used to create detailed profiles of users, influencing their decisions and behaviors—often without their explicit consent.

The potential impact on employment is also significant. AI-driven automation could replace human jobs, leading to increased unemployment, especially in sectors like manufacturing, logistics, and even professional services.

As technological progress advances, it is crucial to develop regulations that protect individual privacy and ensure the ethical use of data. The United States takes a more flexible approach compared to the European Union, aiming to foster innovation without imposing overly strict constraints. The National AI Initiative Act seeks to establish standards and requirements for the safe and ethical use of AI, while the government collaborates with tech companies to develop guidelines that balance innovation and oversight. In contrast, the European Union has introduced the AI Act, a comprehensive regulation designed to protect citizens' rights and ensure transparency and accountability in the use of AI. While the U.S. emphasizes a less regulated approach focused on promoting competitiveness and innovation, it remains vigilant about potential risks.

COMPETITION WITH CHINA

Added to this landscape are the geopolitical implications. The competition for technological supremacy between the U.S. and China is a key factor. Both nations are investing heavily in AI and HPC to gain a strategic advantage. With leading tech companies like Google, Microsoft, and OpenAI—now valued at a potential USD 50 billion—the U.S. is spearheading private-sector innovation and is open to collaborating with other countries, including Italy. Meanwhile, China has taken a more centralized approach, with state-led investments and a national strategy to become the world leader in AI by 2030.

It is a battle on a new frontier, with boundaries yet to be defined. Artificial intelligence, with its promise to replicate and surpass the human mind, stands as a modern Prometheus—bringing the fire of knowledge but also the risk of eternal consequences. In this context, the United States acts as the titan seeking to harness this primordial force, fully aware that mastery over these technologies could shape the future of the nation and the world. But what does this mean for the essence of humanity? In a world where machines think and decide, where does the human soul fit in? The challenge is not just technological, but also ethical and philosophical. Freedom, privacy, and even the very concept of identity are being questioned by algorithms that know neither morality nor compassion—issues increasingly discussed in the American scientific community. Yet, driven by an insatiable thirst for progress, the U.S. presses forward. It stands at a crossroads, ready to face the unknown with courage and determination, hoping that its moral compass will guide it through the storms of progress.

MASSIMO BASILE
A professional journalist since 1991, Massimo Basile has worked for several Italian newspapers, including La Repubblica, Il Tirreno, and Il Corriere dello Sport. Since 2018, he has been living in the United States, where he writes for the Italian news agency Agi and La Repubblica.

THE CHINESE WAY

by Rebecca Arcesati

CHINA'S RACE FOR SUPREMACY IN ARTIFICIAL INTELLIGENCE IS ROOTED IN A QUEST FOR GEOPOLITICAL, ECONOMIC, COMPUTING AND ELECTRIC POWER. BUT TO EXPLOIT AI'S POTENTIAL CHINA WILL HAVE TO FACE MAJOR INTERNAL AND EXTERNAL CHALLENGES

CHINA HAS DESIGNATED artificial intelligence as a strategic technology for enhancing its economic competitiveness, bolstering military capabilities, and strengthening the Chinese Communist Party's (CCP) governance and mass surveillance systems. Party and state leader Xi Jinping views AI through the lenses of national security and geopolitics. "Whoever can grasp the opportunities of new economic development such as big data and artificial intelligence will have the pulse of our times," Xi told BRICS members in June 2022. He frequently describes the current techno-industrial revolution, driven by AI, as an unprecedented chance for China to "overtake on the curve"—surpass advanced economies and restore its position as a global power.

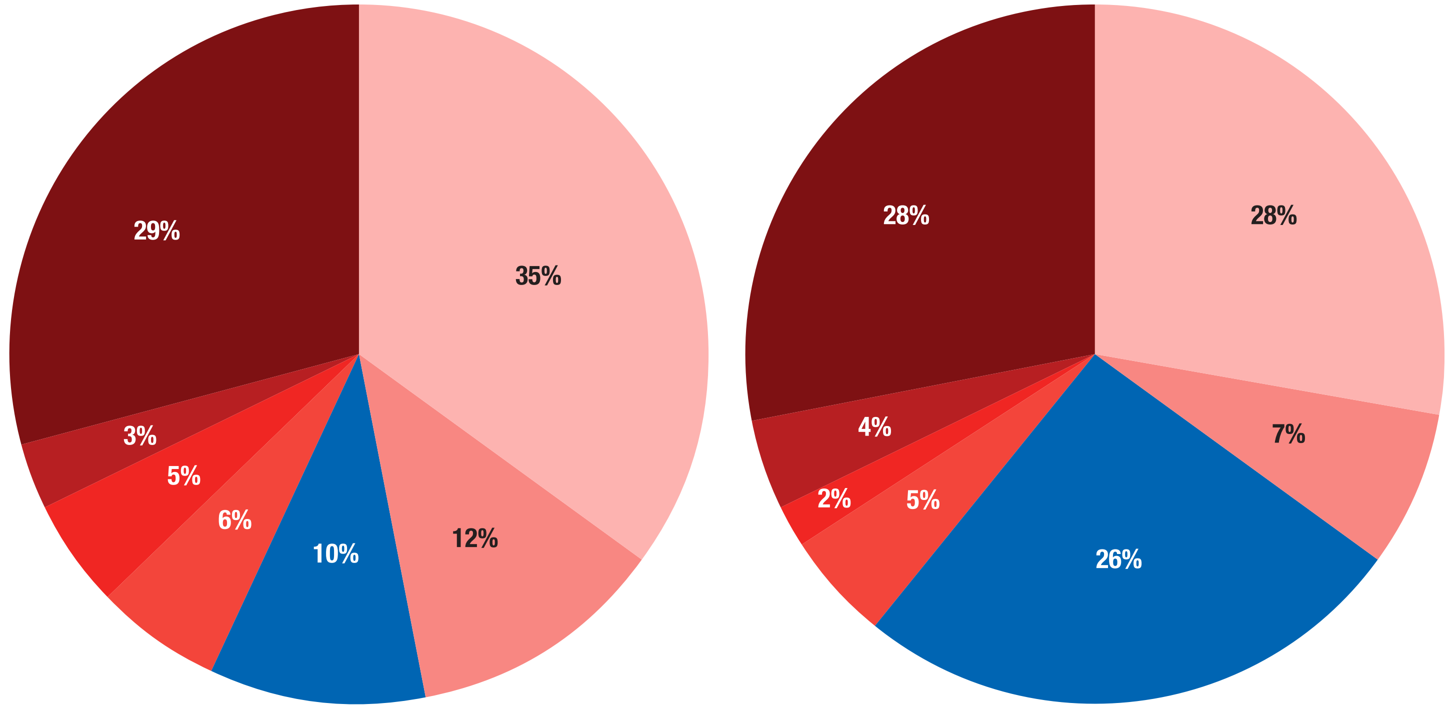
With strong government support and close ties between industry and state-backed academic labs, China's AI ecosystem has made impressive strides. This is evidenced by the increasing volume and quality of its research, a vast and rapidly expanding talent pool,

AI EXPERTS: WHERE DO THEY COME FROM?

China has become increasingly central to talent training in the field of artificial intelligence. As early as 2019, Chinese researchers made up for a significant proportion of the global community, with one-tenth of the most prestigious experts in AI. In 2022, China's pool of top-tier AI talent reached 26 percent of the global total, almost matching the US's.

Source: MacroPolo

- US
- INDIA
- CHINA
- FRANCE
- CANADA
- GERMANY
- OTHERS

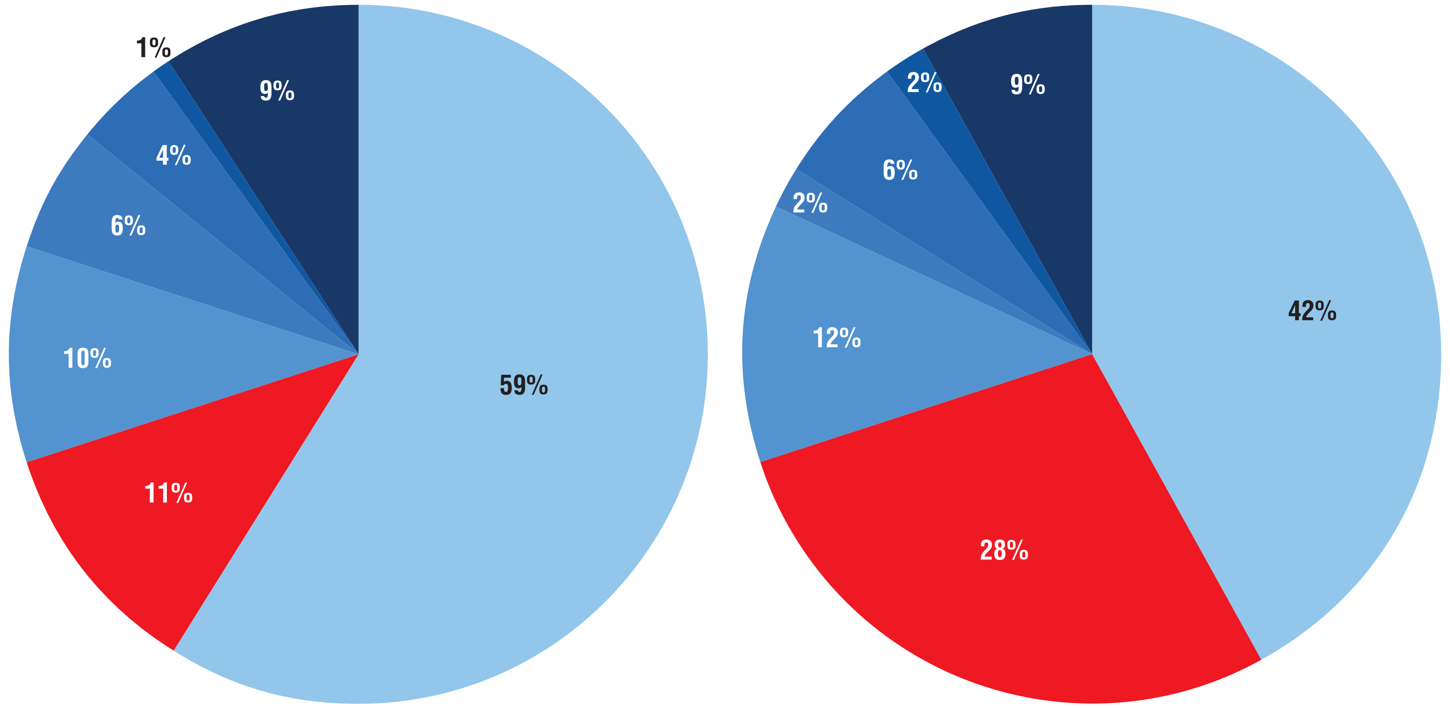


WHERE DO THEY WORK?

In 2022, 28 percent of top AI researchers worked in China. This significant proportion highlights the growth of the country's AI sector and the job opportunities it has generated.

Source: MacroPolo

- US
- CHINA
- EUROPE
- CANADA
- UK
- SOUTH KOREA
- OTHERS



significant state and private-sector investment, and the swift adoption of AI in specific sectors. The release of ChatGPT in November 2022 caused a frenzy in China's generative AI sector, with at least 50 companies developing large language models. These range from major tech firms like Baidu and Huawei to startups like Zhipu AI and 01.AI. Although generally considered to be one to two years behind their US counterparts, some of these models perform quite well on various benchmarks.

Below, we examine three key challenges China faces in leveraging generative AI and other AI innovations to transform its economy: adopting AI to boost productivity, managing the sheer energy consumption of AI systems, and coping with restricted access to foreign semiconductor technology. The analysis concludes by highlighting some of the implications for Europe.

ENHANCING PRODUCTIVITY THROUGH AI IS EASIER SAID THAN DONE

Since coming to power in 2012, Xi Jinping has prioritized national security, resilience, and geopolitical goals over economic growth, efficiency, and market-oriented reforms. He envisions a state-driven economy where the party-state directs resources towards technologies and industries it considers strategic. For Xi, AI is a key driver of "new quality productivity" and the modernization of China's manufacturing base, which he sees as the main/prime

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source of China's competitive advantage. As he put it, "AI's 'head goose' effect will create spillover benefits and drive innovation in other sectors."

China's priority is to apply AI across the "real economy," boosting productivity in traditional sectors like manufacturing. The country is grappling with a prolonged economic downturn, an aging population, and slowing productivity growth. In response, the government is focusing on the technology- and innovation-driven upgrading of China's industrial base—an agenda that took center stage at the CCP Central Committee's delayed third plenary session in July. To advance this vision, policymakers are promoting the 'AI Plus' (AI+) initiative, which echoes efforts dating back to 2015 to transform China's economy and society through internet and information technologies. Part of the plan involves driving demand for large language models (LLMs) and other AI systems in traditional industries to improve efficiency.

Despite Beijing's enthusiastic embrace of techno-solutionism, history shows that transforming an economy into a high-tech powerhouse is not an easy task. AI is no silver bullet, and machine intelligence alone is unlikely to solve the structural issues in China's economy. In fact, Japan's developmental model, which Xi implicitly referenced with his "head goose" analogy, failed to reach its full potential. Similarly, the success of the CCP's technology-driven growth strategy is far from assured; investments in

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AI and other emerging technologies will need to stimulate productivity across other sectors. Previous efforts to promote "smart manufacturing" serve as a cautionary tale. Jeffrey Ding, a leading scholar on China's technology and AI strategy, refers to this as a "diffusion deficit," argues that China suffers from a "diffusion deficit," noting that the country's ability to adiot scientific and technological advancements lags behind its innovation capacity. While it's tempting to hype China's growing innovation capabilities in AI, using metrics like the number of high-impact academic papers or computer science graduates, the reality is more complex. For example, it's no surprise that Chinese government policy is focusing on talent and education, as the country still faces a shortage of qualified AI workers despite its rapidly expanding talent pool. Additionally, China struggles with a skills mismatch and youth unemployment remains high. Although it may seem counterintuitive for a country where 39% of the population will be

over retirement age by 2050, the rapid pace of automation could have disruptive effects on China's fragile labor market.

