AI and energy: the two-way dependency

May 2026

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Executive summary

Artificial intelligence (AI) has rapidly evolved from an academic pursuit to a large and fast-growing industry shaping corporate strategies, economic policies and geopolitics. The surge in data center (DC) construction and AI-related spending has become a significant driver of business investment and GDP growth, especially in the US.[1]

Its capabilities are also poised to transform the energy industry, unlocking productivity and efficiency gains, enabling smarter grid management and clean technology innovation as well as reducing emissions.

Early one-off AI deployments demonstrate tangible benefits: between 10% and 25% lower operating costs, 3%-8% productivity improvements, and 5%-8% gains in energy efficiency, directly translating into emissions reductions.[2] Yet, AI's impact is amplified when paired with human knowledge. Rather than replacing the workforce, AI scales human capabilities and enables new forms of collaboration and decision-making.

However, scaling these successes across enterprises remains challenging. Barriers include fragmented data access (with over 90% of all enterprise data unstructured and largely unanalyzed, and the energy sector sitting at the upper end),[3] limited digital infrastructure, workforce skills gaps and persistent security concerns. The result is a patchwork of localized optimizations rather than system-wide intelligence, leaving energy behind industries like finance, where integrated platforms have become the backbone of operations, with nine in ten banks now using AI for fraud detection.[4]

Conversely, AI's evolution and growth depend on energy, specifically electricity. Training and deploying AI models requires significant computing power concentrated in data centers, which are power-hungry and consume energy at industrial scale. A typical AI-focused DC uses as much electricity as 100,000 households; the largest under construction will use 20 times more.[5] Nowadays, DCs account for 1.5% of global electricity consumption, growing at 13% annually.[6] By 2030, consumption could more than double to levels comparable with Japan's current electricity use. If DCs were a country, by 2035 they could be the fourth largest consumer of electricity after the US, China and India.[7] However, there are uncertainties in the long-term forecast such as future development of more energy efficient AI chips, more efficient cooling systems, and reuse of waste heat.

Electricity grid access constraints already threaten 20% of planned DC projects.[8] This concern could diversify the location of DCs, especially in Europe, pushing emerging regions like Europe Central[9] to grow more rapidly than mature locations.

Capturing AI's full potential for energy and delivering energy for AI requires deeper collaboration among technology providers, energy companies and policymakers. This means aligning value chains, accelerating digitalization and supporting a sustainable power supply while navigating regulatory and security challenges.

This report, based on EY Europe Central Energy Center's research and extensive EY experience in AI together with the industrial and energy sector, provides actionable insights for leaders facing this dual transformation. Our analysis explores how organizations can unlock AI-driven efficiency, secure energy for digital growth and build resilient strategies for a future in which AI and energy are inseparable.

01

Introduction

AI underpins the modern economy, influencing everyday life while unlocking industrial efficiency gains.

AI tools are implemented today in a broad range of processes – from everyday activities (e.g., shopping, travel planning, smart homes) to industrial processes. Irrespective of industry, business functions such as operational efficiency, finance, and HR all use AI.

AI applications by business function

	Automation	Analytics	Prediction	Engagement
HR	Resume screening using natural language processing (NLP); automated interview scheduling	Employee sentiment analysis from surveys	Attrition forecasting; workforce planning	AI chatbots for candidate queries; personalized learning paths
Finance	Invoice processing; expense categorization	Real-time financial dashboards; anomaly detection	Cash flow forecasting; credit risk modeling	AI-driven financial advisory tools
Marketing	Automated campaign execution; social media posting	Customer segmentation; ROI analysis	Predictive lead scoring; churn prediction	Personalized content recommendations; chatbots for product queries
Operations	Robotic process automation (RPA) for repetitive tasks	Process efficiency analysis; KPI dashboards	Demand forecasting; predictive maintenance	AI assistants for operational queries
Customer service	Ticket routing; automated responses	Sentiment analysis on customer feedback	Predicting customer issues before escalation	Virtual assistants; voice bots
IT and cybersecurity	Automated patch management; intrusion detection systems	Network traffic analysis; vulnerability scanning reports	Predictive threat modeling; anomaly detection for breaches	AI-driven security alerts; virtual assistants for IT support
Legal and compliance	Contract review using NLP; compliance document generation	Regulatory change impact analysis; risk scoring dashboards	Predicting litigation risks; compliance breach forecasting	AI assistants for legal queries; automated compliance training
Procurement	Purchase order processing; supplier onboarding workflows	Spend analysis; supplier performance dashboards	Predicting supply chain disruptions; cost trend forecasting	Chatbots for procurement requests; AI-driven negotiation support
Product development	Automated prototyping; design generation with generative AI (GenAI)	Market trend analysis; product performance dashboards	Demand prediction for new products; future success forecasting	AI-driven idea crowdsourcing; virtual assistants for product feedback
R&D	Automated data collection from research sources; AI-driven literature review	Pattern recognition in experimental data; competitor analysis dashboards	Predicting success rates of new formulations; technology trend forecasting	AI-powered collaboration platforms; virtual assistants for research queries

Source: EY Europe Central Energy Center's analysis.

54%

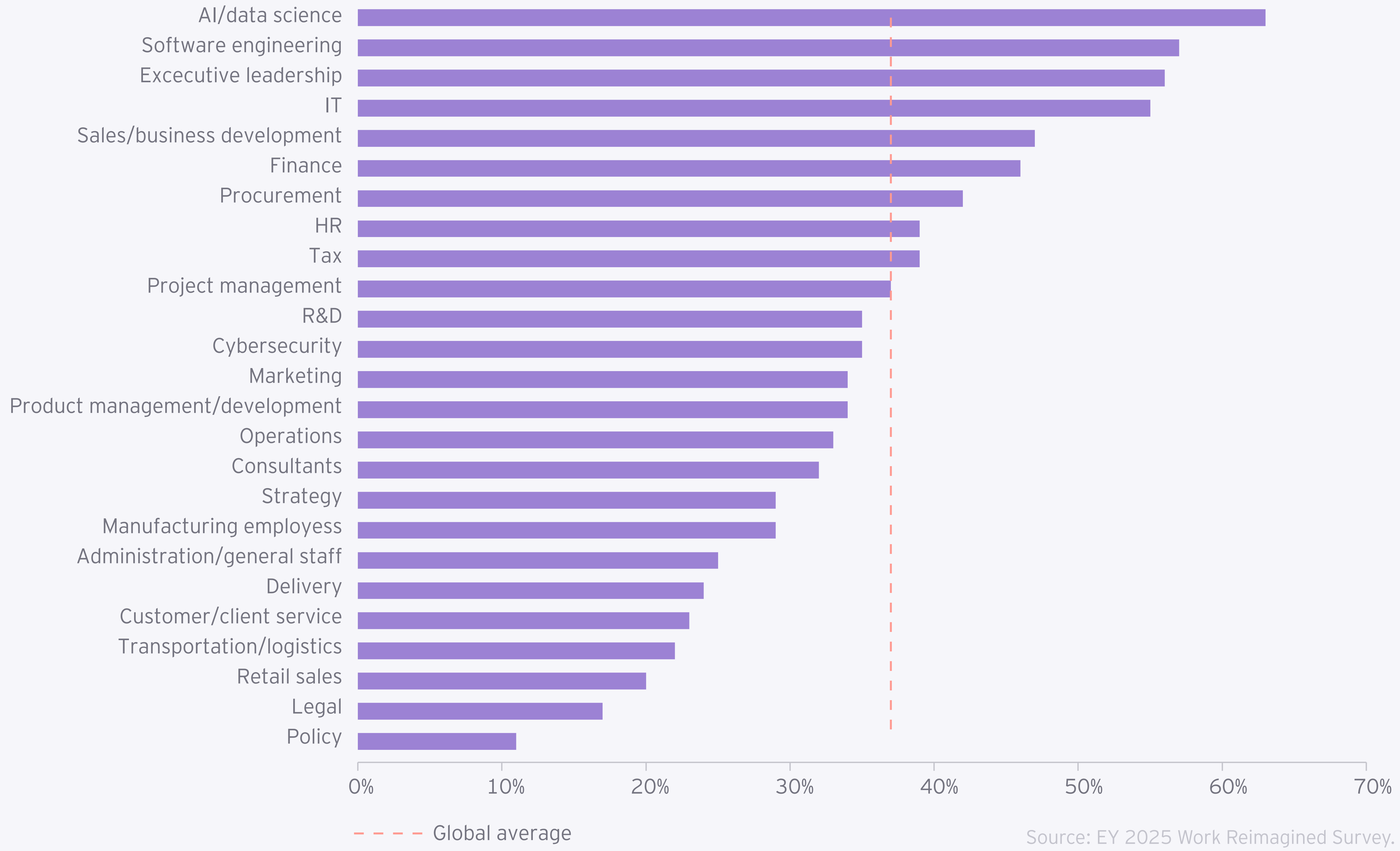
of employees use AI for searching for information

38%

use AI for summarizing documents

According to the recent EY report,[10] data science, software engineering, executive leadership, IT and sales are among the top functions in which employees use AI daily.

Employee AI daily use by business function



Source: EY 2025 Work Reimagined Survey.

While most workers use AI for basic tasks like searching for information (54%) or summarizing documents (38%), only 5% qualify as advanced users who blend multiple tools to unlock roughly a day and a half of additional productivity per week. Advanced users extract far more value, using AI as a thought partner rather than a simple tool.

5% of employees qualify as advanced users who blend multiple tools

02

AI evolution

AI came of age in 2025, having moved from theoretical concepts in the 1950s to advanced generative and agentic systems, marked by funding winters, periods of optimism, and breakthroughs in machine learning.

Rapid and transformative evolution of deep learning techniques, enabling complex pattern recognition, occurred in the mid-2010s.

AI evolution moved through several distinct phases:

01. **Predictive AI and classical machine learning (ML) – from pre-deep learning to present**
Before the generative wave, organizations widely adopted predictive analytics and classical ML (e.g., regression, trees/ensembles, support vector machines) for forecasting, anomaly detection and optimization. Predictive AI emerged as ML models became capable of forecasting outcomes and detecting patterns from large data sets. It shifted AI from descriptive analytics to proactive decision-making, enabling failure prediction, demand forecasting, and operational optimization.

02. **Early GenAI**
Generative Adversarial Networks, introduced in 2014, became mainstream in 2015–16. However, models were narrow, required large data sets, and lacked coherence in long-form text.

03. **Transformer breakthrough enabling modern large language models (LLMs)**
A decisive step came in 2017 with the transformer architecture introduced in the seminal paper "Attention Is All You Need,"[11] which underpins today's LLMs.

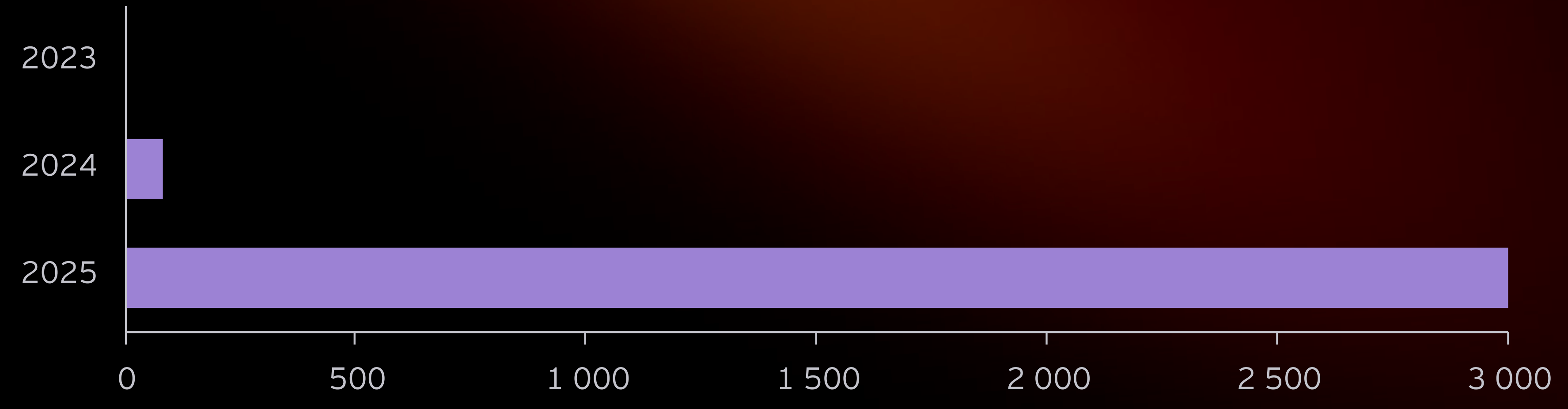
04. **Rise of LLMs**
Models like BERT (2018) and GPT-2 (2019) became capable of contextual understanding of text and better performance in NLP tasks (translation, summarization). Therefore, AI shifted from a rule-based tool to deep learning-driven generative. Transformers are the underlying architecture for these models.

