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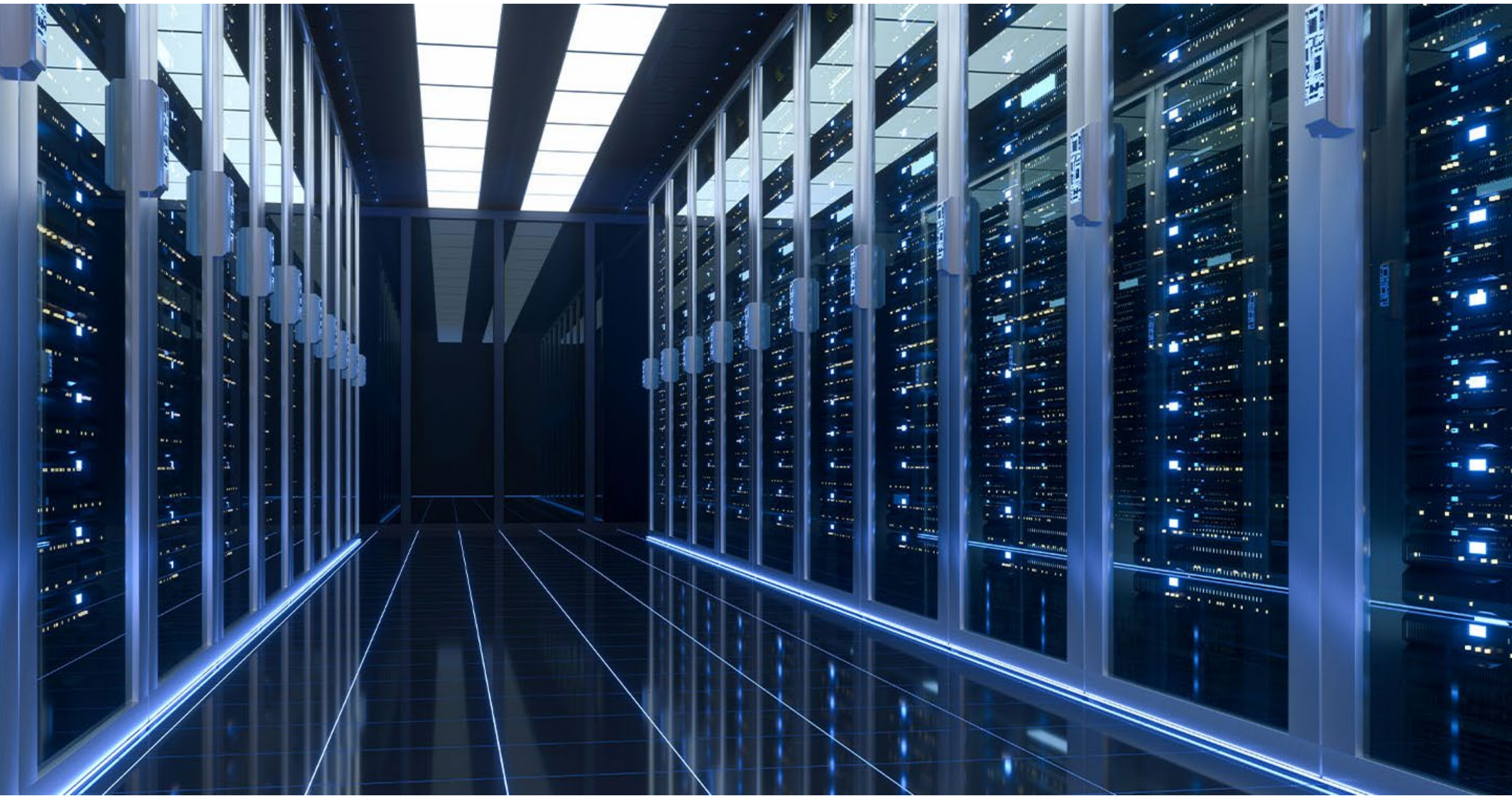
Electric Power & Natural Gas Practice

The role of power in unlocking the European AI revolution

The rise of AI is driving data center demand and shifting power market dynamics. With European demand predicted to more than triple by 2030, significant investments are needed to realize this growth.

This article is a collaborative effort by Anna Granskog, Diego Hernandez Diaz, Jesse Noffsinger, Lorenzo Moavero Milanesi, and Pankaj Sachdeva, with Arjita Bhan and Sofia von Schantz, representing views from McKinsey's Electric Power & Natural Gas and Technology, Media & Telecommunications Practices.