CHINA FACES A TRADEOFF BETWEEN ITS AI AND CLIMATE AMBITIONS

AI could destabilize not only China's labor market but also its energy systems and infrastructure. Despite Big Tech's reluctance to address the issue—let alone disclose the power consumption of its data centers—AI, particularly compute-intensive large language models (LLMs), places enormous strain on natural resources and energy systems. The International Energy Agency (IEA) projects that Chinese data centers will account for nearly 6% of the nation's total electricity demand by 2026. Additionally, generating electricity and cooling these data centers requires vast amounts of water. The Hong Kong-based China Water Risk estimates that total water usage by data centers in China could exceed 3 billion cubic meters by 2030—roughly equivalent to the entire annual residential water consumption of Singapore. China's "war of a hundred AI models" could lead to wasteful competition for already scarce computing resources, threatening to derail the country's green transition.

For China, reconciling its AI ambitions with its climate goals presents a monumental challenge. Beijing aims to peak CO_2 emissions by 2030 and is transitioning to a two-pronged emissions reduction approach: rather than simply limiting energy consumption, China will control both carbon intensity per unit of GDP and total greenhouse gas emissions. Despite leading the world in renewable power generation, structural socioeconomic factors and grid bottlenecks mean that China still relies on coal for two-thirds of its energy mix. As computing infrastructure rapidly expands to meet the growing demand for LLMs, there is a risk that China's energy systems won't keep pace with the AI boom. The government is attempting to address this by relocating data centers and computing hubs closer to cleaner and cheaper energy sources, setting increasingly stringent energy intensity targets, and promoting better coordination of computing resources.

To be sure, AI could also present opportunities for China's energy sector. The concept of a "smart energy brain" has gained traction as policymakers and state-affiliated researchers promote the synergistic development of computing power, AI, and the energy economy. One state-led project, the Tianshu-1 system, reportedly reduced energy consumption by over 15% by integrating AI and big data for tasks such as prediction, management, and maintenance. Chinese LLM developers are also seizing this opportunity, aiming to attract new customers and create models tailored to specific industry applications. For example, China Southern Power Grid has partnered with Baidu to develop a series of AI models for the power sector. However, the success of these initiatives is far from guaranteed.

US EXPORT CONTROLS ON COMPUTING RESOURCES HAMPER CHINA'S AI DEVELOPMENT

These domestic challenges are further complicated by external factors, particularly China's reliance on American semiconductor technology for its AI development. An increasingly zero-sum "AI arms race" has become a key aspect of the strategic great power competition between China and the US. In October 2022, the Biden administration began restricting exports of advanced semiconductor technology to China, including cutting-edge graphics

The Chinese government is promoting an initiative called 'AI Plus' that aims to revolutionize the Chinese economy and society through artificial intelligence and information technologies. Pictured: a rocket drawn in the sky of Nanjing by 2,022 drones during the celebrations of the 70th anniversary of the founding of the University of Aeronautics and Astronautics.

processing units (GPUs)—integrated circuits capable of performing high-speed mathematical calculations critical for machine learning tasks. The controls also extend to the tools, software, and expertise needed to produce advanced chips. Triggered by Beijing's aggressive military-civil fusion strategy and authoritarian surveillance programs, these restrictions were tightened further in October 2023, with more expected to follow.

US export controls, which apply extra-territorially, place additional strain on China's power generation by forcing Chinese firms to rely on larger quantities of older, less efficient chips for AI tasks. The CEO of DeepSeek, a Chinese LLM developer, admitted that indigenous LLMs require four times the computing resources of their US counterparts to achieve results that are still one generation behind. A recent study by scholars at Yale University estimated that if China had access to export-restricted chips for its data centers, the energy saved could equal the yearly power consumption of between 12,000 and 67,000 American households. Beyond hardware optimization, the study also found that a protectionist scenario makes algorithmic improvements less likely, potentially causing both American and Chinese Big Tech to waste the equivalent of the annual energy consumption of 1.8 million US households.

With consolidation in China's generative AI landscape still far off, many players are competing for the limited computing resources available. Encouragingly, some academic and corporate labs are pursuing advanced research into brain-inspired intelligence. Neuromorphic approaches, which prioritize less energy-intensive models based on the brain's structure, offer an alternative to the current trend of scaling up neural networks. This is a promising field internationally, and Chinese scientists are making notable progress. However, amid intense geopolitical competition to build bigger and better models, a broader reconsideration of China's inefficient AI development strategy seems unlikely.

WHAT CHINA'S AI STRATEGY MEANS FOR EUROPE

Despite these challenges, China's advancements make it the most formidable competitor in the AI race alongside the US. European policymakers, lawmakers, companies, and civil society can no longer afford to overlook China's AI ecosystem, particularly as it progresses toward developing frontier AI systems. As Europe strives to degend its position in the geopolitics of technology, there are at least two key priorities to consider.

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First, as highlighted by MERICS research, the European and Chinese AI ecosystems are more interconnected than often assumed, particularly through research collaborations. However, China's state-driven approach, geopolitical objectives, and ambitions for dominance in this field call for a risk-based approach to partnerships with China-based companies, universities, and research organizations. US government policies and regulations—some of which apply extra-territorially, or may in the future—further complicate the delicate balance between national security, ethical technology development, and competitiveness. European governments have an important role to play in ensuring that Europe retains its agency in the AI landscape, not only by fostering AI innovation but also by protecting local talent and technologies from being siphoned off by American and Chinese Big Tech.

Second, Europe needs to articulate a clear vision for how it wants to engage with China on global AI governance. China's government has implemented some of the world's most ambitious AI regulations and is pursuing a proactive, two-pronged AI diplomacy. This approach positions China as a champion of the developing world while simultaneously engaging with the West on shared concerns about safety and potentially catastrophic risks. Bilateral talks with the United States on AI risks are ongoing, despite divergences. Additionally, China co-signed the Bletchley Declaration, the outcome of the AI Safety Summit hosted by the United Kingdom in the fall of 2023. Yet, with few exceptions, the EU has shown little interest in looking beyond political and value differences to better understand—and selectively engage with—China's approach to regulating this powerful and transformative technology.

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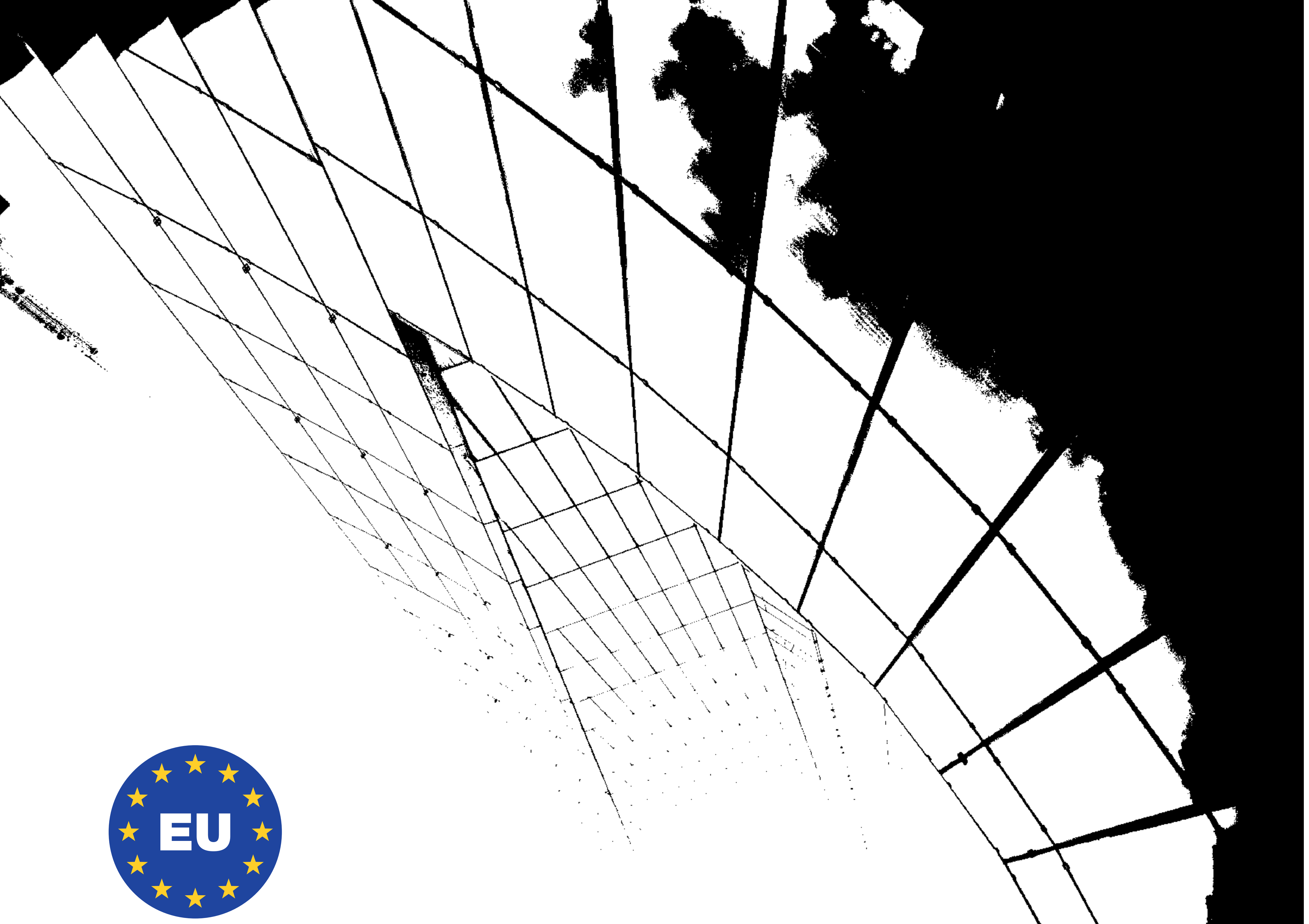

the NORMATIVE POWER

by Brahim Maarad

THE EU WANTS TO ENSURE AI IS SAFE, ETHICAL AND RESPECTS FUNDAMENTAL RIGHTS BY CREATING STANDARDS FOR THE WAY IT'S DEVELOPED AND USED WITHIN ITS BORDERS, AND BEYOND

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IN MAY 2023, the European Union introduced the world's first legislation to regulate artificial intelligence. The AI Act took effect on August 1, 2024, marking the first serious attempt to impose order on a sector many viewed as spiralling out of control. The new law has sparked significant repercussions—and criticism—from some of the key players in technological innovation. Its goal is to foster trustworthy AI both within Europe and globally, ensuring that AI systems respect fundamental rights, adhere to safety and ethical standards, and address the risks posed by highly powerful and impactful AI models.

The European regulation on artificial intelligence applies only to areas within the scope of EU law and includes exemptions, such as for systems used solely for military and defense purposes, as well as for research activities.

A RISK-BASED APPROACH

The regulatory framework follows a 'risk-based' approach: the higher the potential harm to society, the stricter the regulations. AI systems are classified into four risk levels: unacceptable, high, limited, and minimal. Any AI system deemed to pose a clear threat to people's safety, livelihoods, or rights is prohibited, ranging from government social scoring to voice-assisted toys that promote dangerous behavior.

The high-risk category includes technologies used in critical infrastructure (e.g., transport) that could endanger lives or health; education and vocational training, which can affect a person's access to opportunities (e.g., exam scoring); product safety components (e.g., AI in robot-assisted surgery); employment, worker management, and access to self-employment (e.g., CV screening software for recruitment); essential public and private services (e.g., credit scoring that can deny loans); law enforcement activities that could infringe on fundamental rights (e.g., assessing the reliability of judicial evidence); migration, asylum, and border control management (e.g., automated visa application reviews); and the administration of justice and democratic processes (e.g., AI tools for researching judicial decisions).

All of these systems must meet strict requirements before being allowed on the market. This includes thorough risk assessment and mitigation measures, ensuring high-quality datasets to minimize discriminatory outcomes, and registering activities to guarantee traceability. Detailed documentation must also be provided, outlining the system's purpose to allow authorities to assess compliance. Operators must receive clear and adequate information, and human oversight must be ensured. Additionally, systems are required to maintain a high level of robustness, security, and accuracy.

All remote biometric identification systems are classified as high risk and subject to strict regulations. The use of remote facial recognition in publicly accessible spaces for law enforcement is generally prohibited.

Limited exceptions are strictly defined and regulated, such as when necessary to search for a missing child, prevent an imminent terrorist threat, or identify and prosecute the perpetrator or suspected perpetrator of a serious crime. These uses require authorization from a judicial or other independent body and must adhere to strict limits regarding time, geographical scope, and the databases consulted.

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The risks posed by a lack of transparency in AI use are considered limited. The AI Act introduces specific transparency requirements to ensure that people are informed when necessary, fostering trust. For instance, when interacting with AI systems like chatbots, users must be made aware that they are communicating with a machine, allowing them to decide whether to continue or stop.

Providers must also ensure that AI-generated content is clearly identified as such. Furthermore, any AI-generated text published to inform the public on matters of public interest must be labeled as artificially produced. This requirement also applies to deepfake audio and video content.

The AI Act permits the unrestricted use of minimal-risk AI systems, such as AI-powered video games or spam filters.

THE AI PACT

The law, which took effect on August 1, will be fully applicable two years later, with some exceptions: bans will come into force after six months, governance rules and obligations for general-purpose AI models will apply after 12 months, and rules for AI systems integrated into regulated products will take effect after 36 months.

Violators of the prohibitions outlined in the regulation will face fines of up to €35 million or 7 percent of their annual global turnover, whichever is higher.

To ease the transition to the new regulatory framework, the European Commission has introduced the AI Pact, a voluntary initiative to support the implementation of the AI Act. The Pact encourages AI developers in Europe and beyond to pledge compliance with the key obligations of the Act ahead of its full enforcement. As of September 25, over 100 companies, including Amazon, Google, Microsoft, OpenAI, and Palantir, have signed the pledges. However, there is a notable absence of Apple, Meta, and X, which view European regulations as a hindrance to their business operations. These companies have even delayed the launch of some of their latest-generation applications in the European market, pending clearer guidance on the obligations they face. Specifically, Apple has withheld the release of its new AI-based features—Apple Intelligence—on the latest iPhone in the EU. Meanwhile, X has been in conflict with the European Commission for some time over the rules of the Digital Services Act (DSA), which governs web platforms.