05. **Embodied AI in robotics**
AI extended into physical systems through reinforcement learning for control and navigation, but adoption remained limited by high costs, safety concerns, and adaptability to dynamic environments.

06. **GenAI explosion**
The phase became a start of AI tools democratization for creators and businesses with breakthrough models like GPT-3 (2020), DALL·E, Stable Diffusion, Midjourney. AI became accessible via APIs and platforms and capable of text-to-image and text-to-video transformation as well as code generation.

07. **The agentic AI era**
In 2023, AI began moving from passive generation to autonomous decision-making and multistep reasoning and opened the agentic AI era. AI agents started planning, executing tasks, and interacting with tools (e.g., AutoGPT, LangChain). As a result, AI transformed from just a content generator to a problem solver and workflow orchestrator. In earnings calls and on convention floors, the word "agent" – and "agentic" – had a breakout year in 2025.[12]

Mentions of the word "agentic" on earnings calls and investor meetings



Note: Analysis of S&P 500 calls and meeting transcripts through 16 December 2025.
Source: Bloomberg.

The current direction of AI could be classified as agentic and multimodal, combining text, vision, audio and robotics into unified systems. Nowadays, there is also a strong focus on safety, transparency and alignment.

Alongside this technical evolution, organizations are undergoing a structural shift from a "one-to-one" relationship between humans and tools to a "one-to-many" model, in which employees orchestrate networks of AI agents. Rather than replacing capabilities, agentic systems scale human judgment and free talent to focus on higher-value tasks. This organizational evolution is as significant as the technological one and underpins the future of human and AI collaboration.

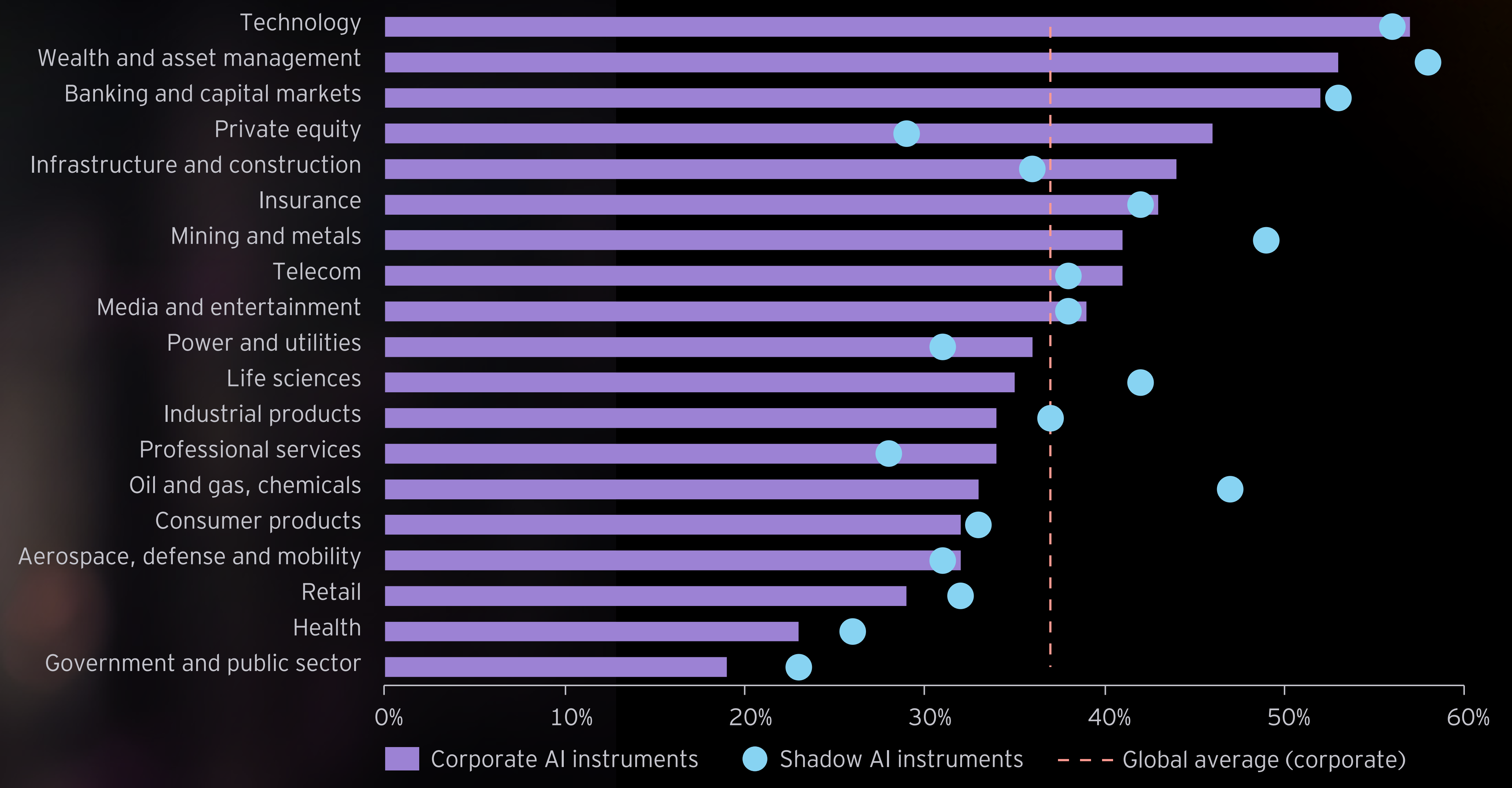
03

AI in energy

Driving efficiency and sustainability

According to the recent EY report,[13] employees in oil and gas as well as in power and utilities sectors are less involved in everyday use of AI than those in technology and banking, and even mining and metals.

Employee AI daily use by industry



Note: Shadow AI in this context refers to employees using their own preferred AI apps or tools at their own expense, in addition to those provided by their employer. | Source: EY 2025 Work Reimagined Survey.

Interestingly, even in the context of active digitalization, employees often bypass corporate rules. Oil and gas employees use third-party solutions more often than those in power and utilities, despite employers' efforts to implement their own corporate AI tools.

Overall, both oil and gas as well as power and utility sectors have broad potential for AI implementation. After decades of fragmented digital progress, a new model for intelligence is emerging, one that brings together the full breadth of data, experience, and science that underpin the sector. The opportunity, for instance to unlock 68% of data collected only from field sensors and smart meters still unprocessed,[14] to eliminate industrial gridlock and to support human experience with tools built for trust, is undoubtedly enormous.

The value delivered by AI can vary widely across individual projects. Outcomes depend on many elements, including regional regulatory conditions, the availability and quality of data, the maturity and compatibility of information technology and operational technology systems, the types of hardware accelerators or chips used, the level of digitalization in existing operations as well as the skills and readiness of the workforce.

The figures in our analysis are, therefore, illustrative examples based on broad research across the energy industry, rather than fixed benchmarks.

3.1

Oil and gas sector

The oil and gas sector is constantly addressing challenges such as cost pressures, safety risks, volatile market conditions and increasing mandates for sustainability. As regulatory frameworks evolve, commodity prices fluctuate, geopolitical dynamics shift, business portfolios grow more complex and environmental commitments intensify, AI is becoming critical to long-term success.

AI is already enabling oil and gas to operate more efficiently, profitably and competitively through each segment (upstream, midstream and downstream). In fact, more than 90% of oil and gas companies are either investing in AI or planning to do so, highlighting the technology's growing strategic importance.[15] However, realizing its full potential is not without challenges.

3.1.1

Upstream (exploration and production)

Exploration and production processes are time-consuming and capital-intensive but are among those which are set to benefit from AI-driven solutions. Around 80% of upstream oil companies see AI as crucial to meeting production targets in the next five years, while 55% of exploration and production companies are part of AI innovation consortiums with the aim of accelerating deployment.[16]

The tools could improve a chain of activities upstream, which include geological assessment, drilling, reservoir engineering, production planning, detection of defects and oil spills, predictive maintenance as well as emissions measurement. For instance, unplanned downtime is one of the costliest risks in the industry; offshore rigs can lose at least US$1 million per day when systems fail. AI-powered predictive maintenance changes that equation, helping operators shift from reactive fixes to proactive resilience.[17]

AI is transforming upstream oil and gas operations, offering operators a wide range of benefits that go beyond traditional efficiencies.

- **Productivity upturn:** By improving processes, AI can increase hydrocarbon recovery, supporting better utilization of resources.
- **Cost reduction:** Predictive maintenance powered by AI identifies assets most likely to fail, allowing operators to act before breakdowns occur. This proactive approach avoids unnecessary scheduled maintenance and prevents catastrophic failures – critical when unplanned downtime can cost upstream oil and gas companies an average of US$49 million per year (in some cases, up to US$88 million annually)[18, 19]
- **Workflow optimization:** From decision-making to supply chain management, AI automates repetitive tasks and analyzes extensive data sets to uncover patterns and provide actionable insights. For example, machine learning can improve transport routes, improve logistics, and even leverage weather and drilling data to create safer working conditions.
- **Safety enhancement:** In environments with heavy machinery, high pressure, and extreme temperatures, AI-powered systems monitor both workers and equipment. Computer vision can detect safety violations in real time, flagging personnel without proper protective gear. AI also tracks asset conditions and monitors toxicity levels, issuing alerts to prevent hazardous incidents such as gas leaks, helping avert catastrophic events before they occur.[20, 21]

As these capabilities mature, the role of geoscientists, drilling engineers and production teams evolves toward supervising AI recommendations, validating edge cases and applying domain experience to strategic decisions. AI reduces manual burden but increases the need for higher-order analytical, safety and scenario-evaluation skills.

Selected AI capabilities and value drivers in oil and gas upstream operations (continues)

Activity – upstream	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Geological assessment (seismic interpretation and subsurface mapping)	Manual interpretation of large three-dimensional (3D) seismic volumes is time-consuming and prone to human bias; complex geological patterns exceed human scalability	▪ Deep learning on 3D seismic and well log data ▪ Automated fault, salt, horizon and facies identification	▪ Seismic interpretation time reduced from months to days (e.g., ~6–8 weeks to ~9–10 days with comparable accuracy)[22] ▪ Up to ~1,000x faster interpretation vs. manual mapping [23, 24] ▪ Reported accuracy up to ~92% depending on task and data quality [25, 26] ▪ 10%–25% reduction in dry hole rates and higher prospect success rates[27] ▪ 30%–50% faster decision cycles from data loading to drill ready prospects[28]	▪ Oversight of AI-generated interpretations ▪ Validation of anomalies and geological complexity ▪ Judgment applied in drilling and subsurface decisions	Performance depends strongly on seismic quality, labeling consistency and geological complexity. AI augments geoscientists rather than replacing expert interpretation
Reservoir management	Physics-based reservoir models are computationally expensive, slow to update and struggle with rapid data assimilation in heterogeneous reservoirs	▪ AI based surrogate and proxy reservoir models ▪ Assisted history matching and parameter calibration ▪ Production and injection optimization ▪ Well control and recovery strategy improvement	▪ 50%–80% faster history matching cycles[29,30] ▪ 5%–20% production uplift in mature fields[31] ▪ ~2%–5% NPV improvement through better recovery and development decisions[32, 33]	▪ Evaluation of AI-modeled reservoir scenarios ▪ Selection of optimized development strategies ▪ Arbitration of high-uncertainty reservoir choices	Enables dynamic reservoir models updated continuously with production, pressure, and surveillance data. AI complements physics-based simulators rather than replacing them

Selected AI capabilities and value drivers in oil and gas upstream operations (continues)