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Digitization, rapid advancements in AI technologies, and slower gains in power usage efficiency have significantly escalated the demand for data centers, with major implications for global power market dynamics. In Europe, demand for data centers is expected to grow to approximately 35 gigawatts (GW) by 2030, up from 10 GW today.[1] To meet this new IT load demand, more than $250 to $300 billion of investment will be needed in data center infrastructure, excluding power generation capacity.[2]

The exponential growth in data center demand comes with a corresponding surge in power demand. At the current rate of adoption, Europe's data center power consumption is expected to almost triple from about 62 terawatt-hours (TWh) today to more than 150 TWh by the end of the decade.[3] This increase will be one of the primary near-term growth drivers for power demand in Europe, with data centers accounting for about 5 percent of total European power consumption in the next six years (from approximately 2 percent today).[4] Based on the net-zero commitments announced by many major data center players, this demand is expected to be largely for green power.[5]

Currently, the entire European power ecosystem faces significant challenges in accommodating this growing demand. These include limited sources of reliable power, sustainability concerns, insufficient upstream infrastructure for power access, land availability issues, shortages of power equipment used in data centers, and a lack of skilled electrical tradespeople for building facilities and infrastructure. In large, established markets such as Dublin and Frankfurt, the time required to supply power to new data centers can exceed three to five years, with lead times for electrical equipment alone often surpassing three years.[6]

Meeting data center demand will be important if Europe is to unleash AI's full economic potential. It could also come with the broader benefit of helping to unlock the critical investment needed in European power infrastructure to support the ongoing energy transition.

In this article, we address this rapidly evolving space, looking at the prospective growth of AI and the corresponding demand for data centers; the challenges in scaling data centers; and how investors and incumbents could get ahead in the race for power (see sidebar "The evolving energy transition: McKinsey's latest analysis").

Data centers can create significant economic value

Globally, data center power demand is skyrocketing to meet the need for greater computing power and the connectivity demands of digitization, cloud migration, and emerging technologies such as AI. In particular, AI is driving power demand because it has significantly higher power density requirements that come with the new generation of graphic processing unit (GPU) chipsets.

According to McKinsey research, about $10 trillion of economic value could be created across the global economy by AI and analytics.[7] However, realizing even a quarter of this potential by the end of the decade would require an additional 50 to 75 GW of data center infrastructure worldwide.

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[1] McKinsey data center demand model. For the analysis in this article, Europe refers to the European Union plus Norway, Switzerland, and the United Kingdom. There may be some gaps in the data based on data availability.
[2] This total excludes investments required for IT equipment inside data centers and upstream investments in transmission and distribution infrastructure.
[3] This calculation excludes power consumption for cryptocurrency.
[4] Paolo Bertoldi and George Kamiya, "Energy consumption in data centers and broadband communication networks in the EU," European Commission, JRC Publications Repository, February 16, 2024.
[5] *Our path to net zero*, Meta, July 2023; "Microsoft is committed to achieving zero carbon emissions and waste by 2030," Microsoft, May 18, 2023; and "The climate pledge," Amazon, theclimatepledge.com, 2019.
[6] Expert interviews; McKinsey data center demand model.
[7] "The executive's AI playbook," QuantumBlack, AI by McKinsey, October 2024.

The evolving energy transition: McKinsey's latest analysis

This article is part of McKinsey's recent series of articles taking stock of the energy transition:

"The energy transition: Where are we, really?" explores the reality gap between current low-carbon technology deployment and what is required to achieve net-zero targets.[1]

Global Energy Perspective 2024 offers a detailed energy demand outlook for 68 sectors and 78 fuels on a 1.5° pathway, as set out in the Paris Agreement, as well as three bottom-up energy transition scenarios: the Sustainable Transformation scenario, the Continued Momentum scenario, and the Slow Evolution scenario. These scenarios have been updated this year to reflect changing global conditions, including geopolitical challenges, increasingly complex supply chains, and higher inflation.[2]

Global Materials Perspective 2024, published for the first time this year, provides an in-depth look at the critical materials needed to enable the energy transition and the impact of this need on the materials supply-and-demand landscape.[3]

The hard stuff: Navigating the physical realities of the energy transition explores the 25 interlinked physical challenges that need to be tackled to advance the energy transition, including developing and deploying new low-emissions technologies and entirely new supply chains and infrastructure to support them.[4]

"How data centers and the energy sector can sate AI's hunger for power" delves into the data center and power infrastructure investment potential in the United States as power demand from AI continues to surge.[5]