The European Commission views artificial intelligence not just as something to be controlled or restricted, but as an area ripe for investment. In November 2023, the Commission, along with the High Performance Computing Joint Undertaking (EuroHPC JU), committed to broadening access to the EU's world-class supercomputing resources. This initiative, part of the EU AI Start-Up Initiative, aims to empower European AI start-ups, SMEs, and the wider AI community.

The European Union is a global leader in supercomputing. Through EuroHPC, three of the EU's supercomputers—Leonardo, Lumi, and MareNostrum5—rank among the best in the world.

THE VON DER LEYEN AND DRAGHI AGENDAS

"Data and AI are the ingredients for innovation that can help us to find solutions to societal challenges, from health to farming, from security to manufacturing. In order to release that potential, we have to find our European way, balancing the flow and wide use of data while preserving high privacy, security, safety and ethical standards. We already achieved this with the General Data Protection Regulation, and many countries have followed our path. In my first 100 days in office, I will put forward legislation for a coordinated European approach on the human and ethical implications of Artificial Intelligence." This was Ursula von der Leyen's pledge in her agenda for a second term as President of the European Commission, presented to the European Parliament last July. "This [legislation] should also explore how we can harness big data for innovations that generate wealth for our societies and businesses. I will ensure that we prioritize investment in artificial intelligence, both through the Multiannual Financial Framework and by expanding public-private partnerships," she emphasized.

The issue was also highlighted by former ECB President and former Italian Prime Minister Mario Draghi in his report, The Future of European Competitiveness.

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"[A] critical issue for Europe will be integrating new technologies like artificial intelligence into our industrial sector. AI is improving incredibly fast, as the latest models released in the last few days show. We need to shift our orientation from trying to restrain this technology to understanding how to benefit from it. The cost of training frontier AI models is still high, which is a barrier for companies in Europe that don't have the backing of US big tech firms. But, on the other hand, the EU has a unique opportunity to lower the cost of AI deployment by making available its unique network of high-performance computers," Draghi said as he presented the paper to the European Parliament in September. "The report recommends increasing the capacity of this network and expanding access to start-ups and industry. Many industrial applications of AI do not require the latest advances in generative AI, so it's well within our reach to accelerate AI uptake with a concerted effort to support companies. That said, the report recognizes that technological progress and social inclusion do not always go together. Major transitions are disruptive. Inclusion hinges on everyone having the skills they need to benefit from digitalization. So, while we want to match the United States on innovation, we must exceed the US on education and adult learning. We therefore propose a profound overhaul of Europe's approach to skills, focused on using data to understand where skills gaps lie and investing in education at every stage. For Europe to succeed, investment in technology and in people cannot substitute for each other. They must go hand in hand," Draghi added.

The "Brussels effect" is also making its mark on AI. On September 5, the Council of Europe signed the Framework Convention on Artificial Intelligence, Human Rights, Democracy, and the Rule of Law—the first legally binding international treaty designed to ensure that AI systems align with these principles. The treaty provides a comprehensive legal framework that covers the entire AI lifecycle, aiming to foster innovation while managing the risks AI may pose to human rights, democracy, and the rule of law. To ensure its longevity, the framework is intentionally technology neutral.

The Framework Convention was adopted by the Council of Europe's Committee of Ministers on May 17, 2024. It was negotiated by the 46 member states of the Council of Europe, the European Union, all observer states (Canada, Japan, Mexico, the Holy See, and the United States), and six non-member states (Argentina, Australia, Costa Rica, Israel, Peru, and Uruguay). Representatives from the private sector, civil society, and academia also played an active role in shaping the convention.

we

BRAHIM MAARAD
AGI reporter. Brussels correspondent.

an ENVIRONMENTAL ALLY?

by Roberto Di Giovan Paolo

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THE BLESSING AND CURSE OF AN INSTRUMENT STILL ENTIRELY IN THE HANDS OF HUMANITY. FOR NOW, ISAAC ASIMOV'S THREE LAWS ARE STILL VALID AND INCREASINGLY OUR RESPONSIBILITY

EVERY TIME we get a new technology or 'killer app', gets floated the debate starts all over again: is this pro or anti-humanity? Will we be overwhelmed, or will we put it to good use? With artificial intelligence, the pattern repeats itself, though with very different characteristics and more serious concerns than the home espresso machine, which was its own kind of 'killer app,' but in the now obsolete field of home automation, relegated to the cybernostalgia of the retro-futurist imagination of the 1960s and 1970s.

Not that we should trivialize the debate surrounding artificial intelligence. Quite the contrary. And not only because AI is impacting many sectors of our humanity: from the economy—including those who spy a 'bubble' in AI-company stocks—to agriculture, the primary basis of human food and, obviously, even our recent spate of wars. With artificial intelligence we are talking about the most intimate aspect of humanity: our thoughts, our logic, our feelings.

Artificial intelligence is approaching the ability to replicate the logical processes of human thought. This raises significant moral and philosophical questions, particularly regarding the future, as the development plans of the major companies in this sector depend not only on the quantity of data but, more importantly, on the quality of that data, which feeds the learning systems. Today, the largest AI systems claim machines and algorithms with learning and processing capabilities that are 4-5 times greater than just a few years ago, at the dawn of tools like ChatGPT. This leap is largely due to the massive increase in data input.

However, there is also a physical aspect to this issue, reminiscent of the internet's dependence on a vast network of undersea cables spanning the globe. In AI, the conversation revolves around chips, the rare earth elements required to produce them, and the geopolitics surrounding those resources, which we explored in the previous issue of this magazine. Beyond the technical aspects, we must also consider the environmental impact—a topic we will now focus on, as it highlights both the potential benefits and drawbacks of this new technology. In doing so, it becomes clear that we must avoid the simplistic di-

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In the United States—which is currently leading the race for artificial intelligence—big tech consumes 6 percent of the nation's electricity, and that share will increase in the coming years. Pictured: Apple Park in Cupertino, California.

vision between the "apocalyptic" and the "integrated," terms made famous by Umberto Eco's work.

OUCH, HOW MUCH DO YOU COST? (ENVIRONMENTALLY SPEAKING)

One of the most contentious issues surrounding artificial intelligence is its environmental impact, especially at a time when the planet is grappling with climate change and many sectors of the global economy are seeking new solutions rooted in clean energy and innovation. The impact of entire industries is often subject to conflicting reports, even when backed by academic studies and scientific research. For example, it's been revealed that the CO_2 emissions from streaming digital music, such as MP3s, exceed those of vinyl records. Similarly, the push for electric mobility has complex implications for energy consumption and the disposal of batteries.

The same concerns apply to artificial intelligence, another technological innovation that may seem futuristic and intangible, but is not without its own environmental footprint.

In the United States, where most of the leading artificial intelligence companies are based, AI's share of national electricity consumption currently stands at 6 percent, and this figure is expected to rise as more businesses adopt AI technologies. In absolute terms, AI's energy use is comparable to that of medium-sized countries such as the Netherlands or Switzerland. Furthermore, there is the issue of cooling data and computing centers, which consume vast amounts of water—raising concerns that some regions could face water shortages or be forced to relocate these facilities within a few years.

A single AI-focused company with a concentrated supply chain can become a significant producer of CO_2 and a major consumer of water and energy in the region where it operates. This environmental impact must be weighed against the economic or strategic benefits that AI technology brings, both for the company and for the state.

NOT EVERYTHING IS SO TRANSPARENT AND CLEAR

Environmental experts, as well as researchers and commentators in the field of new technologies, such as those at the AI Now Institute, have acknowledged the claims made by AI companies that artificial intelligence is helping to develop new computational mechanisms that reduce processing times and, consequently, lower electricity consumption. They also recognize that specific algorithms can optimize procedures to minimize the use of energy and water. However, they agree that there is little independent verification of these claims. Remarkably, given the field, transparency is sorely lacking—not just in how AI models are built but also in demonstrating their environmental benefits.

The AI Now 2023 report, along with a UNESCO document from early 2024, also highlights not only AI's environmental cost but its uneven geographical and social impact. Not all regions have abundant water resources, nor do all areas enjoy equal access to energy. The danger is that our future could be shaped in regions where the very presence of AI companies exhausts local landscapes and resources. This scenario, while paradoxical, is not beyond the realm of possibility.

BUT ARTIFICIAL INTELLIGENCE, LIKE HUMAN INTELLIGENCE, ALSO HAS ANOTHER FACE

Then there's the other side of the coin—the potential of artificial intelligence to help combat climate change, generate cleaner energy, and reduce excess CO_2. There is a growing body of scientific and popular literature on this subject, often presented by the same sources that highlight AI's negative environmental impacts. For instance, the Harvard Business Review, which critiques the unequal environmental costs of AI, also points out that intelligent algorithms could help distribute AI traffic—i.e., the combination of data centers, workloads, and skills—across different locations, regardless of where a company's central computing headquarters are based. This could lead to a "federalization" of environmental costs, spreading the burden more evenly across regions and reducing the strain on local communities.

Geographical redistribution isn't the only positive outcome AI could offer. The European Space Agency (ESA), for example,

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The robot Yumi during the dress rehearsal of a concert at the Teatro Verdi in Pisa, for which it conducted the Lucca Philharmonic Orchestra.

is testing AI to create highly accurate and fast maps of the Arctic and Antarctic. This data collection, processed by AI, provides precise and rapid mapping, invaluable not only for researchers and travelers to these remote regions but also for studying and preserving the ice that helps regulate the planet's temperature. AI's ability to rapidly analyze and store vast amounts of data opens up further possibilities for mapping in areas such as deforestation control, monitoring forest boundaries, identifying waste dumping sites (which often pose significant health risks), and tracking animal populations in Africa.
These maps aren't just snapshots of the present—they offer predictive insights into the future under specific conditions. The value of this data, particularly for those with access to it, is immeasurable and extends into the geopolitics of AI.
AI isn't only being used in extreme environments to benefit the planet. In London, for example, companies like Grey Parrot—one of the most prominent—are using artificial intelligence to analyze waste, optimize the waste cycle, and shorten processing times for recyclable materials, all of which helps improve recycling efficiency in the post-pandemic world.
The pattern is always the same: introducing context and data, analyzing an ever-growing volume of information with increasing speed, and proposing solutions that can continually be refined. Philosophically, this approach works both for logic and the environment. For instance, if instead of focusing on a city's waste cycle, we ask AI to address ocean waste recovery, we could develop a global cleanup model. Starting with mapping the "floating garbage patches"—those vast islands of plastic debris we've seen in dramatic footage from even the most pristine waters—we could tackle this growing environmental crisis. These patches pose a grave threat to ocean health and the animals living there, such as whales and seals. Over time, microplastics from these islands enter the food chain, from fish and mollusks to humans.
By using AI to analyze climate data, ocean currents, and tidal movements, we could devise a precise and phased plan for cleaning the oceans. Similarly, AI could be used in agriculture to map and create reseeding and reforestation plans. By analyzing data on light, soil, and climate, AI can help identify ideal locations for tree cultivation, ensuring their successful growth in the years ahead. These examples show both the risks and benefits of AI's environmental impact.
Despite these possibilities, the future remains far from deterministic. We are still in a phase where Asimov's famous Three Laws of Robotics remain theoretical, and much—if not all—of the responsibility lies in human hands. While AI may have significant environmental costs, these can be mitigated if we invest not only in commercial applications but in environmental solutions as well.
Perhaps most promisingly, AI can also be a powerful ally in reversing the course of climate change and mitigating the harmful effects of human activity through projects aimed at cleaning up cities, oceans, and forests. But, of course, it is up to us to provide the right data for AI to process, intelligently.
we

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AFRICA

by Darlain Edeme

TECHNOLOGY TO BRIDGE THE ENERGY GAP

WE ARE STILL FAR FROM ACHIEVING UNIVERSAL ACCESS TO ELECTRICITY. INNOVATIVE SOLUTIONS AND TECHNOLOGIES, SUCH AS GEOGRAPHIC INFORMATION SYSTEMS AND ARTIFICIAL INTELLIGENCE, CAN IMPROVE ENERGY PLANNING AND ACCELERATE PROGRESS

IN AN ERA WHERE electricity is as essential as food and water, nearly 750 million people around the world still live without it. Four out of five of them are in sub-Saharan Africa, a continent rich in resources yet plagued by energy poverty. Electricity is not merely about flipping a switch; it powers hospitals, schools, and businesses. Without it, efforts to improve healthcare, education, and economic opportunities are stifled, perpetuating a cycle of poverty that is difficult to escape.
The United Nations has recognized this urgent issue, making universal electricity access by 2030 a central goal of Sustainable

AFRICA, ACCESS TO ELECTRICITY

According to IEA estimates, if the policy framework remains unchanged, in 2030, 550 million people in Africa will still be without access to electricity, most of them in rural areas.

Source: IEA, SDG7: Data and Projections, 2024

EARTH AT NIGHT [2016]

Satellite images of Earth at night have been a curiosity for the public and a tool of fundamental research for at least 25 years. They have provided a broad, beautiful picture, showing how humans have shaped the planet and lit up the darkness. Produced every decade or so, such maps have spawned dozens of economic, social sciences, and environmental research projects. This view highlights that much of Africa remains largely in the dark.

Illuminating Africa

Development Goal 7 (SDG7). However, according to the International Energy Agency (IEA), the world is not on track to meet this ambitious target. While millions of people have been connected to the grid in recent years, progress towards universal electrification has stalled. This slowdown is particularly stark in Africa, where, under the current policy framework, 550 million people are projected to still lack electricity access by 2030. The challenges are complex: rapid population growth, rural isolation, and outdated planning methods all present significant obstacles that require innovative solutions.

Traditional electricity access planning often depends on static and outdated data—such as census records that may no longer reflect current realities and household surveys conducted infrequently due to limited resources. These methods struggle to accurately identify and assess unserved populations. In rural areas, where populations are dispersed and infrastructure is scarce, gathering reliable data is both time-consuming and expensive. These information gaps result in inefficient resource allocation, poorly designed systems, and delays in project implementation.