Activity - upstream	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Production forecasting	Static decline-based models do not adapt well to changing operating conditions or continuous Supervisory Control and Data Acquisition (SCADA)/sensor data	▪ Data-driven rate and pressure forecasting ▪ Real time forecast updates using live SCADA data ▪ AI-driven uncertainty quantification for P10/P50/P90 scenarios (high case - 10% probability that actual production will be higher than this value / median case - 50% probability/lower case - 90% probability)	▪ Up to 20%-30% improvement in predictive accuracy vs traditional methods[34] ▪ Forecast errors typically controlled within ~15%[35] ▪ More reliable P10/P50/P90 scenarios for planning and reserves management	▪ Assessment of forecast bands and uncertainty ▪ Integration of operational and contextual factors ▪ Approval of final production plans	Improves short term predictability and scenario planning; enables proactive workover, choke, and artificial lift decisions as forecasts continuously update
Production optimization	Manual optimization is reactive and cannot process large volumes of real time operational data efficiently, leading to sub optimal production and higher costs	▪ Closed loop optimization of artificial lift, choke settings and pump cycles ▪ Integrated sensor/SCADA driven control workflows ▪ Digital twin enabled "what if" analysis	▪ 2%-8% production uplift from gas lift, choke and network optimization ▪ 1%-3% uplift from waterflood rebalancing[36] ▪ Operational cost reductions: 5%-15% compressor energy savings from efficient lift-gas allocation, 5%-12% chemical usage reduction[37] ▪ Optimization response in minutes vs. hours/days manually	▪ Supervision of optimization loops ▪ Approval of adjustments impacting safety or constraints ▪ Intervention during deviations or failures	Digital twins and AI-driven control accelerate decisions, enable proactive interventions, reduce downtime, and drive continuous performance improvement
Drilling optimization	Drilling generates massive real time telemetry streams; manual parameter tuning leads to nonproductive time and higher well costs	▪ Real time telemetry analysis with ML models ▪ Autonomous drilling systems adjusting weight-on-bit (WOB), rotary speed (RPM) and parameters ▪ Digital twins for risk prediction and drilling optimization	▪ 20%-30% improvement in rate of penetration (ROP)[38] ▪ ~30% reduction in well delivery time in drilling automation deployments[39,40] ▪ Up to 30% reduction in nonproductive time[41] ▪ Efficiency enhancement by reducing repetitive tasks by rig operators[42]	▪ Oversight of autonomous drilling systems ▪ Management of operational risks ▪ Expert escalation during abnormal conditions	Autonomous drilling improves safety, consistency and cost efficiency, while supporting predictive maintenance and early anomaly detection

Selected AI capabilities and value drivers in oil and gas upstream operations (continued)

Activity - upstream	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Well-to-Gas-Oil Separation Plant (GOSP) crude allocation optimization	Manual well-to-GOSP allocation is rule-based and static, struggling with changing performance, facility constraints and network interactions, leading to bottlenecks and lost production	▪ AI-based network optimization and allocation across wells, flowlines and GOSPs ▪ Capacity-constrained optimization at equipment level ▪ Use of equipment (compressors, boosters, pumps, separation vessels) at optimal ranges	▪ 2%–5% field-level production uplift through better routing and load balancing ▪ More efficient and responsible use of equipment ▪ Faster re-optimization (minutes vs. hours manually)[43]	▪ Review of routing recommendations ▪ Confirmation of equipment, flow and network constraints ▪ Direction of responses to dynamic changes	Works best when integrated with surface network digital twins. Enables proactive response to equipment outages and changing deliverability
Predictive equipment maintenance	Scheduled or reactive maintenance fails to prevent unexpected failures, leading to costly downtime (an average of 27 days of unplanned downtime annually, resulting in costs reaching US$38 million) and safety risks	▪ AI analysis of vibration, temperature, pressure and operational data ▪ Anomaly detection and remaining useful life prediction ▪ Improved condition-based maintenance scheduling	▪ ~35%-50% reduction in unplanned downtime[45, 46, 47] ▪ 20%-25% reduction in maintenance costs[48] ▪ 25% reduction in field accidents via safety-linked monitoring[49]	▪ Prioritization of AI-flagged interventions ▪ Verification of critical integrity risks ▪ Judgment on repair timing and method	Predictive maintenance improves maintenance timing, extends equipment life, reduces safety incidents, and lowers lifecycle costs
Defect detection and safety monitoring	Remote upstream assets are difficult to inspect frequently; manual inspections miss early-stage corrosion, cracks and leaks	▪ AI enabled computer vision on drones, robots and fixed cameras ▪ Automated analysis of imagery and sensor feeds	▪ Inspection speed increase from 10-20 parts/min (manual) to 100-300 part/min (AI)[50] ▪ 35%-50% faster leak detection[51] ▪ Over 95% leak detection accuracy in controlled deployments[52]	▪ Validation of detected defects ▪ Coordination of field verification ▪ Initiation of safety and incident-response actions	Improves safety oversight, reduces subjective human error, and supports condition-based inspection instead of infrequent manual rounds

Note: The impact is based on open search and verified by EY experience. | Source: EY Europe Central Energy Center's analysis.

Upstream

in a nutshell

The primary barrier to AI at scale in upstream is data fragmentation and inconsistent governance, which can limit model accuracy and trust.

Regulatory and ethical considerations surrounding sensitive geological data further slow deployment, while workforce capability gaps constrain adoption of autonomous and AI-driven operating models.

3.1.2

Midstream (transportation and storage)

The midstream segment of the oil and gas industry faces distinctive challenges, from managing vast pipeline networks to supporting operational safety and regulatory compliance.

Moreover, energy pipeline systems exhibit different operating characteristics, environmental challenges, and data availability patterns based on pressure levels, locations, and transported fluid. For instance, transmission pipelines, which carry fuels over long distances, often travel diverse terrains (e.g., mountains, deserts, rivers, lakes and remote areas) with limited physical access, while urban gas distribution pipelines usually operate across a high population density, complex neighborhood, and elevated safety risks due to the proximity to residential and commercial areas. The offshore pipelines operate in highly challenging and aggressive environments, installed at depths up to 3,000 m with extreme pressures, corrosive environments, and limited accessibility for maintenance and repair. AI is emerging as a game-changer in this space, helping companies enhance performance, reduce risks and support more informed decision-making.

AI applications in midstream operations range from predictive maintenance to real-time monitoring of flow rates and pressure, helping prevent costly disruptions. Machine learning models can analyze sensor data to detect anomalies before they escalate into failures, while advanced analytics support route optimization and inventory management. Furthermore, AI-powered systems enhance safety by monitoring environmental conditions and detecting leaks early, helping to reduce environmental impact and financial loss.

As midstream operations become increasingly complex and data-driven, AI provides the tools to transform raw data into actionable insights – supporting reliability, efficiency, and sustainability across the value chain.

The benefits to midstream from AI implementation include:

- **Reliability and uptime improvement:** By leveraging predictive maintenance and anomaly detection, AI identifies early signs of equipment stress in pumps, compressors and valves. This proactive approach can reduce unplanned downtime by up to 30%,[53] avoiding costly disruptions in pipeline throughput.
- **Logistics and flow optimization:** Machine learning models analyze real-time sensor data, weather patterns, and demand forecasts to improve routing and scheduling for crude and refined products. This can cut transportation costs by between 10% and 15% and improve delivery accuracy.[54]
- **Operational safety enhancement:** Computer vision and sensor analytics monitor pipeline integrity and detect leaks or pressure anomalies in real time. AI-driven alerts help prevent hazardous incidents, reducing environmental and safety risks significantly.
- **Sustainability and compliance support:** Intelligent systems track emissions, monitor energy consumption, and support adherence to regulatory standards. Automated reporting reduces compliance costs by up to 40%,[55] while optimization algorithms lower energy use in compressor stations by between 5% and 10%.[56]
- **Scenario planning through digital twins:** Virtual replicas of pipeline systems allow operators to simulate maintenance schedules, emergency responses, and capacity changes without disrupting actual operations, improving decision-making and reducing planning time.

Human roles also shift from manual surveillance and reactive decision-making to overseeing automated monitoring, validating anomalies and coordinating cross-system responses. Operators increasingly act as supervisors of AI-driven workflows, ensuring safe, compliant and optimized network performance.

Selected AI capabilities and value drivers in oil and gas midstream operations (continues)

Activity - midstream	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Improving chemical dosing (drag reducing agent, DRA)	Manual DRA dosage settings are conservative and static, failing to adapt to changing flow regimes, temperature, crude properties and pipeline conditions, leading to overdosing or underperformance	▪ AI-driven DRA dosage optimization using flow, pressure drop, temperature and viscosity ▪ Real-time learning from trunkline inlet and back pressure ▪ Closed-loop chemical injection control	▪ 5%-15% reduction in DRA chemical consumption for the same throughput ▪ 2%-6% incremental throughput increase ▪ Faster stabilization after transient events[57]	▪ Oversight of dosage adjustments ▪ Confirmation of flow-regime and environmental validity ▪ Correction during unstable operating conditions	Particularly valuable for long pipelines. AI augments hydraulic models and vendor curves with continuous learning from operation
Pipeline integrity, leak detection, and emissions monitoring	Pipeline networks are geographically vast and difficult to inspect manually; corrosion and small leaks pose major safety, environmental and financial risks; increasing methane and CO_2 regulations require more frequent, accurate, and verifiable monitoring than periodic field inspections can provide	▪ Continuous data ingestion (pressure, flow, temperature, humidity) from distributed pipeline and facility sensors ▪ ML-based anomaly detection for corrosion, integrity loss and leak risk ▪ Computer vision on drones, satellites and fixed cameras for crack and plume detection ▪ AI driven methane and CO_2 detection, localization and quantification in near real time	▪ Inspection speed improvement from 10-20 parts/min (manual) to 100-300 part/min (AI)[58] ▪ 40%-50% reduction in inspection costs (e.g., ~45% in North Sea pipeline inspections)[59] ▪ Detection of methane emissions as low as CH_4/hr at facility scale in blind tests[60] ▪ Higher inspection frequency and earlier leak detection versus periodic manual leak detection and repair (LDAR) surveys[61]	▪ Verification of AI-flagged anomalies ▪ Prioritization of integrity and emissions risks ▪ Coordination of required repairs or mitigation	Integrates integrity management with emissions compliance, reducing safety incidents, environmental exposure and regulatory penalties. Enables condition based maintenance and supports EU Methane Regulation, OGMP 2.0 and EPA reporting while prioritizing repairs based on risk and impact
Predictive maintenance (compressors, pumps, valves)	Reactive or time-based maintenance means equipment is serviced at set intervals regardless of its actual condition, which leads to either unnecessary repairs or unexpected breakdowns, i.e., unplanned shutdowns, safety issues and high repair costs	▪ ML based failure prediction using vibration, pressure, temperature, and operating condition data ▪ Digital twin enabled health forecasting and remaining useful life estimation	▪ 20%-30% unscheduled downtime reduction, with some companies reporting up to 50%[62] ▪ 20%-30% reduction in maintenance costs for compressors and pumps[63]	▪ Assessment of failure predictions ▪ Scheduling of targeted inspections ▪ Escalation for critical assets	Improves equipment life, reliability and asset utilization. Complements real time monitoring by shifting maintenance from calendar based to condition based and risk-based regimes

Selected AI capabilities and value drivers in oil and gas midstream operations (continued)

Activity - midstream	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
System level simulation and optimization via digital twins	Traditional monitoring systems provide limited forward looking insight; operators need to understand how complex, interconnected assets behave under changing operating, environmental, and failure scenarios	▪ Real time digital replicas of pipelines, storage facilities, and compressor stations ▪ AI driven scenario simulation for maintenance planning, throughput optimization, and emergency response ▪ Continuous model calibration using live operational data	▪ ~30% reduction in unplanned shutdowns ▪ ~20% reduction in maintenance costs ▪ ~15% increase in asset availability over multiyear deployments[64]	▪ Interpretation of systemwide simulations ▪ Approval of recommended operational adjustments ▪ Intervention where real-world constraints diverge	Digital twins create the greatest value when applied at the system or network level, orchestrating multiple assets rather than individual components. Impact is amplified when integrated with IoT, cloud platforms and ML based anomaly detection
Pipelines	Decommissioning requires complex decisions around environmental remediation, asset recovery, and regulatory compliance, often under conditions of incomplete or inconsistent historical data	▪ AI assisted analysis of historical decommissioning projects, regulatory requirements and environmental conditions ▪ Decision support for removal vs. abandonment, sequencing and campaign optimization	▪ ~15% reduction in total decommissioning costs for oil and gas infrastructure, including pipelines[65]	▪ Review of AI-generated scenario pathways ▪ Evaluation of regulatory and environmental implications ▪ Decision-making on the final decommissioning approach	AI value is concentrated in early stage planning and option selection rather than execution productivity. Benefits are highest for mature assets with poor data quality and increase further when combined with digital twins and environmental data sets
Logistics and route optimization	Transport scheduling across pipelines, terminals and downstream connections is constrained by capacity, weather, contractual terms and infrastructure availability; manual planning struggles with complexity and variability	▪ AI based routing and scheduling algorithms for truck, rail and barge movements ▪ Dynamic reoptimization based on real time disruptions and demand changes	▪ Up to 15% reduction in transport costs vs. traditional planning ▪ 15%–35% reduction in empty miles ▪ 30%–60% reduction in demurrage and waiting costs[66] ▪ Fewer routing and scheduling errors	▪ Supervision of AI-driven scheduling ▪ Validation of constraints (weather, capacity, contracts) ▪ Adjustment of plans during disruptions	Improves throughput, reduces idle time and enhances responsiveness to operational disruptions. Particularly valuable for assets with frequent scheduling changes and high demurrage exposure

Note: The impact is based on open search and verified by EY experience. | Source: EY Europe Central Energy Center’s analysis.