"Electricity demand in Europe: Growing or going?" provides a detailed review of how the rising uncertainty surrounding future electricity demand could complicate Europe's plans for energy transition and power infrastructure investment.[6]

[1] "The energy transition: Where are we, really?" McKinsey, August 27, 2024.
[2] *Global Energy Perspective 2024,* McKinsey, September 17, 2024.
[3] *Global Materials Perspective 2024,* McKinsey, September 17, 2024.
[4] *The hard stuff: Navigating the physical realities of the energy transition,* McKinsey, August 14, 2024.
[5] "How data centers and the energy sector can sate AI's hunger for power," McKinsey, September 17, 2024.
[6] "Electricity demand in Europe: Growing or going?" McKinsey, October 24, 2024.

While the growth in data center build-out will be strongest in the United States, Europe has ample opportunity to grow its market and further stimulate its technology ecosystem.[8] The total IT load demand for data centers in the region is expected to grow from 10 GW in 2023 to approximately 35 GW in 2030 (Exhibit 1).

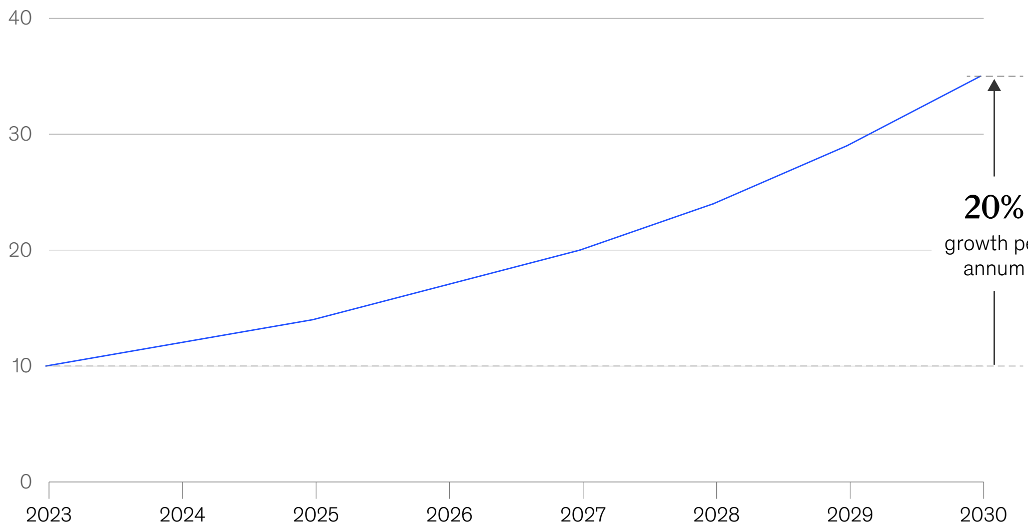
Meeting this demand will require an extensive increase in electricity supply; a notable shift for

[8] "How data centers and the energy sector can sate AI's hunger for power," McKinsey, September 17, 2024.

Exhibit 1

Data center growth in Europe could reach 35 gigawatts by 2030, increasing by 20 percent per annum.

Estimated data center demand (IT load),[1] Europe, gigawatts (GW)



[1]IT load excluding demand for crypto-mining data centers. Assuming London constitutes 90% of the United Kingdom's demand, and Frankfurt and Berlin together constitute 91% of Germany's demand.
Source: DC Byte; McKinsey data center demand model

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Europe, where aggregate power demand has remained relatively stagnant since 2007.[9]

While there has been much discussion about potential increased power demand growth from domestic manufacturing, electric vehicles (EVs), heat pumps, and electrolyzers, the demand from data centers is immediate and substantial. Data center load could account for 15 to 25 percent of all new net European demand added through 2030 (see sidebar "What makes data center load unique?"). Between 2023 and 2030, electricity demand for data centers in Europe is projected to increase by approximately 85 TWh, with a CAGR of about 13 percent (Exhibit 2).

At present, data center growth in Europe is fueled by hyperscalers and colocation leases (see sidebar "Data center archetypes"), with hyperscalers alone driving up to 70 percent of the anticipated demand by 2028 (Exhibit 3).

Challenges across the European power value chain

The expected data center-related surge in power consumption will likely be accompanied by a shift to renewable and low-carbon energy sources as the global energy transition gathers pace and new policies emerge. The European Commission has already adopted regulation to allow it to

[9] "European power demand: Growing or going?" McKinsey, October 2024.

assess the sustainability of data centers within the European Union.[10] The recast Energy Efficiency Directive requires data center operators to report on KPIs to the European database, starting in 2024.