TECHNOLOGICAL ADVANCEMENTS: A BEACON OF HOPE

There are three primary methods to increase electricity access: extending the national grid, constructing mini-grids, or deploying stand-alone systems. Grid extensions involve expanding centralized infrastructure, which works well for densely populated areas that benefit from economies of scale. However, the significant capital investment required often makes this approach cost-prohibitive for electrifying remote communities. Mini-grids, small localized networks that can operate independently or in conjunction with the national grid, are ideal for rural or isolated regions where grid extension is too expensive. Stand-alone systems can quickly and affordably electrify individual households, particularly in areas where grid or mini-grid solutions are not feasible. These systems typically rely on renewable energy, such as solar home systems, and can be easily scaled to meet user needs. Optimizing between these options requires precise data, as each method must carefully balance financial, geographical, and demand considerations.

Collecting this data has traditionally been resource-intensive and time-consuming. However, recent technological advance-

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Advanced technologies such as GIS, AI and HCP can greatly improve data analysis and energy planning, bringing the goal of universal access to electricity for the African population closer.

ments are helping to overcome these challenges. Tools such as Geographic Information Systems (GIS), Artificial Intelligence (AI), and High-Performance Computing (HPC) are revolutionizing the energy sector by enabling more accurate, efficient, and data-driven planning.

For years, GIS has allowed planners to visualize and analyze complex spatial data. However, obtaining GIS data has been a major challenge, as financial and technical constraints have prevented utilities from georeferencing their infrastructure. Additionally, local authorities often lack detailed, up-to-date population and income statistics, which are essential for effective planning. Even when data is available, it is frequently incomplete or outdated, particularly in fast-growing regions where censuses are not conducted regularly.

Scaling mapping efforts effectively is particularly challenging on a vast continent like Africa. Initiatives like OpenStreetMap,

an open geospatial database, have significantly improved data availability for planners, offering unprecedented temporal and spatial resolution on electricity access across the continent. However, as a volunteer-driven, non-profit initiative, it has only been able to cover select areas. The World Bank has also contributed by mapping transmission infrastructure across Africa, providing planners with valuable GIS datasets. Yet, this dataset remains incomplete, notably missing the distribution lines crucial for last-mile planning, and has not been updated since its publication in 2018.

More recently, advancements in remote sensing, AI, and HPC have led to new initiatives aimed at filling these data gaps. Both Google and Microsoft have released free, open-access datasets covering millions of geo-referenced building footprints across emerging and developing economies. Google has even updated its dataset to include multi-year snapshots and building heights. Meanwhile, Meta, through its Data for Good program, developed the Relative Wealth Index, which estimates living standards in 93 low- and middle-income countries by analyzing satellite and mobile network data. This dataset provides granular insights into global socio-economic conditions at a 1.5 km resolution and has been validated against Demographic and Health Surveys (DHS).

Other innovations include predictive models for mapping medium-voltage (MV) infrastructure using publicly available data, such as nighttime radiance collected by the Visible Infrared Imaging Radiometer Suite's (VIIRS) Day-Night Band (DNB) sensor. By feeding this data into grid estimation algorithms, researchers have shown promise in predicting existing grid coverage. The University of Michigan's High Resolution Electricity Access (HREA) project has also assessed power supply reliability by comparing radiance levels at the same location over multiple nights throughout the year.

Global resources like the Solar and Wind Atlas offer downloadable maps and data on solar and wind power potential at a 1 km resolution. Ongoing efforts are focused on creating similar datasets for hydro and geothermal resources, as well as for deposits of minerals essential to the clean energy transition—an important revenue source for many African countries.

Planners are increasingly leveraging these datasets in GIS-based models to identify the most cost-effective strategies for achieving universal electricity access. One of the leading tools in this space is the Open Source Spatial Electrification Tool (OnSSET), developed by KTH Royal Institute of Technology. Institutions like the World Bank, through its Global Electrification Platform, and the IEA use OnSSET to model electrification scenarios for countries that still lack universal access. Complementing OnSSET is the GISEle model, developed by Politecnico di Milano, which provides detailed estimates of distribution grid topology, down to the last mile and individual pole level.

This is just a brief overview of how GIS, AI, and HPC are transforming energy planning. For a more complete picture, the IEA has compiled a comprehensive repository of datasets and models in the Africa GIS Catalogue for Energy Planning. This centralized resource offers stakeholders detailed information on all existing models and datasets for every country across the continent, making it an essential tool for leveraging geospatial analysis to achieve universal electricity access.

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IEA'S BUILDING-LEVEL ELECTRICITY ACCESS AND DEMAND ESTIMATION MODEL

Beyond comprehensive infrastructure maps, a critical gap identified by energy sector planners is the demand estimation step. Demand is a key factor in determining the optimal technology for providing electricity access to a settlement. Yet, it is often overlooked due to the lack of reliable data and the complexity of accounting for context-specific factors that influence energy needs. To address this issue, the IEA, with support from Power Africa, partnered with MIT to develop the Building-Level Electricity Access and Demand Estimation model—a significant advancement in electrification efforts.

Our model can estimate electricity demand in both electrified and yet-to-be-electrified areas by using AI trained to correlate satellite imagery and GIS data with verified electricity consumption data. By factoring in variables such as roof materials, building size, proximity to infrastructure, and internet speed as a proxy for economic activity, the model accurately predicts both current and future demand for buildings without meter data, with an error rate 40 percent lower than traditional methods. This innovation represents a major improvement in electrification planning, enabling more precise and effective energy solutions.

BRIDGING DATA GAPS AND ENHANCING ACCURACY

While technological advancements like GIS, AI, and HPC have greatly improved energy planning, significant challenges still remain to be addressed.

The absence of a a centralized, open-access database accessible to all stakeholders—government agencies, utilities, developers—has created significant information asymmetry. Different stakeholders have varying levels of access to critical data, which hinders coordination and slows progress toward universal electricity access. Without a unified source of validated data, the energy sector suffers from inefficiencies such as duplicated efforts and delays in planning and implementation. This lack

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of consistent data coordination slows decision-making and impedes progress toward universal energy access. A comprehensive repository of unified planning data would not only streamline efforts but also improve data quality and reliability, making planning processes more efficient.
Financial constraints compound the issue. The costs of high-quality data collection, skilled personnel, and advanced computational tools are substantial, and many countries in the region lack the financial capacity to sustain these efforts independently. Advanced technologies require significant investments in infrastructure and expertise, which can strain national budgets. International partnerships, financial support, and targeted investments are essential to overcoming these challenges. Without sufficient funding, both technological solutions and the on-the-ground initiatives they support risk stalling, severely limiting the ability to scale energy access across underserved regions.
To fully capitalize on the potential of these tools, building local capacity is crucial. Many countries face not only financial but also technical limitations, making it difficult to effectively utilize GIS, AI, and HPC tools without external support. By investing in education and training, governments and organizations can empower local experts to take the lead in energy planning. Integrating these technological skills into educational curricula will equip the next generation of planners, while workshops and training programs can upskill current professionals in government agencies, utilities, and local development firms.
Localizing technical expertise is not just about reducing reliance on external consultants; it's about ensuring that energy solutions are tailored to the unique needs and conditions of each region. By equipping local planners with the necessary skills and tools, countries can promote long-term sustainability in energy planning. Additionally, these efforts create a stronger foundation for future innovation, as local experts will be able to adapt and refine global tools to better serve their communities.
Achieving universal electricity access by 2030 is not only ambitious but essential. Electricity is a key driver of economic development, powering vital services like healthcare and education and helping to lift communities out of poverty. While advanced technologies like GIS, AI, and HPC hold great promise, they are not a panacea for achieving universal access. These tools can greatly enhance data analysis and planning, but they cannot fully replace the field surveys, community engagement, and ground-truthing necessary to ensure plans are accurate and contextually appropriate. Tools like the IEA's building-level model are revolutionizing energy planning by directing efforts where they are most needed, optimizing resources, and accelerating progress. However, lasting success depends on combining these technological innovations with traditional, on-the-ground methods. Empowering local stakeholders with the skills to use these tools is crucial for sustaining progress and building a more equitable, prosperous future for millions across Africa.
we

DARLAIN EDEME
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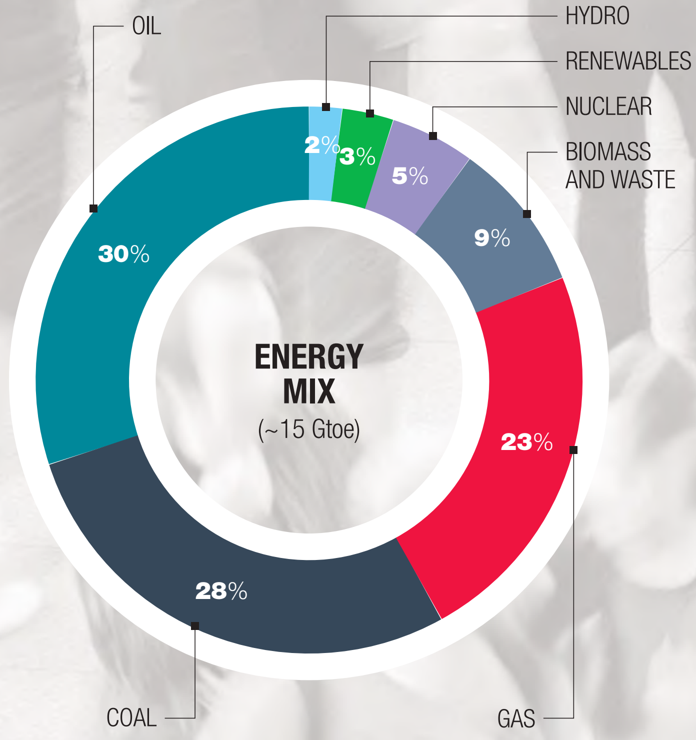
BY **ENI SCENARIOS AND STRATEGICS OPTIONS**

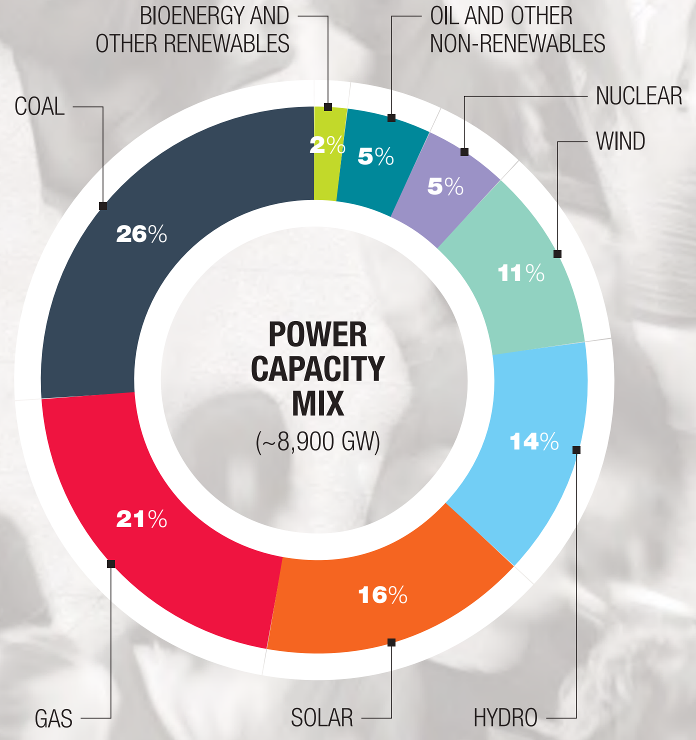
2023 was a challenging year for the energy market. Geopolitical uncertainty, coupled with economic weakness, created increasingly complex scenarios that posed risks to growth prospects. Despite this uncertainty, global primary energy consumption continued its upward trend in 2023, with the energy mix remaining largely stable.
Global oil consumption increased, surpassing pre-pandemic levels, while production also grew, particularly driven by the US. The OPEC+ alliance remained a significant player in controlling the market, with its policy of production cuts keeping prices around $80 per barrel.
Global gas demand held steady. A favorable climate and weakened economic conditions reduced consumption in Europe and limited growth in Asia, leaving supply insufficient to meet demand, including for replenishing stockpiles. Prices at major hubs fell by about 60 percent.

NUMBERS

2023 also set a new record for installed renewable capacity, particularly in solar and wind power, confirming the exponential growth of recent years. Global biofuel production saw a notable increase, marking a key step towards decarbonizing transportation. Critical minerals—essential for transition technologies—experienced strong growth as well.
The global energy landscape influenced CO_2 emissions, which rose by around 1 percent in 2023, reaching a new record. China led the way, accounting for a third of global emissions, followed by the US. For the first time, India overtook the EU to claim third place. The following pages provide an overview of the evolution of the global energy landscape, illustrated through numbers and charts from the 23rd edition of Eni's World Energy Review (WER).