Midstream

in a nutshell

Midstream AI applications face pronounced data limitations and bias risks. Pipeline integrity data sets are often sparse and uneven, with rare failure events limiting model calibration for extreme scenarios.

Performance can also degrade when models prepared for specific regions, pipeline materials or operating conditions are applied elsewhere. Heterogeneity across pipeline systems – transmission, offshore, urban distribution, and emerging hydrogen networks – further complicates model generalization.

3.1.3

Downstream (refining and petrochemicals)

The downstream sector faces unprecedented complexity driven by volatile markets, regulatory pressures, and evolving consumer demands. AI analytics platforms deliver unprecedented end-to-end visibility and real-time optimization across these segments, enabling operators to dynamically balance complex process variables, inventory levels, pricing strategies, and logistics networks.

Such agility is critical amid geopolitical uncertainty, volatile crude prices and changing consumer expectations. By leveraging AI, downstream operators can help reduce stockouts, elevate customer experience, and seize emerging opportunities – positioning themselves for sustainable growth in an increasingly dynamic global market.

The benefits to downstream from AI implementation include:

- **Refining and petrochemical operations optimization:** ML models process real-time unit data to help increase yields, improve energy efficiency and support product-quality specifications, delivering throughput gains and reductions in energy intensity across crackers, hydrotreaters and blenders.
- **Predictive maintenance and reliability:** Every hour of delay becomes a line on the balance sheet. AI monitors critical rotating equipment, heat exchangers and instrumentation to predict failures and improve turnaround schedules. This reduces unplanned outages and extends equipment run lengths.
- **Supply chain and logistics transformation:** Advanced demand forecasting, route optimization and inventory management cut distribution costs. Dynamic scheduling synchronizes refinery output with retail demand, terminals, and transportation assets.
- **Safety and environmental performance enhancement:** Real-time monitoring of flares, tank farms, loading operations and emissions supports compliance and rapid incident response. AI-driven process safety systems reduce safety incidents through anomaly detection and automated shutdowns.
- **Sustainability through carbon optimization:** Digital twins simulate low-carbon process configurations, feedstock blending and energy optimization scenarios. This enables reductions in Scope 1 emissions while maintaining profitability.
- **Scenario planning and digital refinery:** Virtual replicas of entire refinery complexes allow operators to test operating scenarios, feedstock changes, and market shifts without risking production. This accelerates decision-making and improves resilience to disruptions.

Refinery and petrochemical workforce responsibilities move from parameter tuning and manual inspection to supervising digital twins, validating optimization outputs and managing exceptions. AI augments human oversight, enabling teams to focus on safety, reliability and continuous improvement. AI reduces manual burden but increases the need for higher-order analytical, safety and scenario-evaluation skills.

Selected AI capabilities and value drivers in oil and gas downstream operations (continues)

Activity - downstream	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Refinery and petrochemical process optimization	Refining and petrochemical operations are highly complex, nonlinear and tightly constrained; volatile feedstock prices and product markets make manual optimization inefficient and slow	▪ Real time optimization of yields, energy use, hydrogen balance and blending operations ▪ Digital twins and hybrid physics AI models for operating envelope optimization ▪ Integration with advanced process control (APC) and planning systems	▪ Up to 15% reduction in fuel consumption for energy-intensive units (e.g., heaters and distillation)[67] ▪ 3%-5% increase in unit or site efficiency[68] ▪ ~25% reduction in re-blends[69] ▪ US$0.5-1.0/bbl margin uplift, equivalent to US$30 million-US$85 million/year for a mid-size refinery[70]	▪ Oversight of AI-recommended setpoints ▪ Validation against quality and safety envelopes ▪ Intervention during process deviations	Helps increase the yield of higher value products, tightens quality control and lowers both energy usage and operating costs
Business continuity planning (BCP) and operational resilience	Traditional BCP relies on static scenarios and manual impact assessments, which cannot keep pace with rapidly changing operational conditions, cascading failures, and complex interdependencies across assets	▪ AI-driven risk detection and early-warning systems using operational equipment ▪ Scenario simulation and stress-testing of disruption events (equipment failure, pipeline outage, power loss, cyber incidents) ▪ Automated recovery prioritization and resource reallocation recommendation	▪ 20%-40% reduction in time to detect and assess operational disruptions ▪ 15%-30% faster recovery times through improved response sequencing ▪ Reduced production losses and safety exposure during unplanned events[71]	▪ Review of disruption scenarios ▪ Approval of recovery and continuity actions ▪ Coordination across operations during incidents	AI-enabled BCP shifts continuity planning from static documents to living, data-driven resilience systems
Predictive maintenance of equipment	Refinery and petrochemical assets are tightly interconnected; failure of one unit can shut down entire process trains, causing large economic and safety impacts	▪ AI analysis of vibration, temperature, pressure, flow, corrosion and acoustic data ▪ Failure mode detection and remaining useful life prediction ▪ Early identification of abnormal operating conditions	▪ Up to 50% reduction in unplanned downtime[72] ▪ 15%-30% reduction in maintenance costs[73] ▪ Up to 20% extension of equipment life[74] ▪ Higher utilization, shorter repair times, and lower safety incident rates	▪ Verification of critical alerts ▪ Sequencing of maintenance interventions ▪ Human judgment in risk-based decisions	Improves turnaround planning, reduces catastrophic failures and strengthens safety and regulatory compliance

Selected AI capabilities and value drivers in oil and gas downstream operations (continued)

Activity - downstream	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Quality control and virtual sensors	Physical laboratory testing of product quality attributes is slow, costly, and cannot support tight real time control	▪ AI-based virtual sensors predicting quality attributes (e.g., research octane number, sulfur, density) from process data ▪ Continuous quality monitoring integrated with control systems	▪ Reduction in laboratory testing volume ▪ Improved product consistency and on spec rates ▪ 20%–35% reduction in quality sorting and reprocessing costs (pilot deployments)	▪ Validation of inferred product-quality parameters ▪ Oversight of calibration cycles ▪ Correction of off-spec trends	Real-time quality visibility enables tighter process control and faster corrective action
Demand forecasting and inventory logistics	Refined product demand is volatile and influenced by seasonal, economic and logistical factors; manual forecasting misses complex demand signals, leading to over- or under stock	▪ ML-based demand, inventory and price forecasting models ▪ Optimization of production, storage and distribution decisions	▪ 10%–20% reduction in forecast error relative to traditional time series approaches ▪ Improved inventory turnover and lower costs[75]	▪ Interpretation of forecast outputs ▪ Alignment with commercial/ regulatory context ▪ Adjustment of final inventory decisions	Better alignment of production plans with market demand signals improves working capital efficiency
Energy efficiency and emissions management	Refineries and petrochemical plants are extremely energy intensive; rising energy costs and emissions regulations require continuous optimization	▪ AI-driven combustion and burner optimization ▪ Predictive flaring control using anomaly detection ▪ Utility network optimization (steam, power, hydrogen) ▪ Predictive emissions monitoring systems (PEMS) ▪ AI-assisted carbon capture scheduling	▪ Up to 20% reductions in fuel gas usage for process heaters, which reduce both costs and emissions, after implementing AI optimizers that learn the best firing patterns[76] ▪ 5%–15% site wide energy savings from AI enhanced digital twins/APC[77] ▪ ~40% reduction in flaring and over US$500,000 annual savings in ML flaring control pilots[78] ▪ ~20% reduction in CO_2 emissions in process optimization pilots[79] ▪ 10%–20% cost reduction in AI assisted carbon capture operations[80]	▪ Approval of optimization recommendations ▪ Verification of compliance and emissions risks ▪ Intervention when limits are approached	Instrumentation quality, APC maturity and digital twin integration are key enablers. AI supports both cost reduction and decarbonization objectives

Note: The impact is based on open search and verified by EY experience. | Source: EY Europe Central Energy Center's analysis.

Downstream

in a nutshell

Realizing AI's full value downstream requires more than advanced technology. Organizational silos and fragmented data continue to limit impact – globally, only a small share of refinery data informs operational decisions today.

While unused data remains the hidden bottleneck, mechanical unreliability and aging assets remain the most visible obstacles to sustained AI-enabled performance.

3.2

Power and utilities

AI implementation in power and utilities sits at an emerging-to-scaling maturity stage, positioned between energy trading's advanced deployment and oil and gas physical operations' foundational phase.

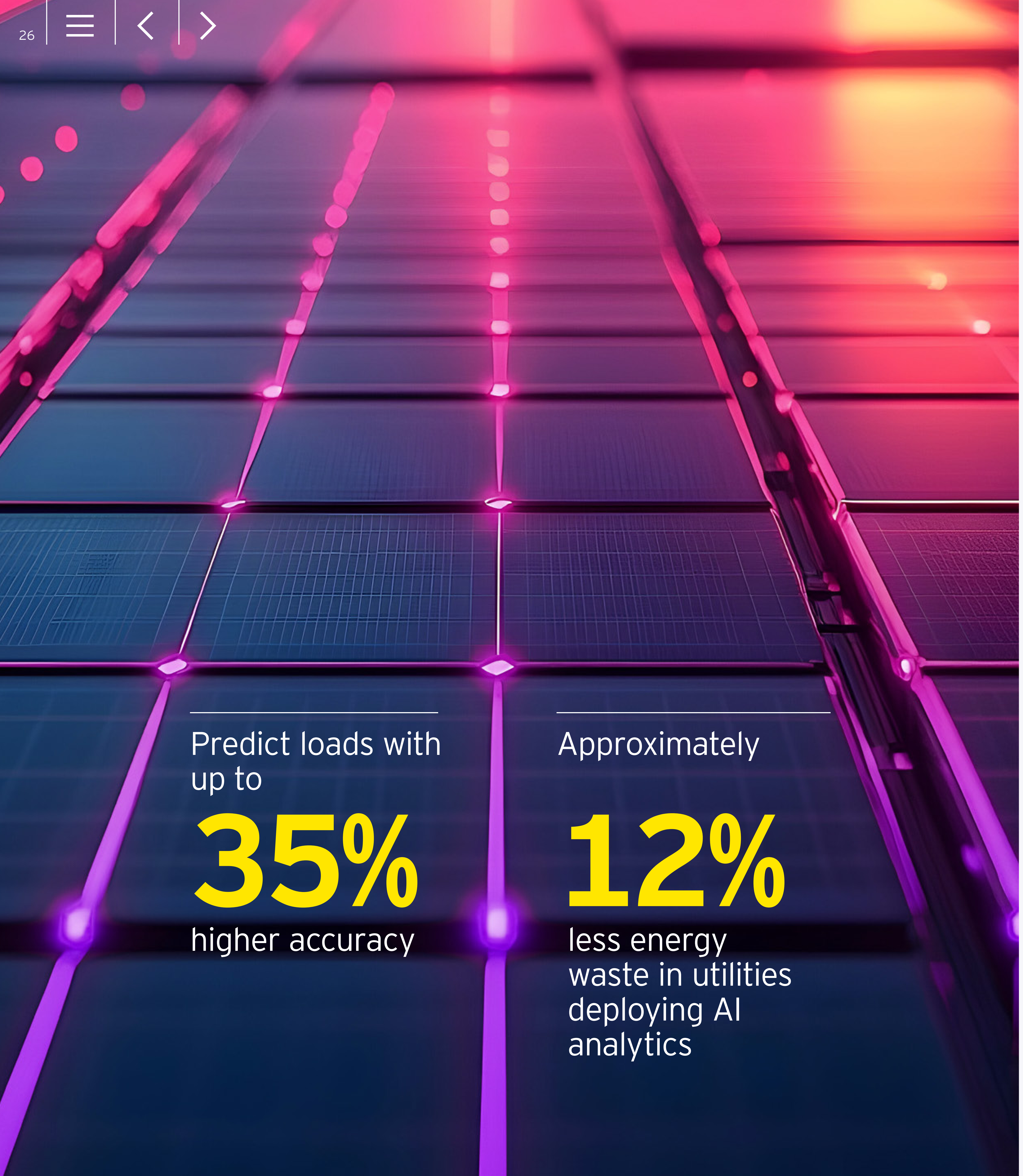
Almost 95% of utility executives expect AI to contribute significantly to revenue growth within the next three years, while 88% expect measurable competitive advantage.[81, 82]

Also, AI-driven analytics tools have helped utilities identify cost-saving opportunities amounting to US$1.5 billion annually.[83]

Cost-saving opportunities from AI amounting to

US$1.5

billion annually



Predict loads with up to

35%

higher accuracy

Approximately

12%

less energy waste in utilities deploying AI analytics

The benefits to power and utilities from AI implementation include:

- **Demand forecasting and grid balancing:** Deep learning integrates weather patterns, industrial signals, EV charging trends and renewable generation data to predict loads with up to 35% higher accuracy than traditional models.[84] This could prevent blackouts and unlock savings through improved dispatch.
- **Predictive maintenance and asset optimization:** Machine learning monitors transformers, substations and transmission lines via IoT sensors, identifying potential failures in advance. Predictive analytics can cut unplanned outages and maintenance costs significantly; utilities using such systems report between 20% and 30% fewer unplanned outages[85] and substantial savings from extended asset life and reduced emergency repairs.
- **Distributed energy resource (DER) orchestration:** Virtual power plants and DER aggregation using AI improve utilization of rooftop solar, batteries and EV chargers, boosting system flexibility during peaks. While exact figures vary by deployment, AI coordination can meaningfully reduce peak grid stress and enable higher renewable integration.
- **Dynamic pricing and demand response (DR):** Advanced AI-enabled DR programs and real-time pricing algorithms can meaningfully shift consumption patterns. Tailored incentives and automated adjustments are major drivers of DR enrollment and participation, supporting peak-load reduction and grid stability.
- **Operational cost reduction:** Predictive maintenance, smart dispatch, and grid automation improve efficiency and cut waste. Industry surveys find up to 15%–20% operational cost reductions and ~12% less energy waste in utilities deploying AI analytics.[86, 87]

Grid operators and utility staff evolve from reactive issue resolution toward proactive orchestration of AI-guided decisions, enhanced situational awareness and risk anticipation. Human judgment remains central in oversight of critical infrastructure, supported by AI-driven insights.