Data center operators need to consider three key factors when building out new capacity:

1. **Energy intermittency:** Meeting higher requirements for access to fast power with zero risk of interruption (that is, reducing time to grid and ensuring backup solutions)

2. **CO_2-free energy:** Securing green energy in the market, including through power purchase agreements (PPAs)

3. **On-site generation:** Adopting independent generation capacity at data center sites

[10] "Commission adopts EU-wide scheme for rating sustainability of data centers," European Commission, March 15, 2024.

What makes data center load unique?

Depending on the workload, data centers can draw power around the clock, with some intraday variation, much like other industrial centers.[1] However, data centers present a unique profile that differentiates them from utility companies and investors.

First, most data centers are sited with backup energy storage systems to ensure high uptime requirements are met. This backup can be dispatched to offset a data center's load when grid conditions become tight, thus creating a load that is, in effect, highly responsive.

Second, data center owners typically have a higher willingness than most other power customers to pay for power. Electricity operating expenditures can make up about 20 percent of the total cost base for data center business models, which have proved to be highly profitable for large companies. Therefore, higher power rates do not disrupt the business model. In comparison, for other electricity sources, such as green-hydrogen production, the final product cost is highly dependent on electricity prices, and the expected margins are much thinner.

Third, the demand outlook for data centers and owners' willingness to pay are outliers among uses of electricity. For most uses, power is converted to a physical final product (such as an LED light bulb) and energy efficiency is measured as a percentage (for example, an LED light bulb uses 90 percent less energy than an incandescent one). Computing power is measured by order of magnitude rather than percentage, and the output of power consumption for data centers is information rather than a physical good. Breakthroughs that allow access to low-cost, highly efficient compute do not necessarily lower the demand for electricity. Rather, such breakthroughs may increase the complexity of models that can be run, and they may even enable more use cases that lead to more power demand. In short, the power sector's conventional operational parameters may warrant some reconsideration before they are applied to data centers.

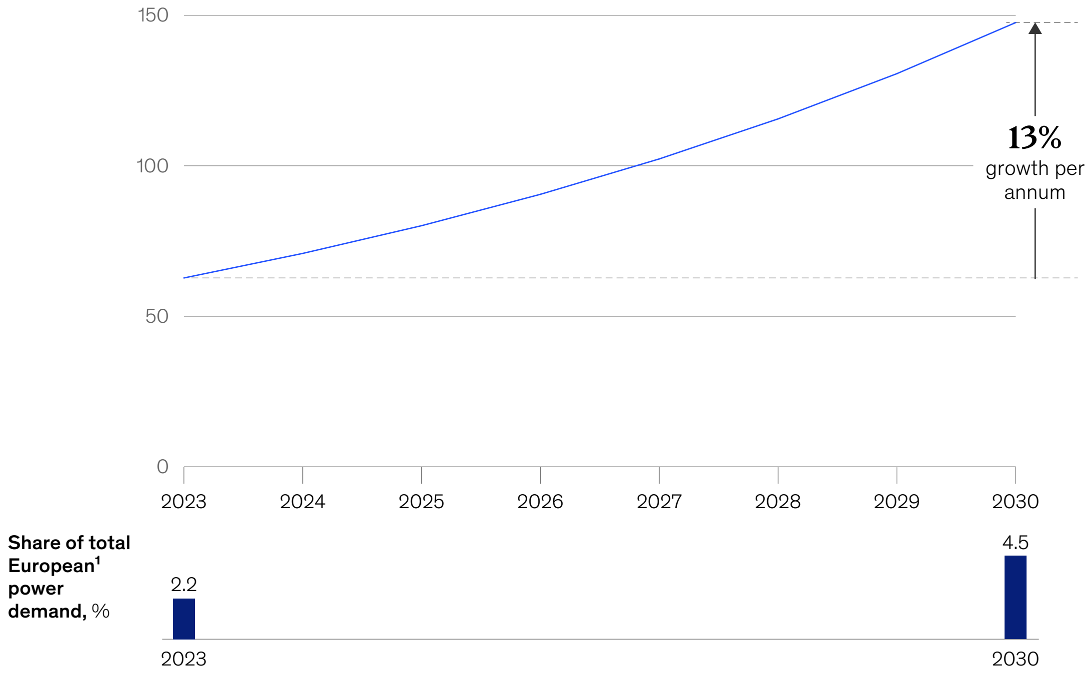
Fourth, innovative cooling solutions offer significant savings potential. After IT equipment and servers, data center cooling systems generally consume the most energy, highlighting a major opportunity for enhancing efficiency. Hyperscalers are experimenting with remote locations to take advantage of local conditions—for example, using cold outside air to cool server rooms, thereby consuming minimal energy during colder months. Additionally, such locations offer opportunities to recycle heat generated at data centers into district heating systems.[2]