WORLD ENERGY MIX AND ELECTRICAL CAPACITY MIX

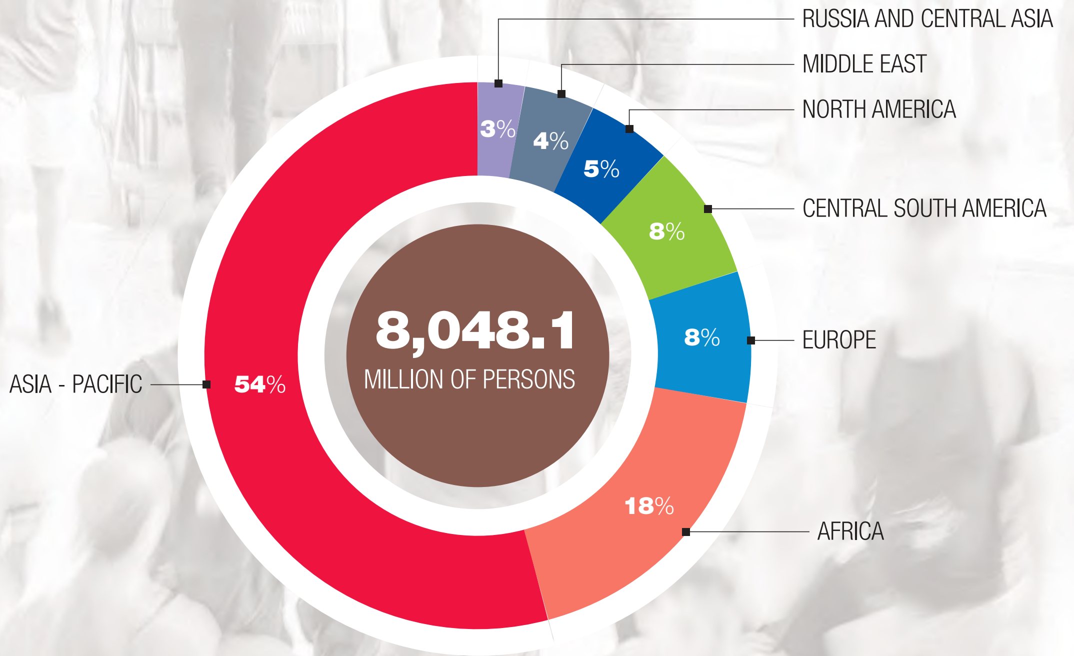




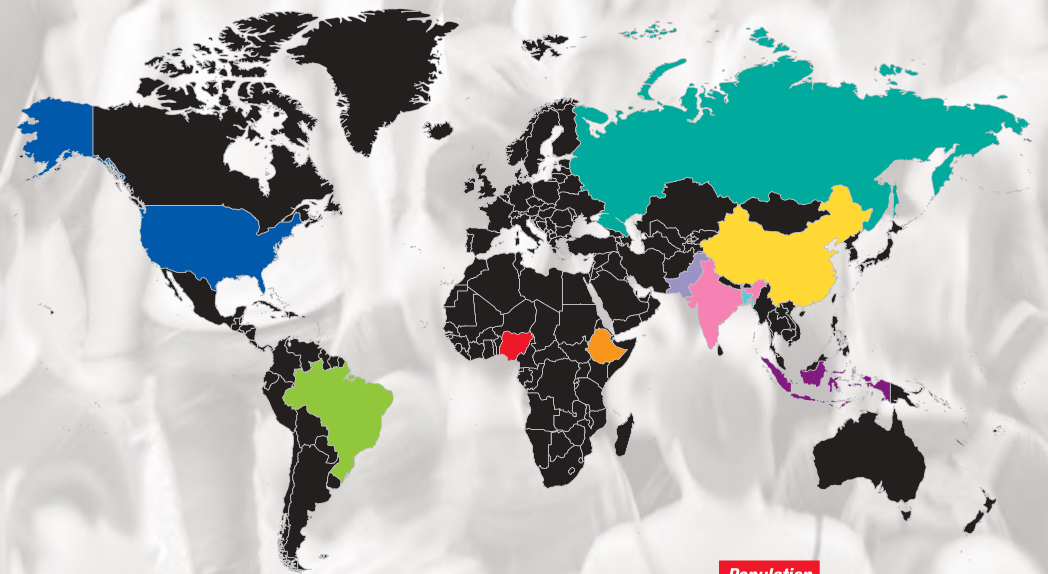
In 2023, global primary energy consumption reached approximately 15 Gtoe, with a growth rate of nearly 2 percent compared to 2022, continuing the steady trend observed over recent decades.
In terms of composition, fossil fuels once again accounted for about 80 percent of energy demand, with the proportions remaining largely unchanged: oil at 30 percent, coal at 28 percent, and gas at 23 percent. This stability reflects a pattern that has persisted for the past thirty years. While the share of solar PV and wind energy is growing, their overall contribution to the energy mix remains modest, at less than 3 percent.
When it comes to electricity capacity, fossil fuels still make up approximately 50 percent, followed by nuclear power at 5 percent, wind and solar at 27 percent, and hydropower at 14 percent.

POPULATION

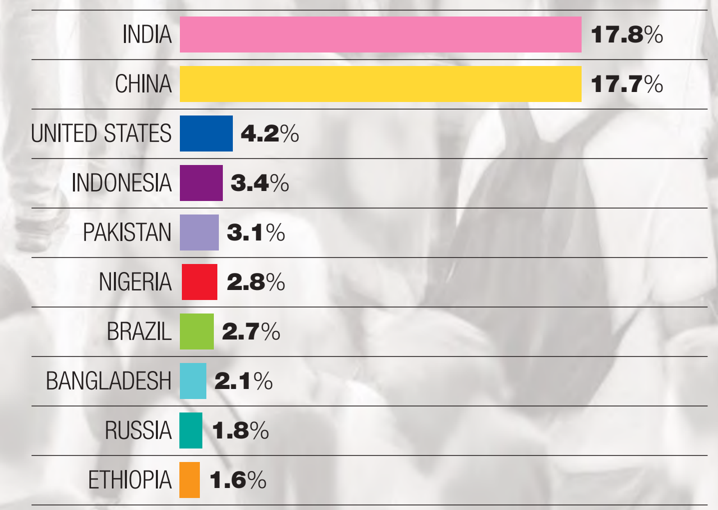
In 2023, the global population reached 8 billion, reflecting a growth rate of 0.9 percent (+70 million).
This increase was primarily concentrated in Africa (+2.3 percent) and the Middle East (+1.7 percent), while Europe was the only region to experience a decline (-0.4 percent), marking its second contraction in the past decade, following a 0.5 percent drop in 2022 compared to 2021. India, with a population exceeding 1.4 billion, has overtaken China to become the world's most populous country for the first time. Among the top ten most populous nations, the greatest growth occurred in Africa—Ethiopia (+2.6 percent) and Nigeria (+2.4 percent)—followed by Pakistan, Bangladesh, and the United States. Russia, meanwhile, saw its population decline.



THE WORLD TOP 10

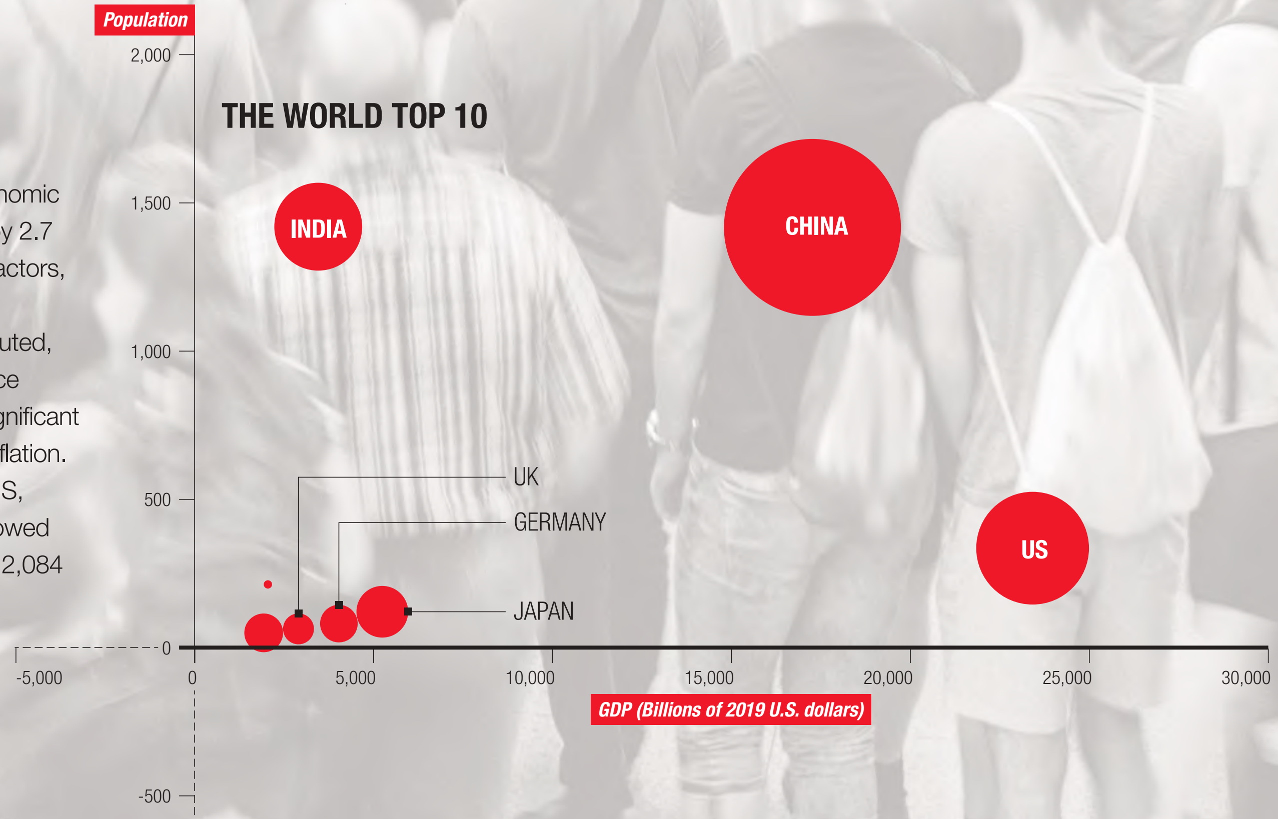


SHARE OF WORLD



GDP

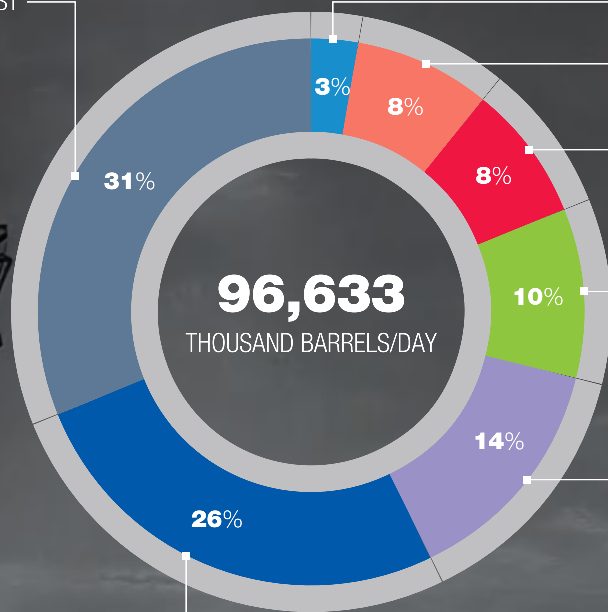
In 2023, despite widespread fears of a global recession, economic activity proved to be surprisingly resilient. Global GDP grew by 2.7 percent, consistent with 2022, driven by favorable demand factors, including stronger-than-expected government spending and household consumption. Supply-side expansion also contributed, helping to ease inflationary pressures. This economic resilience occurred in the face of weak overall growth, largely due to significant interest rate hikes by major central banks aiming to control inflation. The top ten economies by GDP continued to be led by the US, which saw a 2.5 percent increase compared to last year, followed by China and Japan. Italy ranked eighth, with a GDP of USD 2,084 billion, marking a 1 percent growth from 2022.



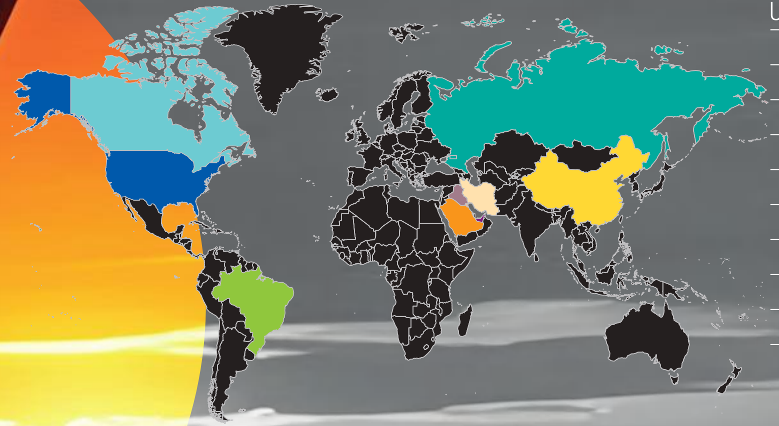
oil

PRODUCTION

Global oil production in 2023 grew by 1.8 mb/d compared to 2022, reaching 96.6 mb/d. This increase was concentrated in non-OPEC countries, particularly the US, which saw year-on-year growth of 1.5 mb/d. In contrast, OPEC production fell by 0.4 mb/d, reflecting the production cuts implemented throughout the year. By the second half of 2023, Saudi Arabia's production had fallen to around 9 mb/d, the lowest level since 2011 (excluding the pandemic period).
This decline was partially offset by strong growth in Iran, which, not being part of the OPEC+ agreement, saw its production rise to 4.2 mb/d—the highest since 2018. Despite Western sanctions, Russia maintained near-constant production levels, remaining at around 11 mb/d, almost unchanged from the previous year.