Selected AI capabilities and value drivers in power and utilities (continues)

Activity - power and utilities	Why is AI needed?	Where does AI help?	Impact (examples, numbers, sources)	Human role evolution	Additional comments
Demand forecasting and load management	Demand variability, electrification and renewable intermittency strain traditional forecasting and reserve planning; poor forecasts increase costs and grid stress	- AI time series models integrating weather, smart meter and calendar data	- 35% improvement of load forecasting accuracy[88] - Accuracy improvement of grid load predictions by 15% across multiple utilities thanks to AI-powered weather forecasting[89] - Peak load reduction by an average of 12% due to AI-driven demand response programs[90]	- Supervision of forecast outputs - Reconciliation with real-time system conditions - Determination of dispatch and reserve strategies	Supports better reserve margins, load balancing and avoidance of costly peaking assets
EV charging optimization	Uncontrolled EV charging creates local congestion and peak demand spikes	- AI-based charging scheduling using price, grid capacity and user constraints	- 10%–25% reduction in charging-related peak loads - Improved transformer and feeder utilization	- Review of charging-schedule outputs - Validation against local grid constraints - Intervention during overload or congestion	Defers grid upgrades and supports large-scale EV adoption
DER orchestration	Rapid growth of rooftop solar, batteries, EVs and prosumers introduces coordination challenges beyond manual control	- AI orchestration of DERs via aggregators and virtual power plants - Real-time balancing across thousands of assets	- 20%–40% improvement in DER utilization[91] - Peak shaving and congestion reduction without grid reinforcement	- Coordination of distributed resource actions - Oversight of grid impacts - Judgment during volatile operating conditions	Critical for future distribution grids with high DER and prosumer participation
Renewable energy integration and storage optimization	Variable wind and solar generation complicate balancing supply and demand; storage dispatch decisions are complex and interdependent	- AI forecasts renewable generation forecasting - Optimization of battery storage dispatch and virtual power plants	- Renewable energy output forecast with 90%-95% accuracy[92,93] - 15%-20% improvement in storage dispatch efficiency[94]	- Evaluation of renewable and storage dispatch strategies - Approval of system-level adjustments - Corrective oversight during variability spikes	Enables higher renewable penetration and more efficient storage utilization

Selected AI capabilities and value drivers in power and utilities (continued)

Activity - power and utilities	Why is AI needed?	Where does AI help?	Impact (examples, numbers, sources)	Human role evolution	Additional comments
Grid reliability, predictive maintenance and outage management	Traditional maintenance is reactive and often identifies equipment issues too late; manual monitoring cannot keep pace with dynamic loads, extreme weather events, and aging grid infrastructure; outages are costly and restoration is often slow	▪ Predictive ML on SCADA, IoT and sensor data for transformers, breakers and lines ▪ Asset health scoring and failure probability forecasting ▪ Real-time anomaly detection and fault localization ▪ AI-supported outage management, restoration sequencing and crew dispatch	▪ 40% earlier prediction of system issues[95] ▪ Equipment failures reduction by 30%[96] ▪ 20%–30% reduction in unplanned outages[97] ▪ Up to 40% reduction in outage duration ▪ Up to 35% faster grid restoration after outages[98]	▪ Confirmation of failure predictions ▪ Prioritization of restoration actions ▪ Leadership of outage-recovery sequencing	Improves reliability indices (SAIDI/SAIFI), extends asset life, enables condition-based maintenance and significantly increases grid resilience during extreme weather events
Operational cost and efficiency optimization	Rising operating costs and complexity from distributed assets, renewables and customer expectations	▪ AI for grid-wide analytics, automated asset management, and decision support	▪ 15%-20% reduction in utility operational costs[99] ▪ 12% reduction in energy waste via AI load predictions[100]	▪ Assessment of efficiency opportunities ▪ Integration of regulatory and customer impacts ▪ Arbitration of systemwide trade-offs	Improves both utility economics and customer satisfaction.
Capital planning	Capital investments are large and long dated; poor planning leads to over or under investment	▪ Scenario based CAPEX optimization	▪ Defers or avoids capital expenditure by 5%-15% through better timing ▪ Long-term grid investment efficiency improvement	▪ Review of AI-supported investment scenarios ▪ Selection of viable long-term pathways ▪ Judgment across system and policy constraints	Increasingly important for regulators and rate case justification
Environmental and emissions optimization	High renewable penetration and conventional generation dispatch create complex emissions trade-offs	▪ AI for emissions-aware unit commitment, predictive carbon footprint modeling ▪ Optimization of dispatch for low emissions	▪ Reduction of GHG emissions by 10%[101] ▪ Improved regulatory compliance and ESG performance	▪ Oversight of emissions strategies ▪ Validation of compliance impacts ▪ Intervention to maintain ESG alignment	Aligns operations with climate goals and regulatory requirements

Note: The impact is based on open search and verified by EY experience. | Source: EY Europe Central Energy Center's analysis.

Power and utilities

in a nutshell

Implementing AI in power and utilities is constrained by legacy infrastructure, regulatory oversight and cybersecurity demands.

Aging supervisory control and data acquisition (SCADA) and operational technology (OT) systems trap data in silos, limiting real-time analytics, while rules like EU network codes and the Regulation on Wholesale Energy Market Integrity and Transparency (REMIT) require human approval for critical grid decisions, slowing the deployment of autonomous AI.

3.3

Energy trading

Energy trading within the energy industry demonstrates notably higher maturity in AI implementation compared with upstream, midstream and downstream oil and gas operations. It relies on vast, high-frequency data sets – real-time prices, weather, demand signals, geopolitical events – that mirror financial markets where AI excels.

Proprietary algorithms for price forecasting, high-frequency trading, and risk management have been production-grade for over a decade, with firms deploying ML models that execute millions of automated trades daily.

The benefits of energy trading from AI implementation include:

- **Enhanced price forecasting:** AI integrates satellite imagery, weather data, LNG flows, refinery activity and geopolitical signals to generate more accurate price predictions. This helps companies across power, gas, oil, and carbon markets make informed decisions and capture consistent margins. However, it is important to acknowledge the inherent limitations and uncertainties involved, particularly in the context of evolving geopolitical risks.
- **Trading decisions acceleration:** Automated systems analyze large volumes of market data in real time, uncovering opportunities that would be difficult or impossible to detect manually.
- **Risk management transformation:** Systems monitor portfolios continuously, simulate extreme scenarios and support automated hedging to reduce exposure, improve capital use and maintain regulatory compliance.
- **Insights from alternative data:** From satellite imagery and tanker positions to regulatory filings and executive communications, AI identifies market trends and supports more resilient decision-making during periods of uncertainty.
- **Portfolio optimization and asset utilization:** By improving the scheduling of LNG shipments, power plants and storage facilities, AI boosts efficiency, reduces operational risk and increases the value of physical and financial positions.
- **Compliance risk reduction while boosting efficiency:** Automated surveillance and smart document analysis streamline oversight, helping firms stay ahead of regulations and focus on strategic trading decisions.
- **Trading scenarios:** Digital twin models create virtual replicas of trading books to test strategies under market shifts, regulatory changes or competitor behavior, enabling faster adaptation to new carbon markets and renewable energy opportunities.

Traders transit from manual signal scanning to managing AI-enhanced decision systems, stress-testing automated strategies and applying market intuition to final decisions.

The human role focuses on governance, strategy and navigating uncertainty rather than data processing.

Approximately

20%

reduction in forecasting error

AI identifies market trends and supports more resilient decision-making

Selected AI capabilities and value drivers in energy trading (continues)

Activity - energy trading	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Market forecasting (prices, demand, renewables, weather)	Energy markets are affected by many factors at once (weather, demand shifts, outages, renewable variability, global events). Humans and simple models struggle to combine all these signals quickly and consistently	▪ Predicting day ahead and intraday prices and demand ▪ Translating weather and system conditions into market expectations ▪ Detecting unusual patterns (e.g., spikes) earlier	▪ ~20% reduction in forecast error vs. traditional approaches in normal environment (e.g., day ahead power prices)[102] ▪ More reliable short-term demand and renewable output estimates	▪ Interpretation of AI-generated signals ▪ Reconciliation with trader insight and macro context ▪ Approval of bids and positions	Improved forecast accuracy directly supports better bidding, hedging and dispatch decisions across commodities
Risk and hedge decisions	Risk can change rapidly (volatility spikes, supply shocks, policy surprises). Manual risk reviews are often reactive and deciding how to protect a portfolio across many products and time periods is complex	▪ Early warning for volatility and extreme scenarios ▪ Stress testing and scenario analysis ▪ Suggesting hedges/protective actions under constraints	▪ Earlier detection of sudden price swings and extreme risk events ▪ Better timing of protective actions compared with delayed indicators ▪ Reduced exposure during adverse market conditions	▪ Supervision of stress-scenario outputs ▪ Evaluation of exposure pathways ▪ Execution of hedging actions	Helps organizations prepare for shocks rather than reacting after losses occur
Automated market execution	Market opportunities can appear and disappear quickly; manual execution can be slow and inconsistent, especially when many decisions must be made at once	▪ Faster and more consistent execution of decisions ▪ Managing many small actions automatically (within agreed limits) ▪ Handling location/time price differences where relevant	▪ Execution speeds exceeding human capability ▪ Back-testing studies show automated strategies can outperform simple baseline approaches in certain market designs	▪ Oversight of execution algorithms ▪ Enforcement of risk and compliance guardrails ▪ Intervention under abnormal market conditions	Strong governance is essential: automation amplifies both strengths and mistakes, making controls and oversight as important as model quality

Selected AI capabilities and value drivers in energy trading (continued)

Activity - energy trading	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
External event and disruption monitoring	Price moves are often triggered by external events (news, geopolitics, outages, logistics issues). These signals are too numerous and fast moving for manual monitoring	▪ Scanning news, reports, outage updates, logistics signals ▪ Highlighting events likely to impact markets ▪ Turning "noise" into prioritized alerts	▪ Earlier detection of market moving events and operational disruptions ▪ Minutes instead of days for disruption analysis ▪ Faster response and adjustment before impacts fully show up in prices	▪ Validation of AI-flagged events ▪ Assessment of market impact ▪ Prioritization of required adjustments	AI strengthens them by adding external context
Regulatory and compliance monitoring	Rules can change quickly, and missing updates can create compliance risk and financial penalties. Manual review of large documents is slow and prone to oversight	▪ Tracking regulatory updates and announcements ▪ Summarizing changes and flagging relevance ▪ Supporting audit trails and reporting	▪ Faster detection of regulatory changes ▪ Reduced reaction lag and improved consistency of compliance workflows	▪ Review of regulatory summaries ▪ Confirmation of relevance and obligations ▪ Approval of compliance actions	Supports governance, reporting and risk management across regulated markets
Decentralized/ peer-to-peer energy pricing	Future energy systems may include many small participants and local markets, which create scale and pricing complexity that manual coordination can't handle	▪ Automated pricing and matching of buyers/sellers in local markets ▪ Dynamic decision making across many participants	▪ ~7%-13% increase in electricity sales revenue (baseline vs. P2P AI system)[103]	▪ Supervision of matching algorithms ▪ Enforcement of fairness and balance ▪ Correction of market imbalances	Represents an emerging AI application for future decentralized energy trading systems

Note: The impact is based on open search and verified by EY experience. | Source: EY Europe Central Energy Center's analysis.