[1] "How data centers and the energy sector can sate AI's hunger for power," McKinsey, September 17, 2024.
[2] Ben Townsend, "Our first offsite heat recovery project lands in Finland," Google, May 20, 2024.

Exhibit 2

Power demand for data centers will rise significantly in Europe.

Data center energy consumption, Europe,[1] terawatt-hours (TWh)



[1]EU-27 + the United Kingdom.
Source: Global Energy Perspective 2024; McKinsey analysis

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Data center archetypes

There are three types of data centers: hyperscalers, colocators, and enterprise (self-owned).

A **hyperscaler** refers to a player that offers large-scale cloud computing services with the ability to rapidly scale up or down. Hyperscalers such as Amazon Web Services (AWS) and Microsoft Azure operate vast global networks of data centers, providing infrastructure as a service (IaaS) and platform as a service (PaaS) offerings. They manage massive amounts of computing power and storage, allowing businesses to leverage these resources on demand, paying only for what they use. Hyperscalers are known for their ability to handle enormous workloads and provide a seamless experience for customers with diverse needs.

A **colocation** provider, on the other hand, offers physical space, power, and cooling in its data centers for customers to house their own servers and networking equipment. Unlike hyperscalers, colocation facilities do not provide the hardware; instead, they provide a secure, managed environment where businesses can rent space and maintain control over their own equipment.

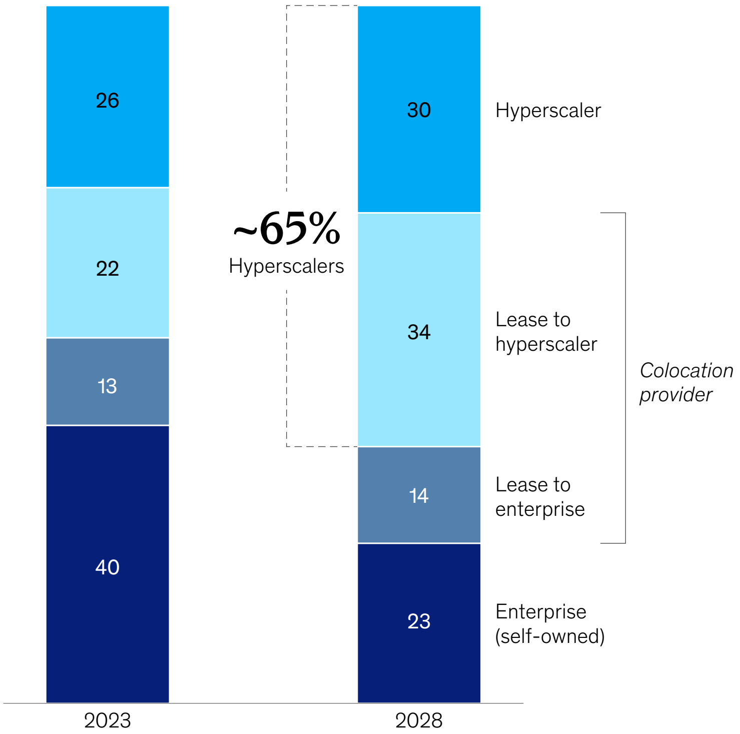
This model is ideal for companies that require full control over their hardware but still want the benefits of a professional data center, such as enhanced security, reliability, and connectivity.

An **enterprise** (self-owned) data center is a facility that a company owns and operates to house its own IT infrastructure, including servers, storage, and networking equipment. Unlike hyperscalers or colocation facilities, where infrastructure or space is rented from a third party, enterprise data centers are fully controlled by the organization that owns them. These data centers are typically located on the company's premises or at a dedicated off-site location and are designed to meet the specific needs and requirements of that business.

Exhibit 3

Hyperscalers are forecast to drive 65 to 70 percent of the demand for data centers by 2028.

Data center demand by ownership, Europe, %



Note: Figures may not sum to 100%, because of rounding.