THE WORLD TOP 10 / PRODUCTION

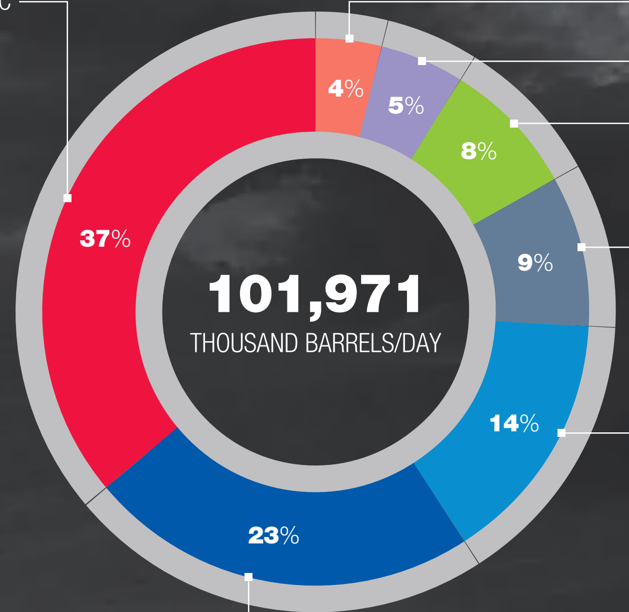


SHARE OF WORLD / PRODUCTION

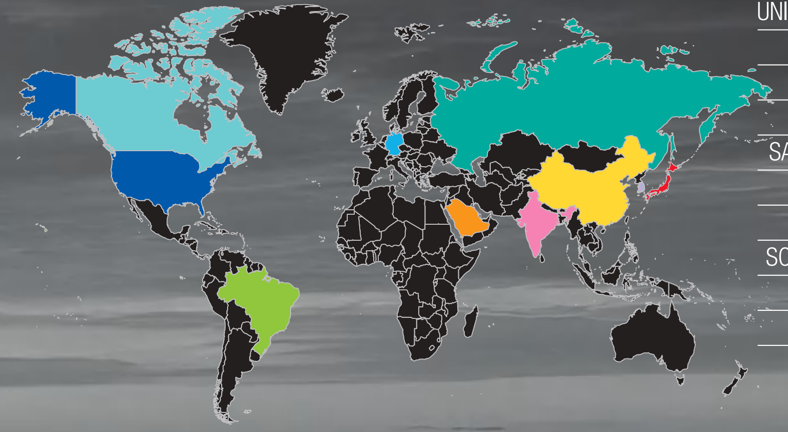
UNITED STATES	20.1%
SAUDI ARABIA	11.9%
RUSSIA	11.3%
CANADA	6.0%
IRAQ	4.6%
CHINA	4.4%
IRAN	4.4%
UAE	4.3%
BRAZIL	3.6%
KUWAIT	3.0%

CONSUMPTION

In 2023, global oil demand increased by 2.3 mb/d, reaching 102 mb/d, surpassing 2019 levels of 100.6 mb/d.
This growth was primarily driven by a surge in jet kerosene consumption, reflecting the post-COVID recovery of the aviation sector, as well as rising demand for raw materials in the petrochemical industry—namely naphtha, LPG, and ethane—fueled by the sector's continued expansion in China.
Global demand growth was led by non-OECD economies, with China alone accounting for nearly 80 percent of the increase in 2023.
In terms of consumption by country, the United States remained the largest consumer at 20.3 mb/d, followed by China at 16.4 mb/d, India at 5.4 mb/d, and Russia at 3.7 mb/d.



THE WORLD TOP 10 / CONSUMPTION

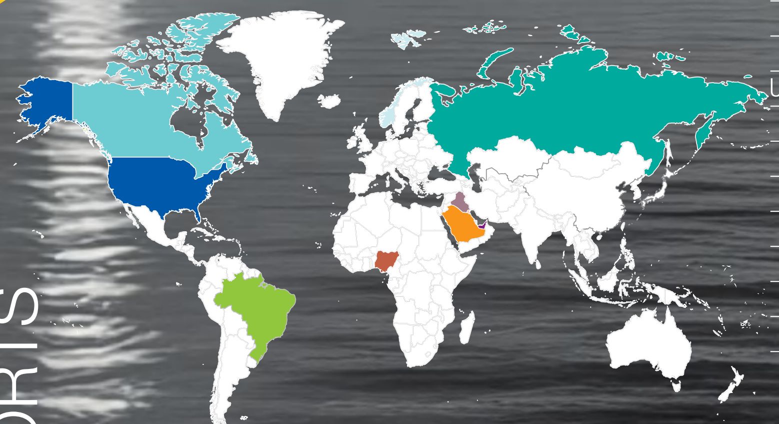


SHARE OF WORLD / CONSUMPTION

UNITED STATES	20.0%
CHINA	16.1%
INDIA	5.3%
RUSSIA	3.7%
SAUDI ARABIA	3.7%
JAPAN	3.3%
BRAZIL	3.2%
SOUTH KOREA	2.4%
CANADA	2.4%
GERMANY	2.0%

EXPORTS

THE WORLD TOP 10 / EXPORTS



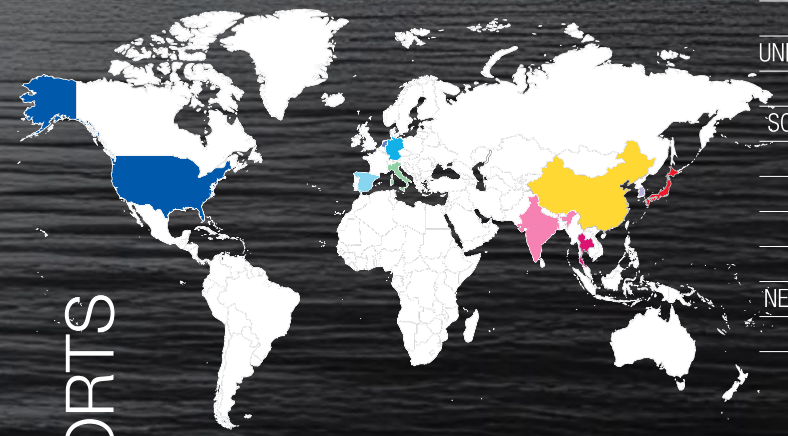
SHARE OF WORLD / EXPORTS

SAUDI ARABIA	15.3%
RUSSIA	11.2%
UNITED STATES	9.2%
CANADA	9.1%
IRAQ	7.9%
UAE	6.1%
NORWAY	3.9%
BRAZIL	3.7%
KUWAIT	3.6%
NIGERIA	3.4%

In 2023, the top five oil exporters were Saudi Arabia (6.6 mb/d), Russia (4.9 mb/d), the United States (4.0 mb/d), Canada (3.9 mb/d), and Iraq (3.5 mb/d).
Compared to the previous year, Saudi Arabia's exports dropped by 9.6 percent, while the United States saw a significant increase of 12.7 percent.

IMPORTS

THE WORLD TOP 10 / IMPORTS



SHARE OF WORLD / IMPORTS

CHINA	24.6%
UNITED STATES	14.0%
INDIA	10.2%
SOUTH KOREA	5.9%
JAPAN	5.5%
GERMANY	3.4%
SPAIN	2.7%
ITALY	2.7%
NETHERLANDS	2.3%
THAILAND	2.2%

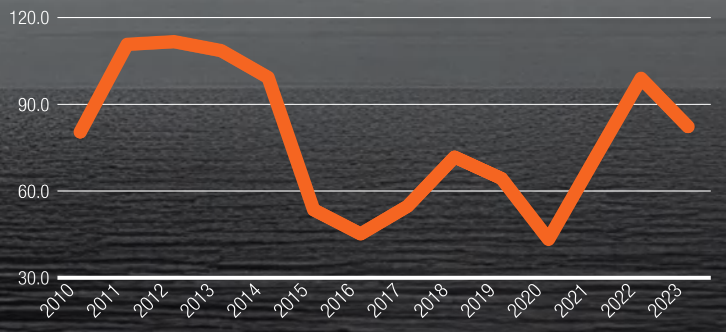
As in the previous year, in 2023 the top five oil importers, ranked in order, were China (11.3 mb/d), the United States (6.4 mb/d), India (4.7 mb/d), South Korea (2.7 mb/d), and Japan (2.5 mb/d).
Compared to the previous year, the respective changes in imports were: 11 percent for China, 3.3 percent for the United States, 0.4 percent for India, -0.9 percent for South Korea, and -6.7 percent for Japan.

FUTURES PRICES

In the futures market, Brent prices declined compared to the previous year, though they remained elevated.
The market found a partial balance, following the volatility of the early 2020s. This period was initially marked by a sharp decline during the COVID-19 pandemic, when prices dropped to $43 per barrel, followed by a spike in 2022 due to tensions related to the Russia-Ukraine war.
A similar trend was observed for WTI, which also decreased from 2022 levels but continued to remain high.

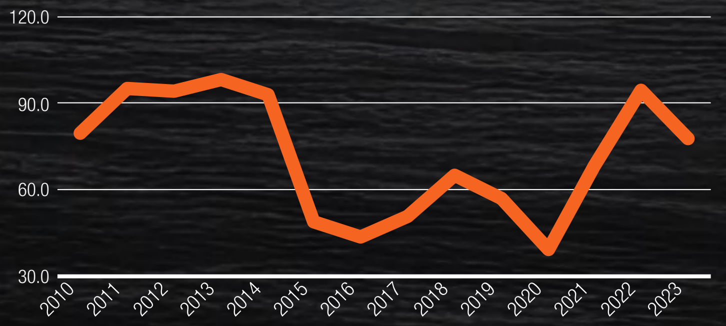
ICE BRENT PRICE - ONE MONTH

(US$/barrel)



CME WTI PRICE

(US$/barrel)

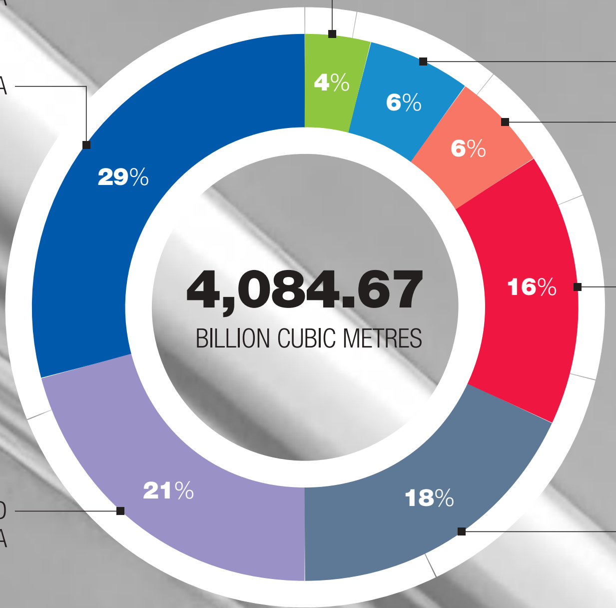


gas

PRODUCTION

Global gas production saw a slight increase in 2023, rising by 0.3 percent compared to 2022, reaching approximately 4,000 bcm. The United States recorded a notable growth of 3.4 percent (+34 bcm), while China grew by 6 percent (+12 bcm). In contrast, Russia experienced a decline in production of around 5 percent (-34 bcm), driven by reduced exports to Europe. The largest producers remained the United States, with a global share of 25.2 percent, followed by Russia (15.3 percent) and Iran (6.5 percent).

In terms of the production-to-consumption ratio, Norway led with a ratio of 23.71, followed by Qatar and Australia, both at 3.66.



THE WORLD TOP 10 / PRODUCTION

SHARE OF WORLD / PRODUCTION

UNITED STATES	25.2%
RUSSIA	15.3%
IRAN	6.5%
CHINA	5.5%
CANADA	5.0%
QATAR	4.4%
AUSTRALIA	3.8%
NORWAY	3.0%
ALGERIA	2.6%
SAUDI ARABIA	2.5%

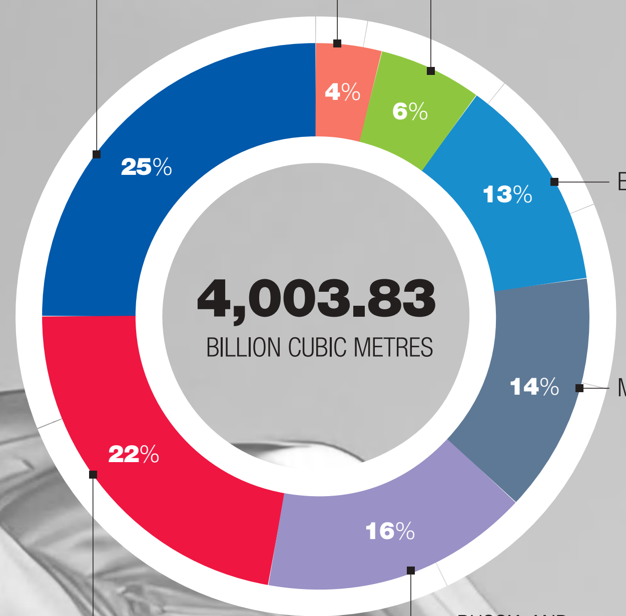
CONSUMPTION

Global gas demand remained stable in 2023, increasing by just 0.1 percent compared to 2022, holding at around 4,000 bcm. This stability masked divergent dynamics on a global scale: favorable weather conditions and economic factors reduced demand in Europe and limited growth in Asia, allowing supply to meet gas requirements, including the replenishment of stockpiles.

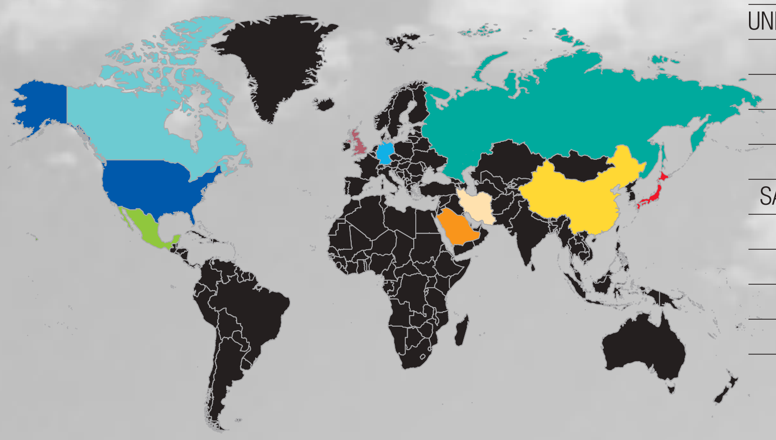
While China saw a consumption increase of 7 percent, the EU experienced a decline of 7 percent, largely due to reductions in the residential and power sectors.

In 2023, the largest gas consumers remained the United States (883 bcm), Russia (498 bcm), and China (371 bcm), accounting for 22.1 percent, 12.4 percent, and 9.3 percent of global consumption, respectively.

In terms of per capita consumption, Canada led the world with 3,500 cubic meters per person, followed by Russia (3,400) and Iran (2,800).