Energy trading

in a nutshell

Although AI tools for energy trading are technically well developed, their use is often limited by real world organizational challenges.

Data needed for decision making is spread across many different systems and sources, such as trading platforms, weather information, satellite data and news reports. Bringing this information together and helping to confirm that it is accurate and consistent requires significant effort before any meaningful analysis can take place.

In addition, strict regulatory rules require that automated decisions can be clearly explained and reviewed, especially during periods of market instability. Older trading systems, a lack of professionals who understand both energy markets and AI, and ongoing skepticism from traders toward systems that are difficult to interpret all slow adoption. These barriers are particularly strong at times when risks are highest, and trust is most critical.

3.4

Energy retail

Energy retail, across both power and oil and gas, leverages many of the same AI foundations used in energy trading, including forecasting, event monitoring and automated decision support. However, unlike trading, retail relies on high granularity customer data, smart meter signals, fuel station volumes, billing and payment flows and customer service interactions.

Retailers benefit from AI tools that enhance demand prediction, pricing, personalized customer engagement, billing accuracy, service automation, logistics planning and load/flexibility management. AI therefore becomes a critical enabler of lower cost to serve, improved customer experience and stronger commercial performance.

Retail teams increasingly orchestrate AI-driven forecasting, personalization and service automation, while focusing on customer relationship management, trust building and resolving complex or sensitive cases. AI expands rather than substitutes human capacity in customer-facing roles.

Selected AI capabilities and value drivers in energy retail (continues)

Activity - energy retail	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Forecasting and procurement planning	Volatile electricity load and fuel demand require more accuracy than manual models can deliver	▪ Power load forecasting ▪ Station-level fuel demand predictions ▪ EV/heat pump load forecasts ▪ Solar and distributed energy sources output forecasts	▪ Up to 20% lower forecast error[104] ▪ Improved hedging and inventory decisions	▪ Review of forecast outputs ▪ Alignment with commercial strategy ▪ Approval of procurement decisions	Foundation shared with energy trading but adapted to customer/ asset granularity
Pricing, tariffs and retail offers	Retail margins depend on fast pricing and customer-specific offers	▪ Personalized/dynamic tariffs (P&U) ▪ Automated fuel pricing and promotions (O&G)	▪ Higher margin capture ▪ Better retention and acquisition	▪ Oversight of tariff design ▪ Validation of customer impact ▪ Final pricing decisions	Connects market signals with customer level economics
Billing, metering and revenue assurance	Smart-meter data issues create disputes and revenue leakage.	▪ Meter anomaly detection ▪ Missing data reconstruction ▪ Theft/fraud detection	▪ Fewer disputes ▪ Higher revenue accuracy	▪ Verification of anomalies ▪ Arbitration of billing disputes ▪ Handling of sensitive customer cases	Core difficulty for power retail
Customer acquisition	Retail competition is high, and traditional marketing often struggles to identify and target the right prospects efficiently	▪ Identifying high-potential customer segments ▪ Predicting likelihood to switch or join ▪ Personalizing offers and onboarding journeys ▪ Improving marketing expenses across digital channels	▪ More efficient targeting and higher conversion rates (qualitative) ▪ Reduced acquisition cost through better segmentation and prioritization	▪ Interpretation of customer segments ▪ Refinement of targeted offers ▪ Direction of marketing actions	AI improves precision in outreach and enhances the effectiveness of acquisition campaigns across both P&U and O&G retail

Selected AI capabilities and value drivers in energy retail (continued)

Activity - energy retail	Why is AI needed?	Where does AI help?	Impact (research tests and estimates)	Human role evolution	Additional comments
Customer contacts and support services	Retailers face heavy inquiry loads (billing, outages, contracts, fuel cards); manual service is slow and costly	▪ Chatbots and voicebots for first line support ▪ AI-assisted email/CRM triage ▪ Agent assist tools (summaries, recommendations) ▪ Sentiment detection for escalation	▪ ~30% call volume reduction[105,106] ▪ Faster resolution ▪ Improved customer satisfaction by 25%[107]	▪ Management of complex or escalated cases ▪ Resolution beyond AI capabilities ▪ Delivery of empathy-based service	AI significantly supports customer-facing operations – especially during peak billing or price swings
Churn prediction and customer retention	Retail markets are highly competitive; churn is expensive and often detected too late	▪ Predicting high risk churn segments ▪ Triggering targeted retention actions ▪ Identifying vulnerable customers	▪ Earlier detection of churn risk ▪ Improvement in retention effectiveness ▪ Cost advantage of retention vs. acquisition	▪ Review of churn-risk indicators ▪ Design of targeted retention measures ▪ Prioritization of high-value customers	Strongly improves customer lifetime value and reduces acquisition spend
Regulatory and compliance automation	Frequent regulatory updates require constant monitoring	▪ Automatic document summaries ▪ Compliance alerts ▪ Report generation	▪ Reduced compliance risk ▪ Faster audits	▪ Assessment of compliance requirements ▪ Verification of obligations ▪ Approval of remediation steps	Support in customer protection for P&U; safety and environment for O&G
Back-office automation	High administrative workload across billing, settlements, loyalty and logistics	▪ Workflow automation ▪ Document intelligence ▪ AI knowledge assistants	▪ Reduced manual effort ▪ Shorter cycle times	▪ Oversight of automated processes ▪ Resolution of exceptions ▪ Enhancement of end-to-end process quality	Supports all retail subsectors

Note: The impact is based on open search and verified by EY experience. | Source: EY Europe Central Energy Center's analysis.

Energy retail

in a nutshell

Although AI is advancing quickly in energy retail, companies still face several practical barriers.

Data needed for AI – such as billing information, customer records, point-of-sale data and smart-meter readings – is often scattered across old systems and sometimes incomplete, making it difficult to use reliably.

Because AI can influence customer-facing decisions like tariffs or billing adjustments, companies must also work to make these decisions transparent and fair, which adds extra oversight. Legacy processes and systems make it challenging to integrate new AI tools smoothly, and strict rules around privacy, cybersecurity and consumer protection further shape how customer data can be used.

3.5

From pilots to impact

The barriers that limit AI at scale in energy

The major barrier for implementing AI across the energy sector is not the sophistication of algorithms, but the foundational infrastructure: fragmented data, legacy systems and uneven digital maturity. Energy operations generate massive volumes of operational technology (OT) and process data, yet much of it remains siloed in SCADA systems, proprietary historians, energy trading and risk management (ETRM) platforms and asset-specific applications. This fragmentation makes integration costly and slows reuse, creating a "local optimization trap" where AI pilots struggle to generalize across assets, regions or extreme, rare events.

Governance is another critical constraint. Explainability, regulation and trust become more pressing as AI moves from analytics into control. In trading and commercial functions, compliance demands auditability of model-driven decisions, in physical operations – pipelines, refineries and grids – the tolerance for "black-box" behavior is far lower, because safety, reliability and environmental outcomes are at stake. Utilities face strict human-in-the-loop requirements, and regulatory frameworks in many markets limit full automation even when models are technically capable.

Cybersecurity and infrastructure interdependence add a third layer of complexity. As AI connects OT and IT systems and moves workloads to cloud and edge platforms, the attack surface expands, making security a gating factor for deployment.

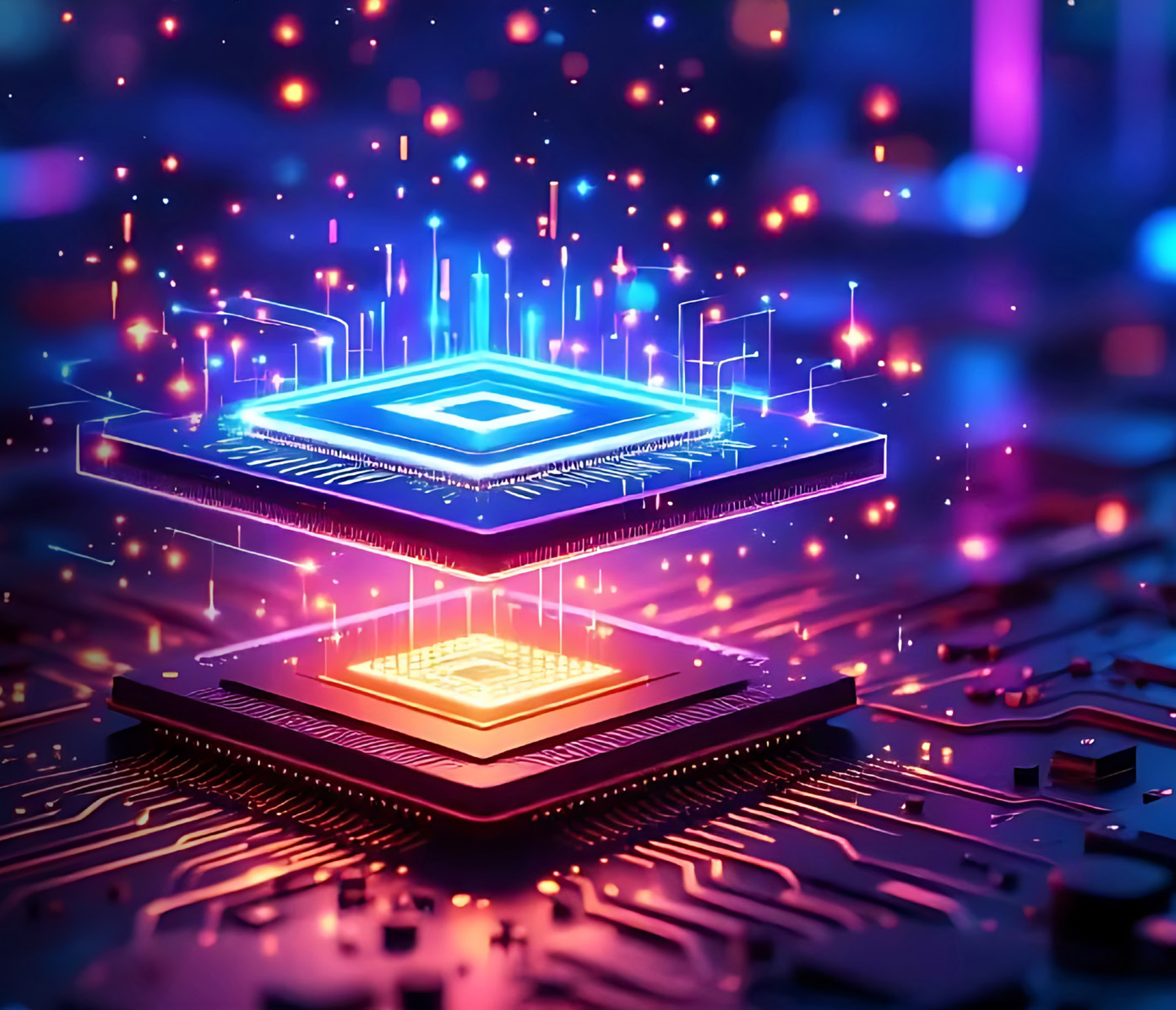
At the same time, the relationship between AI and energy is becoming reciprocal. Energy-intensive AI workloads are emerging as concentrated electricity demands, placing new stress on generation and grid capacity. Conversely, AI itself is increasingly a tool for improving energy systems and efficiency as well as unlocking latent capacity on existing networks.

The energy sector now sits at the intersection of these forces, highlighting both the opportunities and the responsibilities of integrating AI at scale.

04

Energy for AI

The hidden cost of intelligence



AI expansion is driving rapid growth of data centers. Once passive warehouses for email and websites, DCs are now energy-hungry “refineries” of the digital age, transforming raw data into economic value. In doing so, they place growing demands on electricity grids, water resources and critical minerals.

As the focus of this report is the interdependency of AI and energy, this chapter, exploring energy for AI, will examine the energy needs of AI and the implications for power systems.