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Energy intermittency

According to data center experts, hyperscalers have an average capacity utilization of 80 to 95 percent. While data centers operate quite steadily, their high uptime requirements necessitate a stable connection to power. However, they may lack control mechanisms to ensure consistent power, largely due to demand growth by 2030. Given that a 10 percent fluctuation in power demand across a set of five 1 GW data centers is equivalent to the power output of a full gas power plant, this high uptime requirement is likely to stress the grid and increase the need for flexibility.

In locations where the power system is unable to accommodate them all, data centers may need to manage their own power balancing. A combination of (underutilized) combined-cycle gas turbines and battery storage paired with on-site backup generators could provide this balancing capacity. In Europe, green firming solutions—such as hydro, thermal capacity with carbon capture, utilization, and storage (CCUS), and nuclear (though this is less common and country- or bidding-zone specific)—could also help to balance the system.

Transmission capacity affects various aspects of data center performance, including speed, scalability, reliability, and energy efficiency. McKinsey research shows that, for data center operators, time to market is the most critical consideration when deploying new capacity. However, connection time for new facilities has increased significantly due to a combination of factors, including renewables being connected to the system, growing electrification across the economy (from EVs, heat pumps, and electrolyzers), and grid investments lagging behind those in generation.[11] In addition, the long lead times of transmission planning—compared to the shorter time frame required to plan and build data centers—creates a potential shortfall in transmission capacity.

The time required to get new power connections for data center sites in major hubs such as Frankfurt has been on the rise. There are even locations, such as Amsterdam and Dublin, that have placed moratoriums on new data center builds in recent years, primarily because of a lack of power infrastructure to support them.

CO_2-free energy

The data center industry faces a big challenge to decarbonize its footprint and reach net-zero targets on a 2030–40 timeline.[12] Both hyperscalers and colocators are partnering with energy players to secure low-carbon electricity supply during hours when power from their own renewable energy sources is low. So far, PPAs have emerged as the leading strategy for hyperscalers to fulfill their renewable energy commitments. Technology companies remain a large contributor of PPA growth; last year, Amazon acquired more PPAs globally than any other company.[13]

Hyperscalers are relying on renewable energy certificates (RECs) to offset their real-world emissions.[14] While some focus on matching their energy consumption with RECs from the grids where they operate, others are increasingly purchasing certificates tied to power generated at different times and locations. Researchers point out that this carbon matching has a minimal impact on long-term emissions in power systems and rarely incentivizes the development of new projects or the generation of clean energy in areas that wouldn't otherwise see such initiatives.[15]

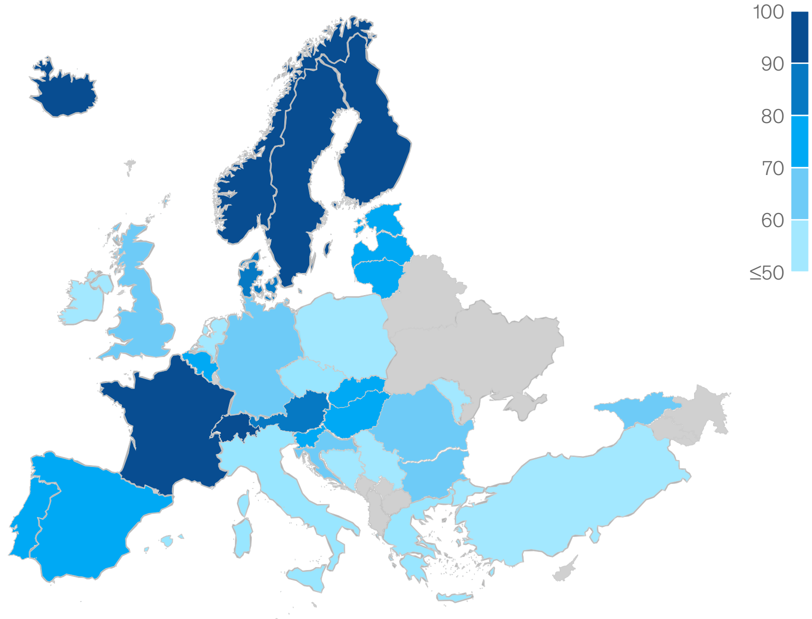
Energy-related emissions can also be partially reduced through strategic site selection. This includes choosing locations where the grid mix has a high proportion of carbon-free energy and where temperatures are inherently lower, reducing the need for cooling-related power consumption (Exhibit 4).