THE WORLD TOP 10 / CONSUMPTION

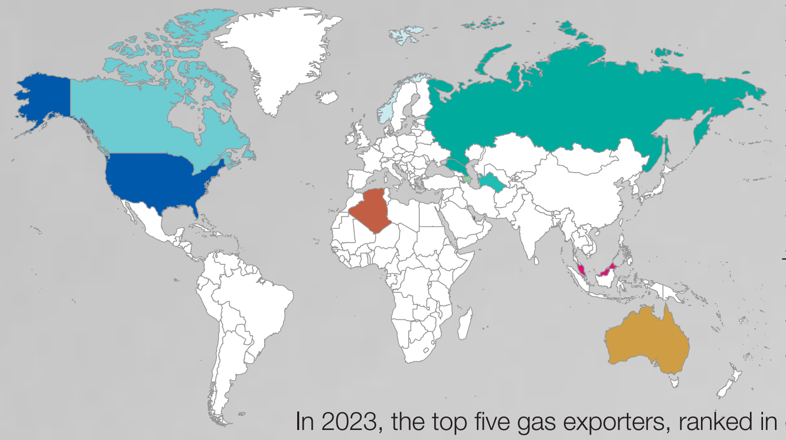


SHARE OF WORLD / CONSUMPTION

UNITED STATES	22.1%
RUSSIA	12.4%
CHINA	9.3%
IRAN	6.3%
CANADA	3.5%
SAUDI ARABIA	2.5%
JAPAN	2.3%
MEXICO	2.2%
GERMANY	1.8%
INDIA	1.7%

EXPORTS AND IMPORTS

THE WORLD TOP 10 / EXPORTS

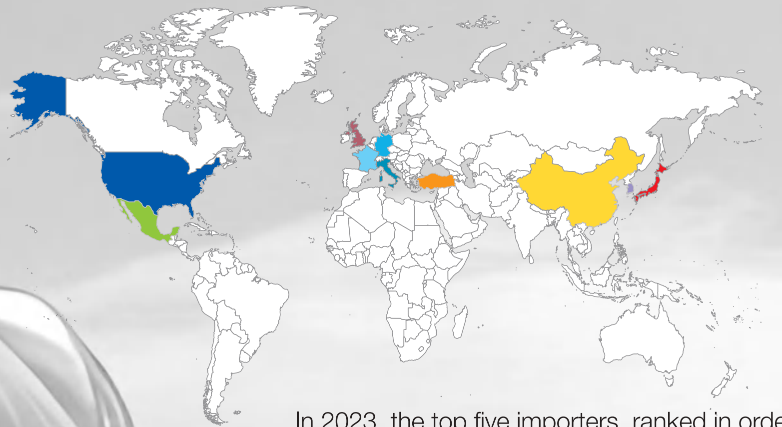


SHARE OF WORLD / EXPORTS

UNITED STATES	17.6%
RUSSIA	10.9%
QATAR	10.7%
NORWAY	9.6%
AUSTRALIA	9.4%
CANADA	6.7%
ALGERIA	4.3%
TURKMENISTAN	4.2%
MALAYSIA	2.8%
AZERBAIJAN	1.9%

In 2023, the top five gas exporters, ranked in order, were the United States (212 bcm), Russia (132 bcm), Qatar (129 bcm), Norway (116 bcm), and Australia (114 bcm). The growth rates from 2010 to 2023 were 16.1 percent for the United States, -2.3 percent for Russia, 2.1 percent for Qatar, 0.9 percent for Norway, and 12.6 percent for Australia.

THE WORLD TOP 10 / IMPORTS



SHARE OF WORLD / IMPORTS

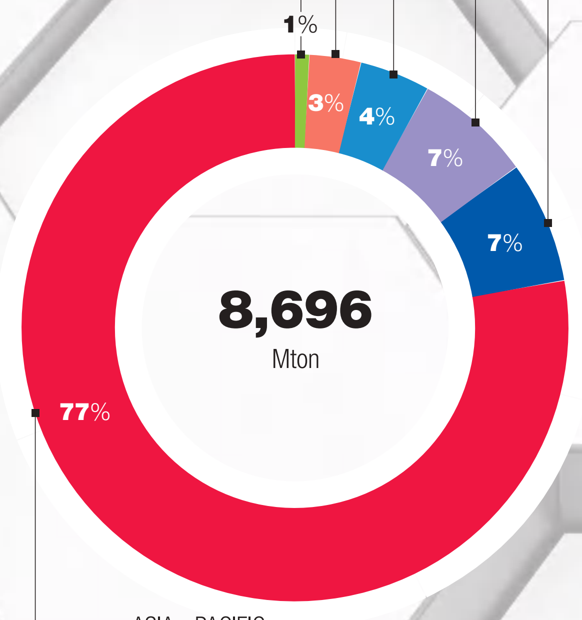
CHINA	13.1%
JAPAN	7.7%
UNITED STATES	7.1%
GERMANY	6.0%
SOUTH KOREA	5.3%
ITALY	5.1%
TÜRKIYE	4.2%
FRANCE	4.2%
MEXICO	4.0%
UK	3.9%

In 2023, the top five importers, ranked in order, were China (151 bcm), Japan (89 bcm), the United States (82 bcm), Germany (69 bcm), and South Korea (61 bcm). Notably, China's growth rate from 2010 to 2023 was 19.6 percent.

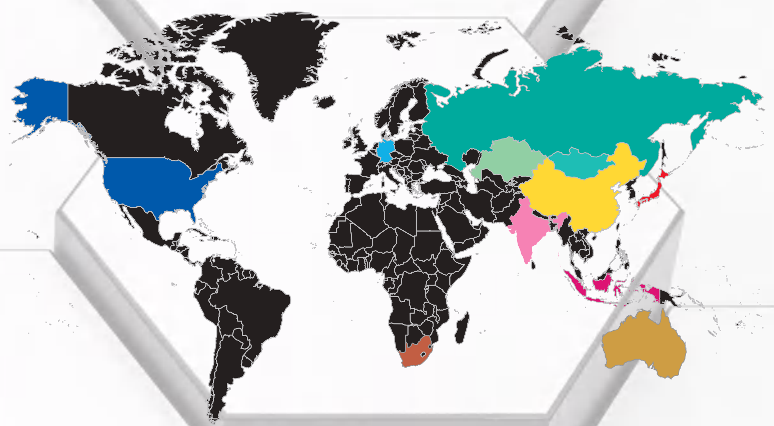
coal

PRODUCTION

In 2023, coal production reached approximately 8,700 Mt, an increase of 2.6 percent compared to 2022. China dominated the market, accounting for 51 percent of global production, with a trend of continuous growth. Following China were Indonesia (0.8 Mt), India (0.7 Mt), the United States (0.6 Mt), and Russia (0.5 Mt).



THE WORLD TOP 10 / PRODUCTION

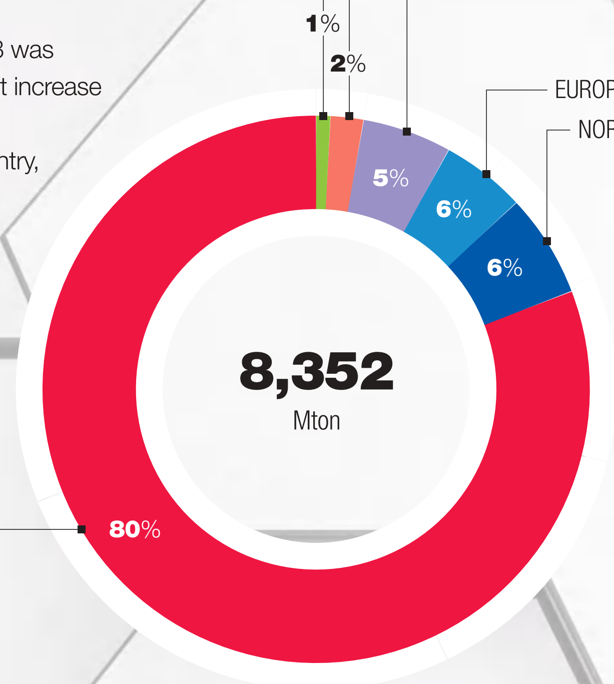


SHARE OF WORLD / PRODUCTION

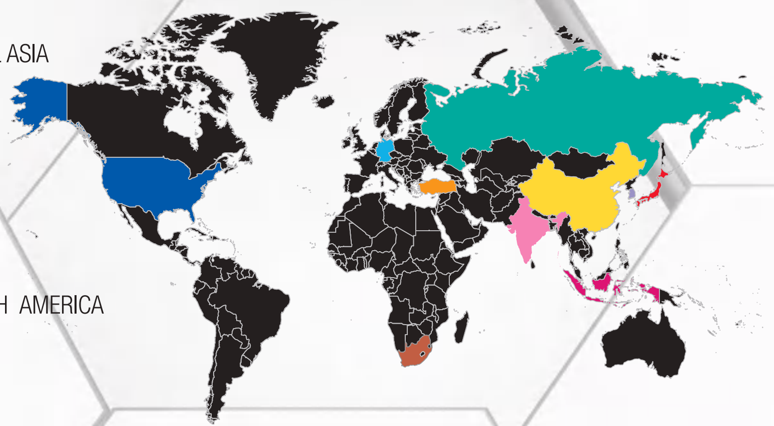
CHINA	50.9%
INDONESIA	9.3%
INDIA	8.9%
UNITED STATES	6.6%
RUSSIA	5.7%
AUSTRALIA	5.6%
SOUTH AFRICA	3.0%
KAZAKHSTAN	1.2%
GERMANY	1.1%
MONGOLIA	1.0%

CONSUMPTION

Global coal consumption in 2023 was approximately 8.3 Mt, a 2.2 percent increase from the previous year.
In terms of consumption by country, China led with 4.7 Mt, followed by India at 1 Mt and the United States at 0.4 Mt.



THE WORLD TOP 10 / CONSUMPTION



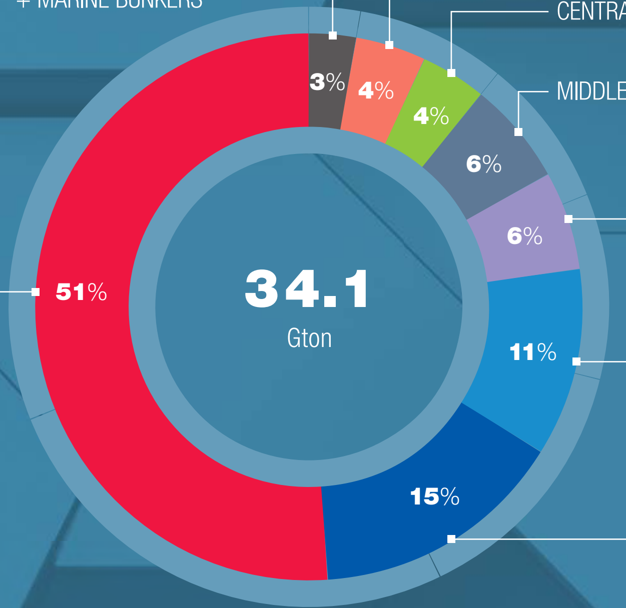
SHARE OF WORLD / CONSUMPTION

CHINA	56.0%
INDIA	12.0%
UNITED STATES	5.4%
RUSSIA	3.5%
INDONESIA	2.4%
JAPAN	2.2%
SOUTH AFRICA	2.1%
GERMANY	1.5%
SOUTH KOREA	1.5%
TÜRKIYE	1.3%

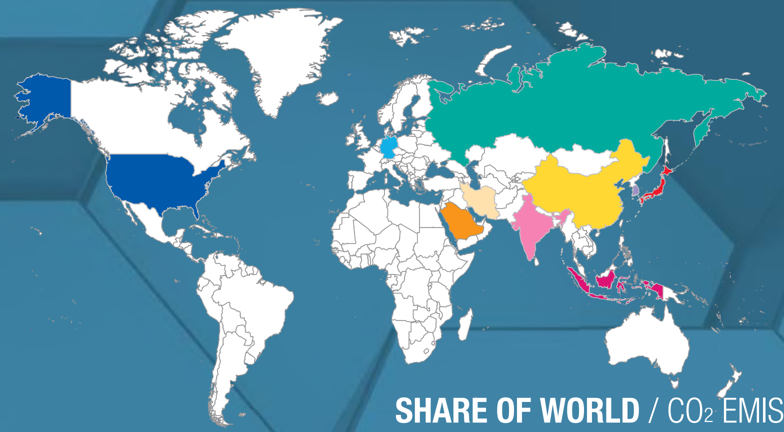
emissions

CO_2 EMISSIONS

In 2023, global energy-related CO_2 emissions increased by 1.1 percent, reaching a new record of 37.2 Gt. The increase was driven by China, which alone accounted for one-third of the global CO2 emissions, and India, which for the first time surpassed the EU by contributing over 7%.
In contrast, emissions from advanced economies fell to levels not seen in 50 years, primarily due to coal-to-gas switching and a greater contribution from clean energy in electricity generation.