4.1

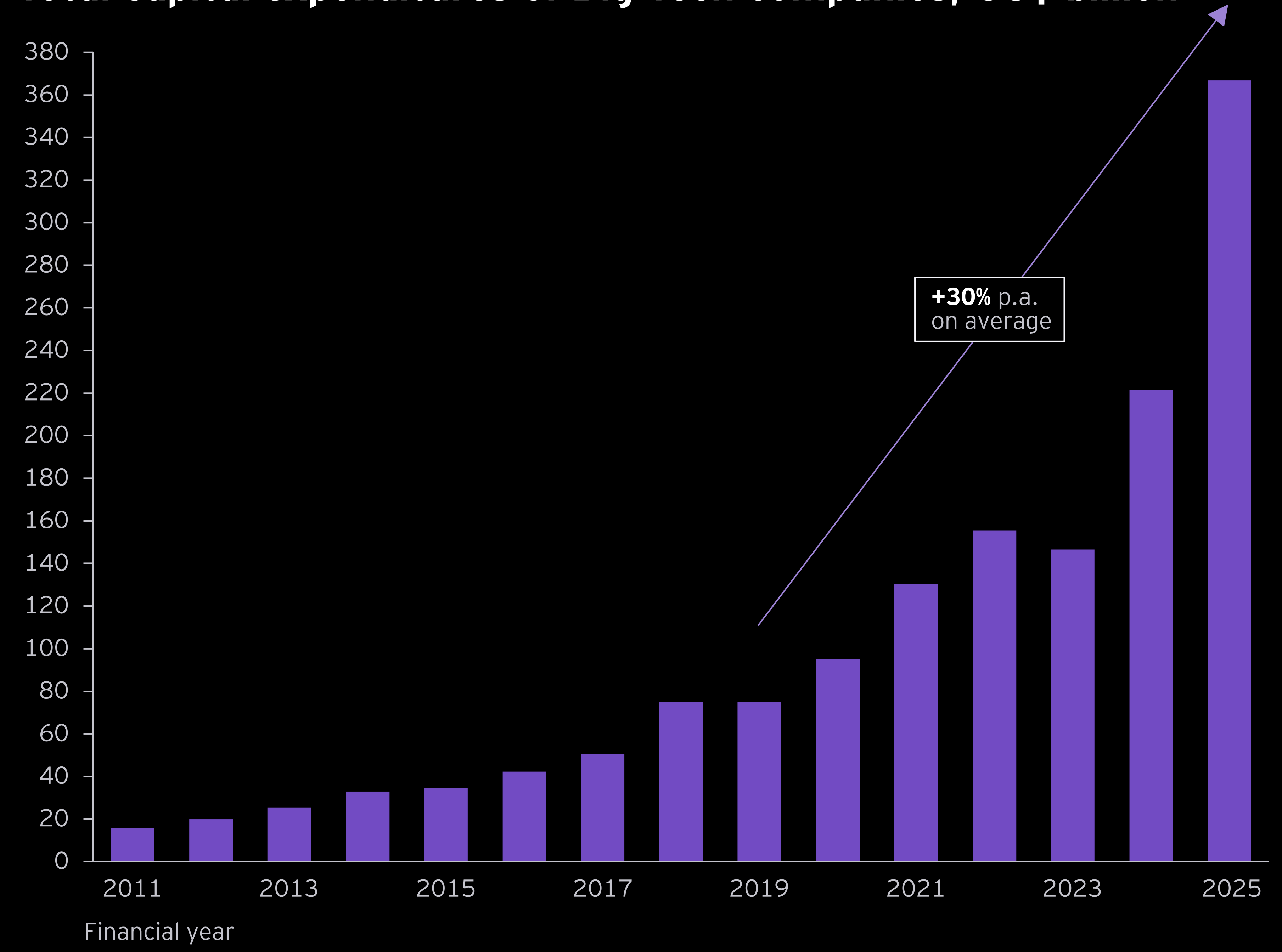
Data centers

“Bigger is better” is driving AI growth

Big Tech companies are investing hundreds of billions of dollars in AI, driven by the expectation that it will materially raise productivity and reshape how people work and create value. Between 2020 and 2025, the cumulative capital expenditure of five major technology firms[108] – which dominate the hyperscale data center landscape (see Box 1) – is estimated to have increased by more than 280%.[109]

A growing share of this investment is directed toward new data centers, which have become critical infrastructure underpinning cloud computing, AI, IoT and edge applications, as well as the highly capital-intensive computing hardware required to train advanced AI models.

Total capital expenditures of Big Tech companies, US$ billion



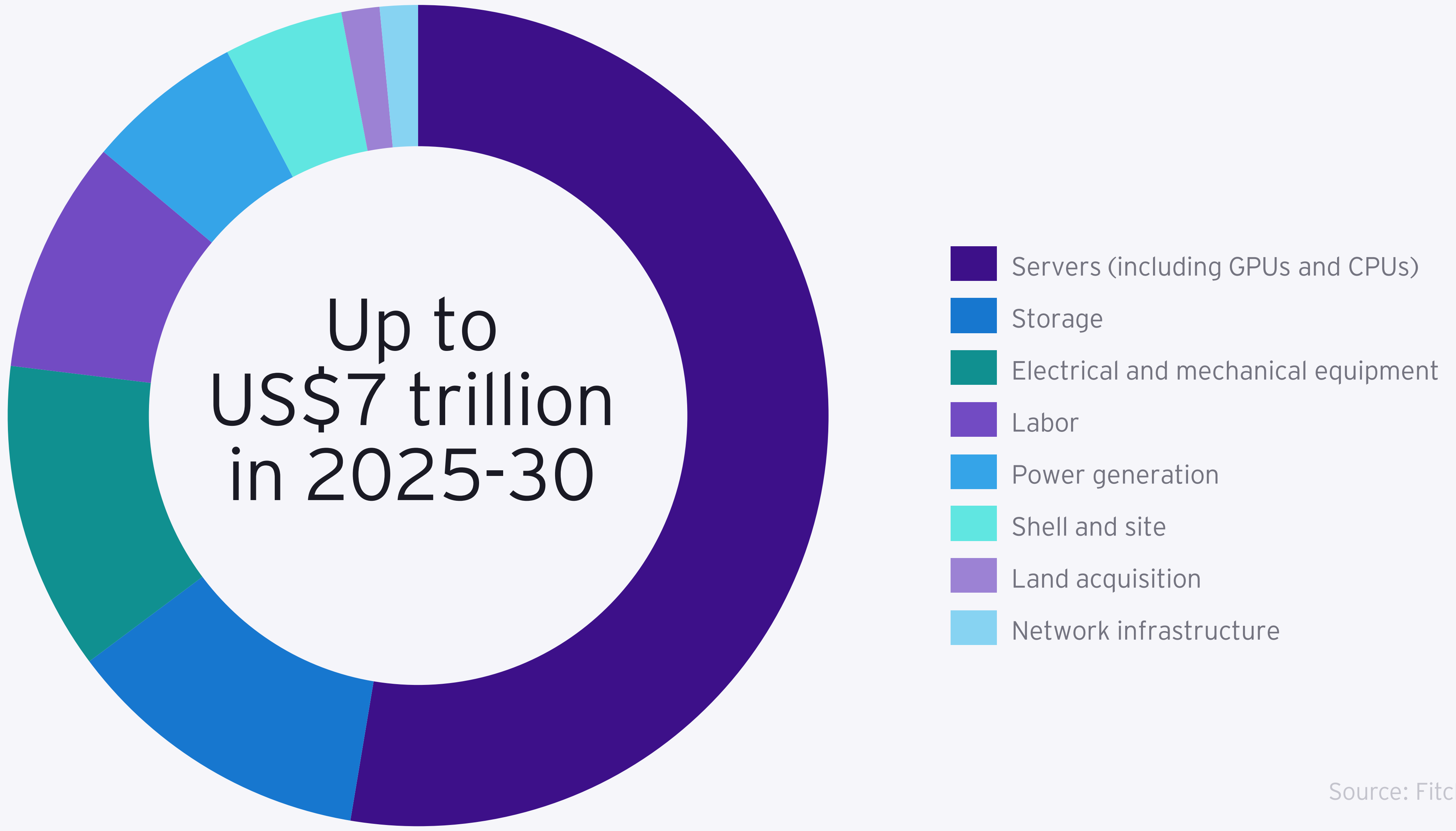
Note: The cumulative CAPEX of five major technology firms.
Source: EY Europe Central Energy Center’s analysis of the companies’ reports.

Global investment in data centers could reach up to **US$7 trillion**

Global investment in data centers could reach up to US$7 trillion between 2025 and 2030, driven largely by hyperscalers’ capital expenditure, with more than half directed toward computing hardware such as advanced chips.[110, 111]

This wave of investment could result in over 2,000 new data centers worldwide, many of them built at significantly higher capacity and density than today’s facilities.[112]

Global distribution of capital investments for data centers, 2025–30 (estimates)



Source: Fitch Ratings.

As of late 2025, there were almost

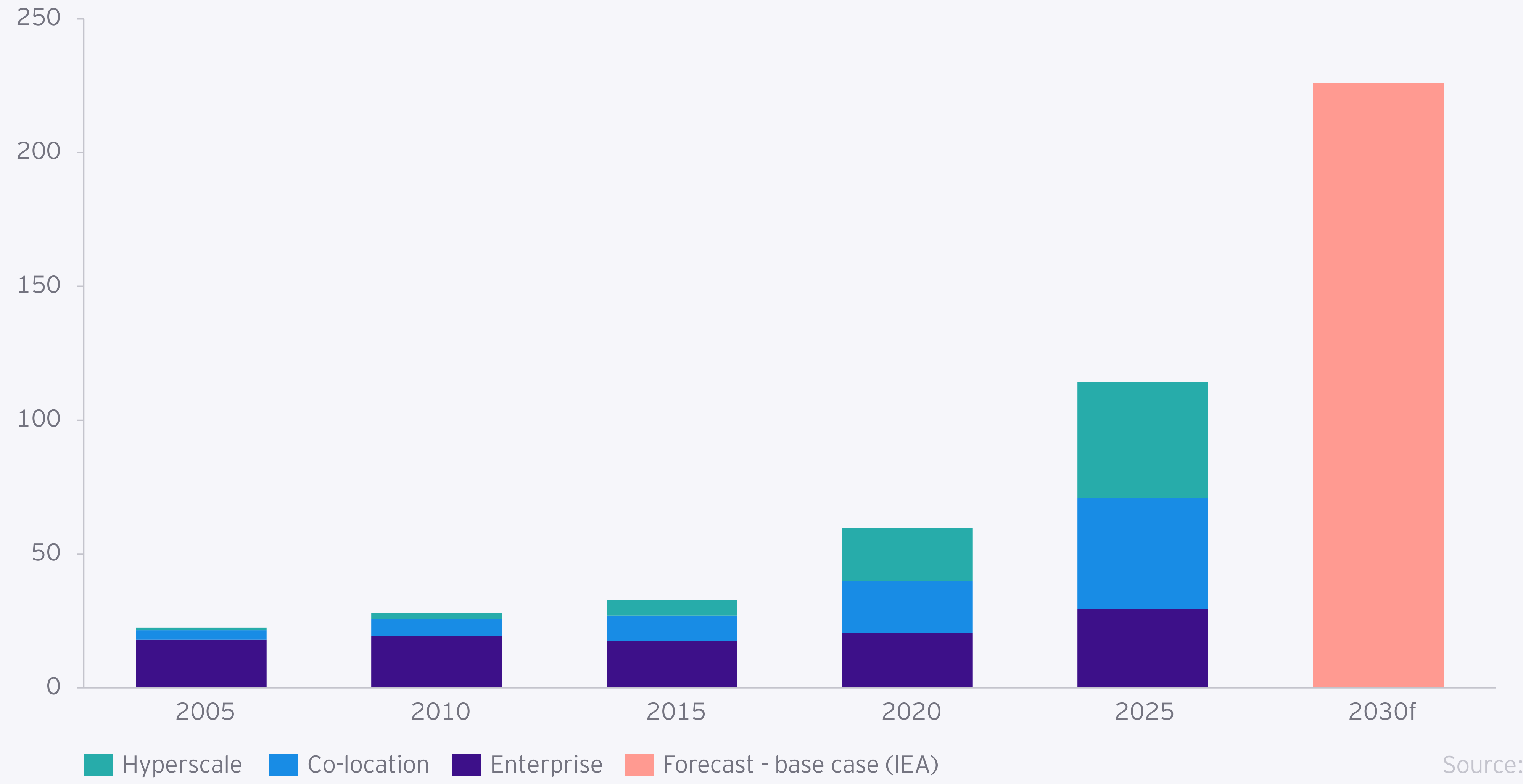
12,000

data centers worldwide

As of late 2025, there were almost 12,000 data centers worldwide, with the US accounting for roughly 45% of the total. Europe (including both EU and non-EU countries) represented around 27%.[113]

According to the International Energy Agency (IEA), global installed DC capacity grew at an average rate of 13% per year between 2020 and 2025, expanding from 60 GW to 114 GW.[114] Under the IEA's base case scenario, growth is expected to accelerate toward the end of the decade, averaging 15% annually,[115] with total installed capacity potentially reaching 226 GW by 2030. While not all this capacity is currently dedicated to AI workloads, AI's share is expected to rise materially over time.