[11] *World energy investment 2024,* International Energy Agency, June 2024.
[12] "24/7 Carbon-free energy by 2030," Google Data Centers; "Microsoft's sustainability commitments," Microsoft Datacenters.
[13] Kyle Harrison, "Amazon is top green energy buyer in a market dominated by US," BloombergNEF, February 26, 2024.
[14] Kenza Bryan, Camilla Hodgson, and Jana Tauschinski, "Big Tech's bid to rewrite the rules on net zero," *Financial Times,* August 14, 2024.
[15] Qingyu Xu et al., "System-level impacts of voluntary carbon-free electricity procurement strategies," *Joule,* February 21, 2024, Volume 8, Issue 2.

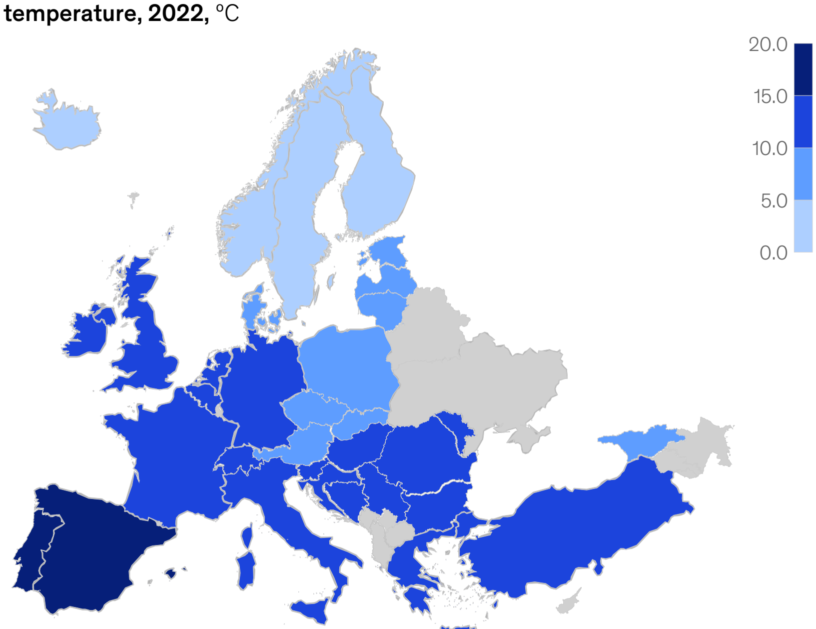
Exhibit 4

Areas with abundant carbon-free energy and lower temperatures could be used for strategic site selection.

Share of carbon-free electricity in grid in 2023, %



Average annual temperature, 2022, °C



Note: The boundaries and names shown on maps do not imply official endorsement or acceptance by McKinsey & Company.
Source: Electricity maps: Live 24/7 CO2 emissions of electricity," Electricity Maps, accessed October 23, 2024

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Currently, many new data centers are designed for AI training, which has less stringent latency requirements than traditional data center activity. Over time, some of these may shift to AI inferencing, which demands much higher speeds than AI training or traditional use; those in remote locations with poor latency may not be suitable for this.

In the absence of fully CO_2-free energy, there is a growing interest in carbon removal solutions, particularly among hyperscalers. Companies such as AWS are actively purchasing substantial carbon removal credits to offset their emissions. For example, AWS has committed to buying CO_2 removals of 250,000 metric tons over a decade.[16]

On-site generation

In most global markets, the major bottleneck slowing power access is a limited ability to connect to the transmission grid, rather than an inability to generate the power itself.[17] Latent capacity in the generation fleet largely comes from fossil fuel plants that currently operate below maximum levels.

In locations with access to power on the bulk transmission grid, there are further constraints on the supply of power equipment, such as transformers, on-site backup generators, and power distribution units, with historically high lead times of up to nearly two years in some cases (Exhibit 5).

As power grids near their capacity limits and lead times for new grid connections increase, data center operators will be called on to innovate. Energy for powering data centers must meet the different growth demand and load profiles of data centers. Additional sources may be needed to ensure 24/7 power, alongside renewables and the bulk grid supply. Many operators are already exploring alternative strategies for on-site generation, including small modular reactors, hydrogen fuel cells, and natural gas.

In the last two decades, no technology has driven the need for accelerated power infrastructure development in Europe more than AI, and particularly generative AI (gen AI). What's more, this demand is mostly for clean energy.

Investment in green energy solutions for the sector is gaining momentum, but significant untapped potential remains, given exponential data center growth. Unlike traditional data center acquisitions, such as real estate or technology, green energy investments present different risk/return profiles, likely attracting investors with specific objectives. As data centers play an increasingly crucial role in the European economy, exploring the entire energy value chain is essential to identify and capitalize on these emerging opportunities.