THE WORLD TOP 10 / CO_2 EMISSION

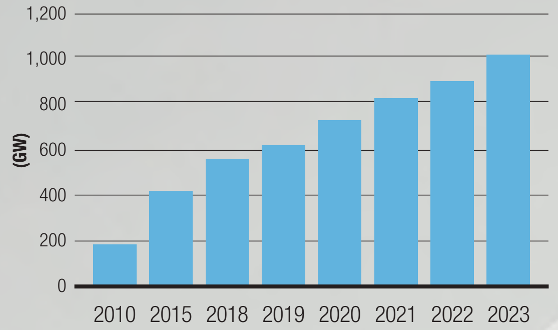


SHARE OF WORLD / CO_2 EMISSION

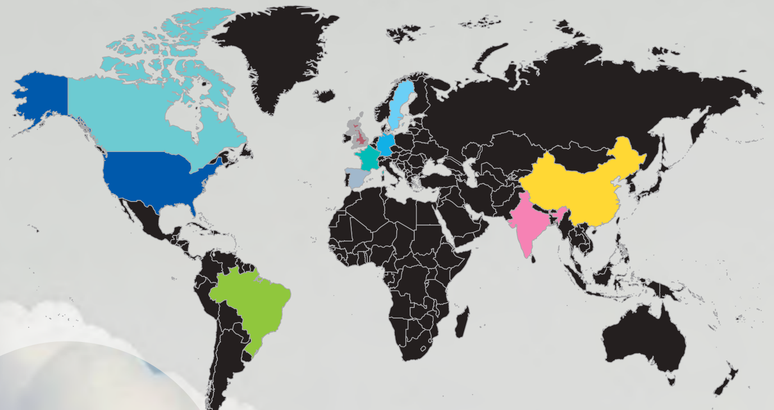
CHINA	32.5%
UNITED STATES	13.2%
INDIA	7.8%
RUSSIA	4.8%
JAPAN	2.7%
IRAN	2.1%
INDONESIA	1.8%
GERMANY	1.5%
SOUTH KOREA	1.6%
SAUDI ARABIA	1.6%

renewables

WIND POWER CAPACITY



THE WORLD TOP 10 / WIND POWER CAPACITY



SHARE OF WORLD / WIND POWER CAPACITY

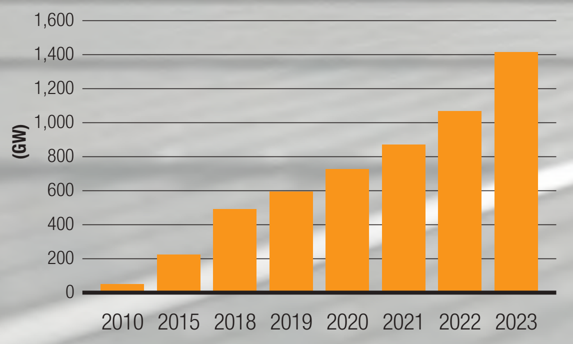
CHINA	43.4%
UNITED STATES	14.5%
GERMANY	6.8%
INDIA	4.4%
SPAIN	3.0%
UK	3.0%
BRAZIL	2.9%
FRANCE	2.0%
CANADA	1.7%
SWEDEN	1.6%

WIND POWER

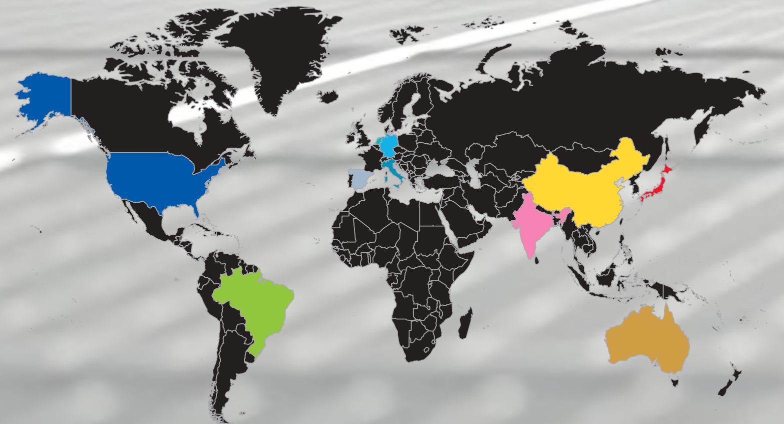
In 2023, the wind energy sector experienced growth, with capacity increasing by 115 GW compared to 2022 (+13 percent), bringing the total to 1,017 GW.
China and the United States remained the dominant players in this sector, accounting for 43 percent and 15 percent of the global total, respectively.

China contributed the most to this growth, with a year-on-year increase of 76 GW.
Wind energy generation reached 2,119 TWh in 2022, up 13.7 percent from 2021.
The largest producers were China (885 TWh), the United States (430 TWh), and Germany (140 TWh).

SOLAR POWER CAPACITY



THE WORLD TOP 10 / SOLAR POWER CAPACITY



SHARE OF WORLD / SOLAR POWER CAPACITY

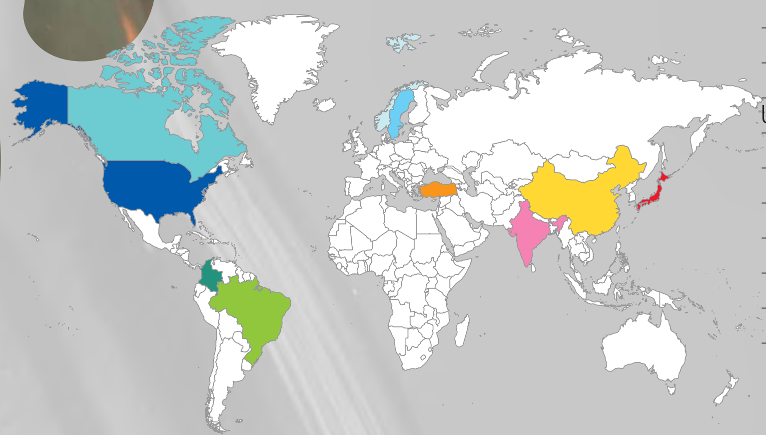
CHINA	43.2%
UNITED STATES	9.8%
JAPAN	6.3%
GERMANY	5.8%
INDIA	5.2%
BRAZIL	2.7%
AUSTRALIA	2.3%
ITALY	2.1%
SPAIN	2.0%
NETHERLANDS	1.7%

PHOTOVOLTAICS

In 2023, the photovoltaic sector continued to lead the renewable energy industry, with capacity increasing by 347 GW (+33 percent) compared to 2022. This growth was primarily driven by China (+217 GW, +55 percent from the previous year) and, to a lesser extent, the United States (+25 GW, +22 percent from the previous year).
By the end of 2023, total cumulative capacity had reached approximately 1,411 GW, with China and the United States accounting for 43 percent and 10 percent of global capacity, respectively.
Solar energy generation reached 1,293 TWh in 2022, a 27 percent increase from 2021. The largest producers of solar energy were China (584 TWh), the United States (213 TWh), and India (119 TWh).

power generation

THE WORLD TOP 10



CHINA	1,248,423 GWh
BRAZIL	425,996 GWh
CANADA	363,559 GWh
UNITED STATES	241,512 GWh
INDIA	143,871 GWh
NORWAY	136,725 GWh
JAPAN	76,747 GWh
SWEDEN	66,283 GWh
TÜRKIYE	63,840 GWh
COLOMBIA	57,245 GWh

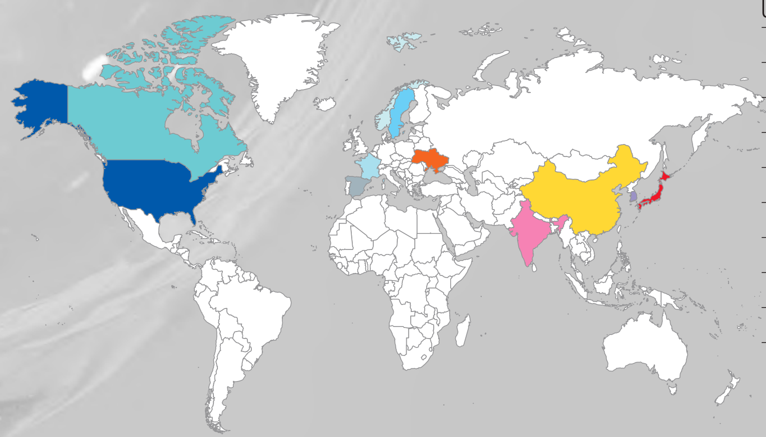
HYDROPOWER

In 2023, China remained the world's leading country for hydropower generation, producing approximately 1,250 TWh, a 5 percent decrease compared to 2022. Brazil ranked second globally with 426 TWh, followed by Canada with 363 TWh.

NUCLEAR

In 2023, the United States was the world's leading country for nuclear power generation, producing approximately 810 TWh, followed by China with 435 TWh and France with 340 TWh.

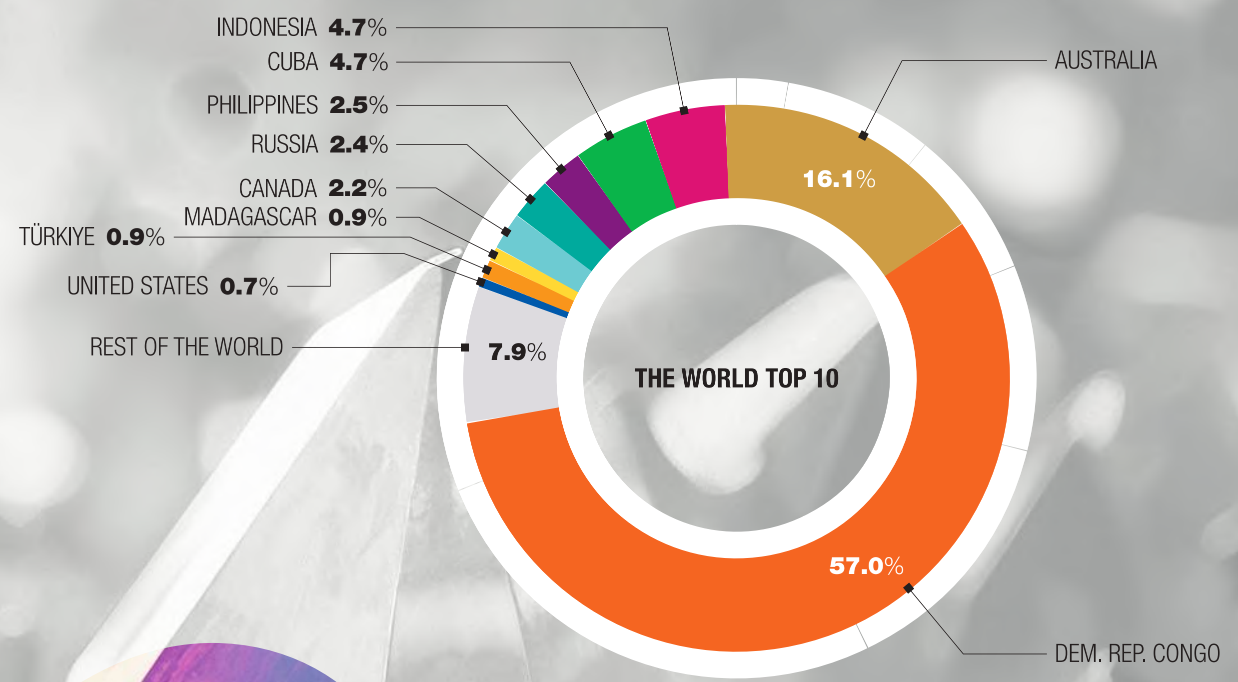
THE WORLD TOP 10



UNITED STATES	808,667 GWh
CHINA	434,720 GWh
FRANCE	338,202 GWh
SOUTH KOREA	180,479 GWh
CANADA	89,640 GWh
JAPAN	84,055 GWh
SPAIN	56,873 GWh
UKRAINE	51,937 GWh
SWEDEN	48,289 GWh
INDIA	47,937 GWh

COBALT RESERVES

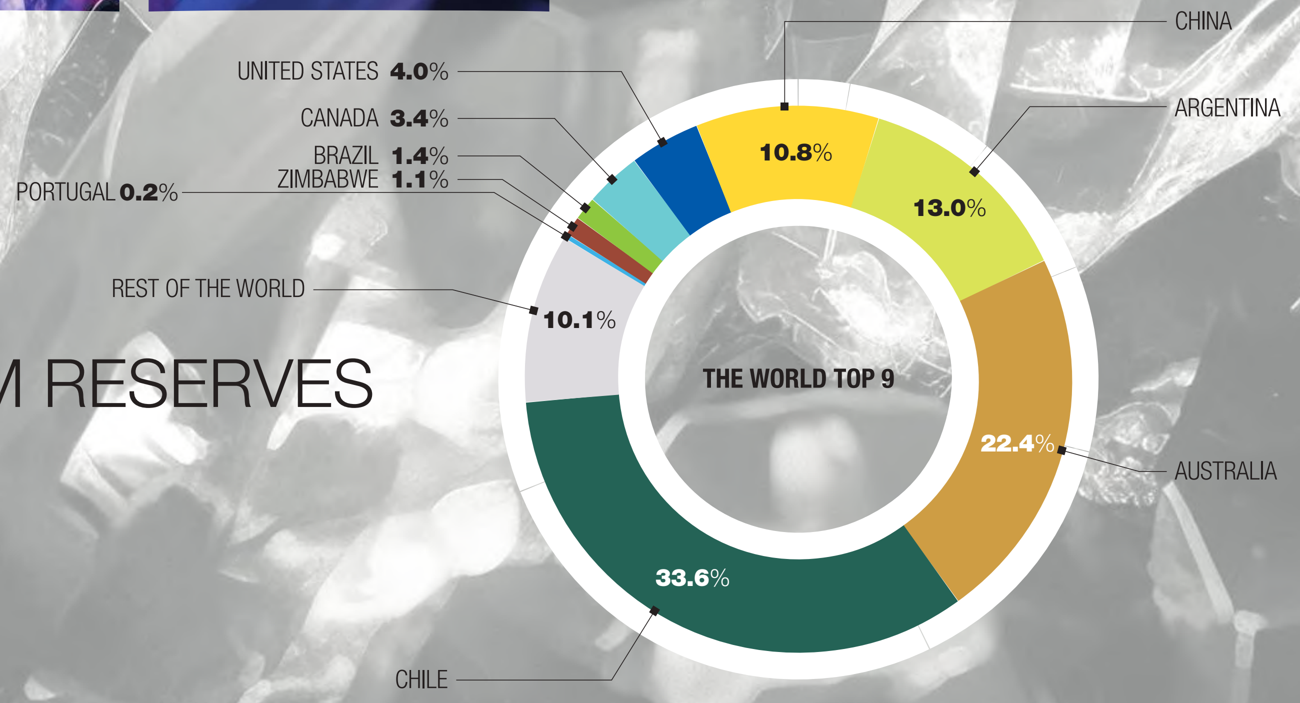
Cobalt and lithium are the most concentrated critical minerals in terms of reserves and production.
Cobalt reserves grew by 2,700 kt (+33 percent) in 2023, with the most significant increase recorded in the Democratic Republic of Congo (+2,000 kt), which now holds 57 percent of the world's reserves.
For lithium, reserves increased by 2,000 kt compared to 2022, driven by larger reserves in China and Argentina. However, Chile remains the country with the highest concentration of lithium reserves, holding 34 percent of the global total.



critical minerals

In terms of production, 74 percent of the world's cobalt is concentrated in the Democratic Republic of the Congo (DRC), 68 percent of rare earth elements in China, over 50 percent of nickel in Indonesia, and nearly 50 percent of lithium is produced in Australia.

LITHIUM RESERVES



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