Low-carbon power is an increasingly important area of investment. Companies across the data center sector are using many different instruments and approaches to manage their carbon accounting, including unbundled and time-matched RECs, PPAs, carbon matching, offsets, CO_2 removals, and accreditation activities—but many stakeholders have been left to define their own motivations, ambitions, and directions for the future.

As Europe confronts an increasingly strained power grid, the future of data centers—critical to the continent's digital infrastructure and competitiveness—depends on strategic choices about location and energy management. In a landscape where reliable and swift power access is no longer guaranteed, companies that rely on or build data centers must confront this new reality head-on. The trade-offs between power availability and data transmission infrastructure are no longer theoretical; they demand urgent action.

To balance the increased penetration of intermittent renewables, Europe will require more dispatchable energy sources. It may also need to overbuild the peak capacity of renewable installations to meet the unexpectedly high demand from data centers for green energy.

For transmission system operators, the imperative is clear: accelerate and increase investments in energy

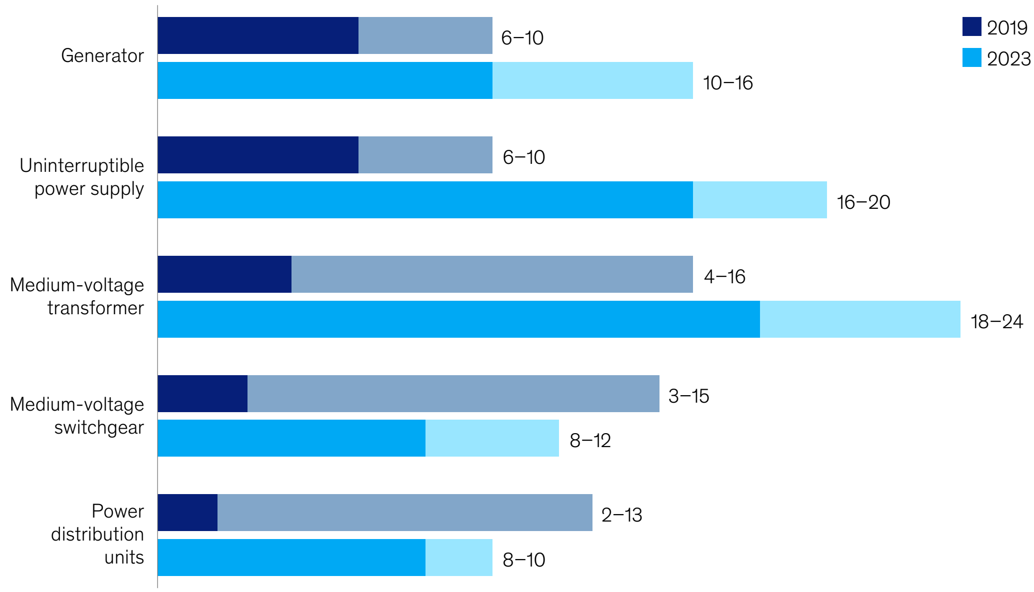
[16] "1PointFive announces agreement to sell 500,000 metric tons of direct air capture carbon removal credits to Microsoft," 1PointFive, July 9, 2024; "1PointFive and Amazon announce 10-year carbon removal credit purchase agreement," 1PointFive, September 12, 2023.

[17] *Grid access challenges for wind farms in Europe,* WindEurope, June 24, 2024; "Immediate actions needed to unblock grid capacity for more wind energy," WindEurope, July 5, 2024.

Exhibit 5

Accelerated demand and supply chain constraints have increased lead times for obtaining equipment, resulting in project delays.

Lead time of major data center critical equipment, months



Source: Expert interviews; McKinsey analysis

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infrastructure to ensure stability and reliability. The influx of investment could serve as a catalyst for developing purpose-built infrastructure that is well-connected to European industry, transport, and households, as outlined in the EU Grid Action Plan.[18] In other words, addressing the energy needs of data centers could help to bridge the investment gap that has historically lagged advancements in power generation.

Moreover, strengthening the link between generation and distribution grids is crucial to support expanded generation capacity and ensure efficient power delivery. By addressing these challenges proactively and investing in the necessary infrastructure and technologies, Europe could create a more resilient and sustainable energy future.

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[18] "Commission sets out actions to accelerate the roll-out of electricity grids," European Commission, November 28, 2023.