Global installed DC capacity, GW



Source: IEA.

The regional split shows marked differences in the pace of DC capacity expansion. Between 2020 and 2024, the US led global growth, with installed capacity increasing by an average of 16% per year, a pace expected to be sustained through 2030. China followed with 14% annual growth over the same period and is projected to accelerate to around 19% per year by the end of the decade. Europe is also expected to see faster expansion between 2024 and 2030 than in the past, with growth accelerating to around 9% annually, compared with a historical average of 5%.

Despite this acceleration, Europe's share of global DC capacity is expected to continue declining – not because of absolute contraction, but because expansion in the US and China is occurring at a significantly faster rate, while growth in traditional Western European hubs moderates. As a result, Europe's share is projected to fall from 25% in 2015 and 22% in 2020 to around 16% in 2024, before declining further to approximately 12% by 2030.[116]

13%

per year - the average growth rate of global DC capacity in 2020-25

In the US, a typical data center now averages around

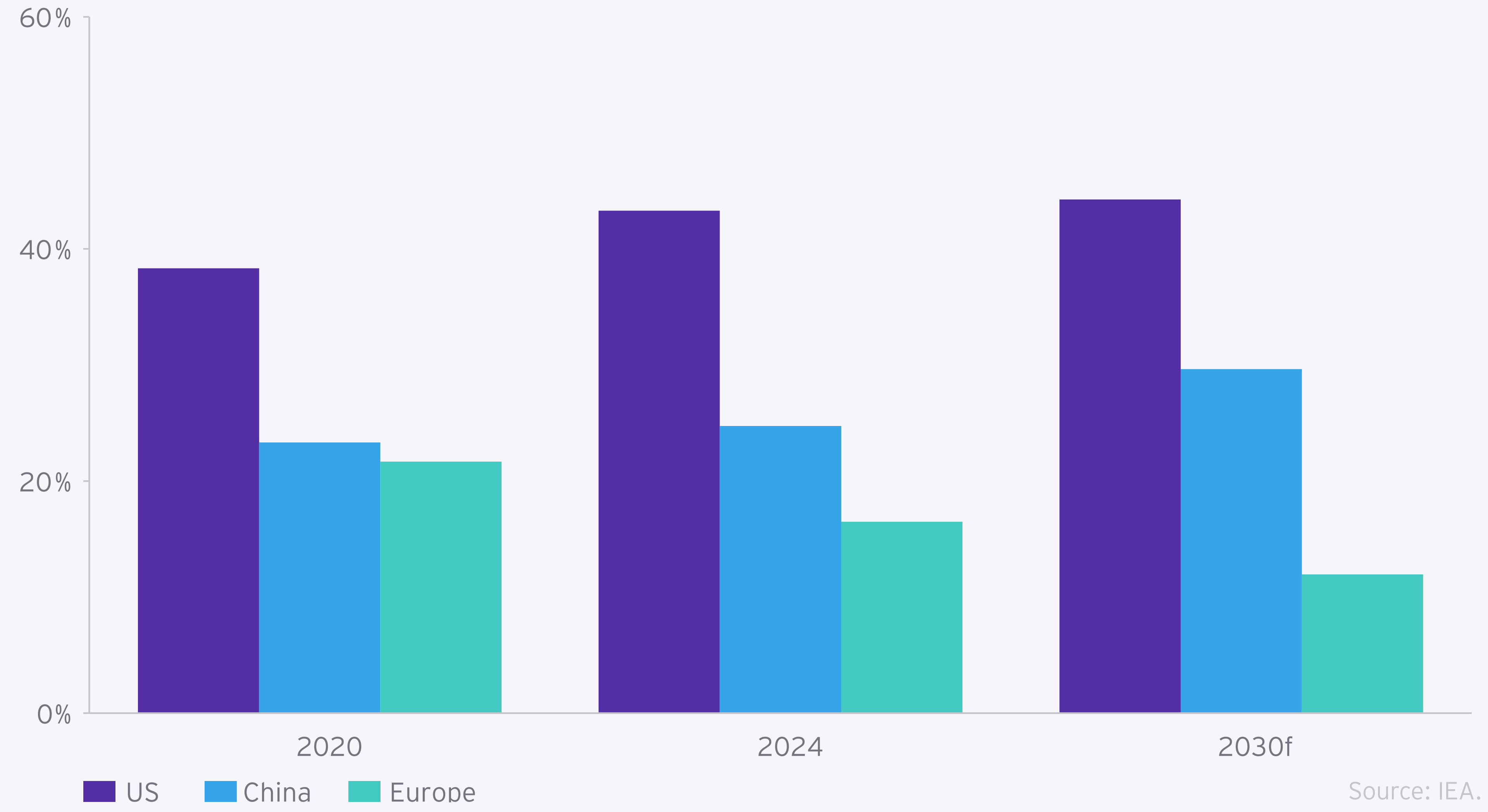
10 MW

per site

In 2025, nearly 30 new hyperscale campus proposals exceeding

1 GW

Shares of data center global capacity



Source: IEA.

Across global markets, hyperscale and co-location facilities are steadily increasing their share of total DC capacity, while the role of traditional enterprise data centers continues to diminish – with the enterprise share declining from 34% in 2020 to 26% in 2025.[117] At the same time, average facility size is rising. In the US, a typical data center now averages around 10 MW per site, roughly double the average capacity in the EU,[118] and further increases are expected across all regions.

This shift reflects fundamental changes in computing architecture. Modern data centers are becoming larger and denser, processing far more data per square meter as they deploy AI accelerator chips that operate in parallel rather than sequentially. These architectures are essential for handling AI training and inference workloads and are driving a clear "bigger-is-better" design paradigm.

Technology leaders are therefore concentrating investment into ever larger campuses, deploying thousands of high-performance chips within single sites to build increasingly sophisticated AI systems. In 2025 alone, nearly 30 new hyperscale campus proposals exceeding 1 GW were identified globally, alongside close to 100 additional projects in the hundreds-of-megawatts range, in addition to some 200 projects previously announced.[119]

Even if only a portion of these projects is ultimately delivered – for example, assuming a 25%–50% completion rate, consistent with large-scale renewable energy developments – the resulting build-out would still amount to tens of gigawatts of new capacity, primarily dedicated to AI training workloads, with inference playing a secondary role.

Looking ahead, newly built hyperscale facilities between now and 2029 are expected to average almost twice the capacity of today's data centers. Combined with major retrofits of existing campuses, this trajectory would push global hyperscale DC capacity to nearly triple by 2030.[120]

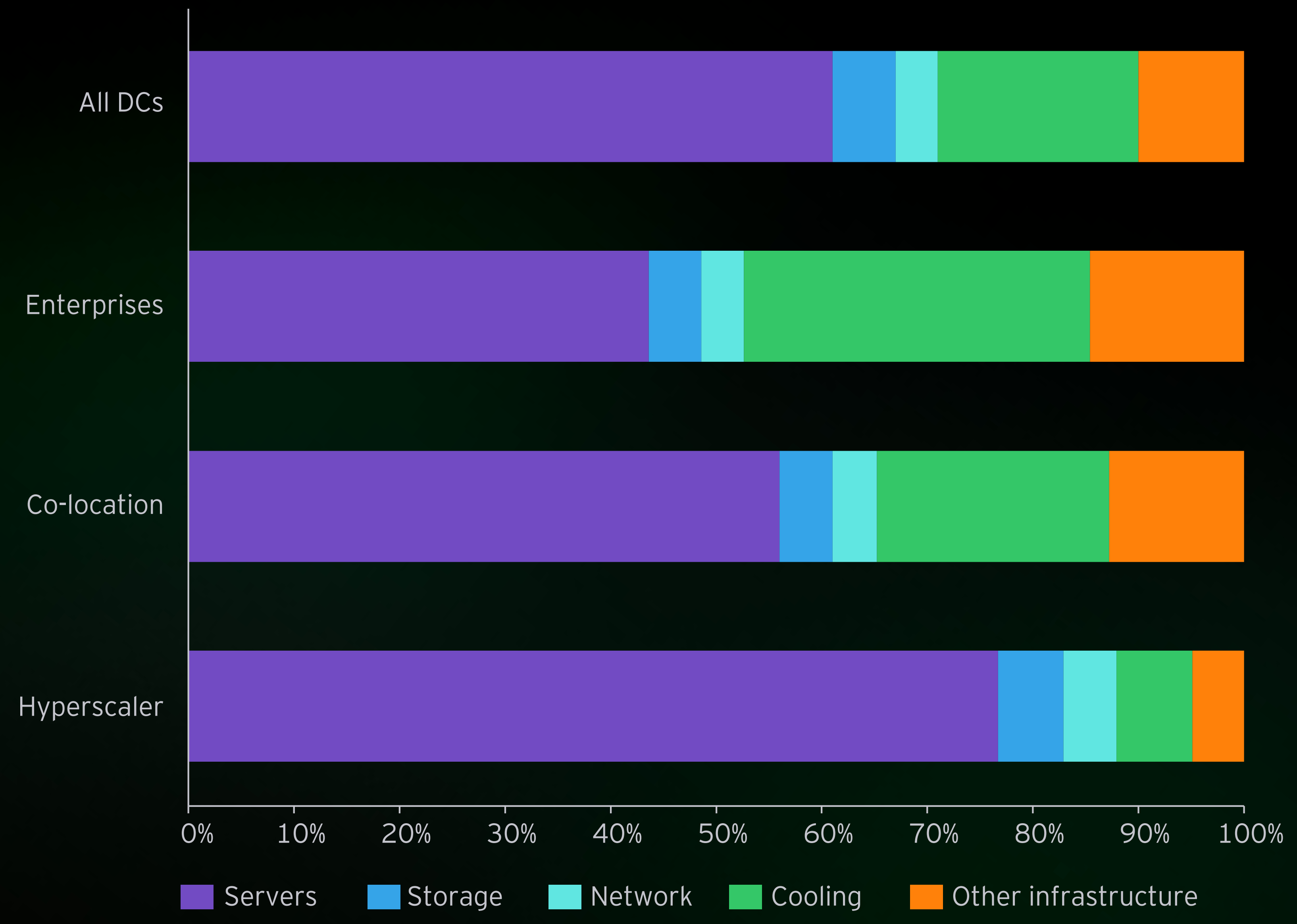
BOX 1. The types of data centers and key players (continues)

Enterprise DCs (up to 10 MW)	**Co-location DCs (1 MW-20 MW)**	**Hyperscale DCs (20 MW-100+ MW)**
DCs typically located on premises and designed to support specific organizations (i.e., a huge proportion of the company's IT infrastructure).	Facilities which allow multiple organizations to rent space, power and cooling infrastructure within shared environments.	Facilities of massive scale, energy efficiency and ability to handle diverse workloads (e.g., cloud, AI training, global digital services).

▪ DCs are exclusively owned and operated by a single organization.
▪ They are built to support internal IT workloads only (no external customers).
▪ Costs, design, security, and staffing are fully controlled by the organization.
	▪ Third-party providers lease secure, conditioned space to multiple customers (pay-as-you-go basis).
	▪ Customers either bring their own IT equipment ("retail co-location") or lease powered shell/data hall capacity ("wholesale co-location").
	▪ Provider owns and operates the building, power distribution and backup, cooling infrastructure, physical security.
	▪ Customers control their IT stack (servers, storage, AI accelerators, software).
	▪ Co-location is especially valuable for industries like banking, healthcare, telecom and hyperscale cloud providers that need performance consistency, compliance with data sovereignty laws, and cost efficiency.
	▪ Market leaders: US-base digital infrastructure company (more than 280 DCs worldwide),[121] US-based data center real estate investment trust (over 300 DCs across over 50 metropolitan areas).[122]
		▪ Built and operated by Big Tech or equivalent hyperscale cloud providers.
		▪ Support both the company's own workloads and customer workloads.
		▪ Hyperscale operators often build and own entire campuses, as well as lease full buildings from co-location providers to enter new markets quickly.
		▪ Hyperscale DCs worldwide nearly tripled to ~1,300 between 2018 and end 2025:
		  ▪ 58% capacity operated by three major technology firms.
		  ▪ 55% capacity concentrated in the US.[123]
		▪ Pipeline of 770 facilities at various stages of being planned, built or designed.[124]

Depending on the type of DC, power consumption could differ. For instance, compared with enterprise and co-location facilities, hyperscale DCs devote a larger share of their energy to IT equipment and a smaller share to cooling, thanks to highly improved designs.

Share of electricity consumption by DC and equipment type



Source: IEA (2024).

BOX 1. The types of data centers and key players (continued)

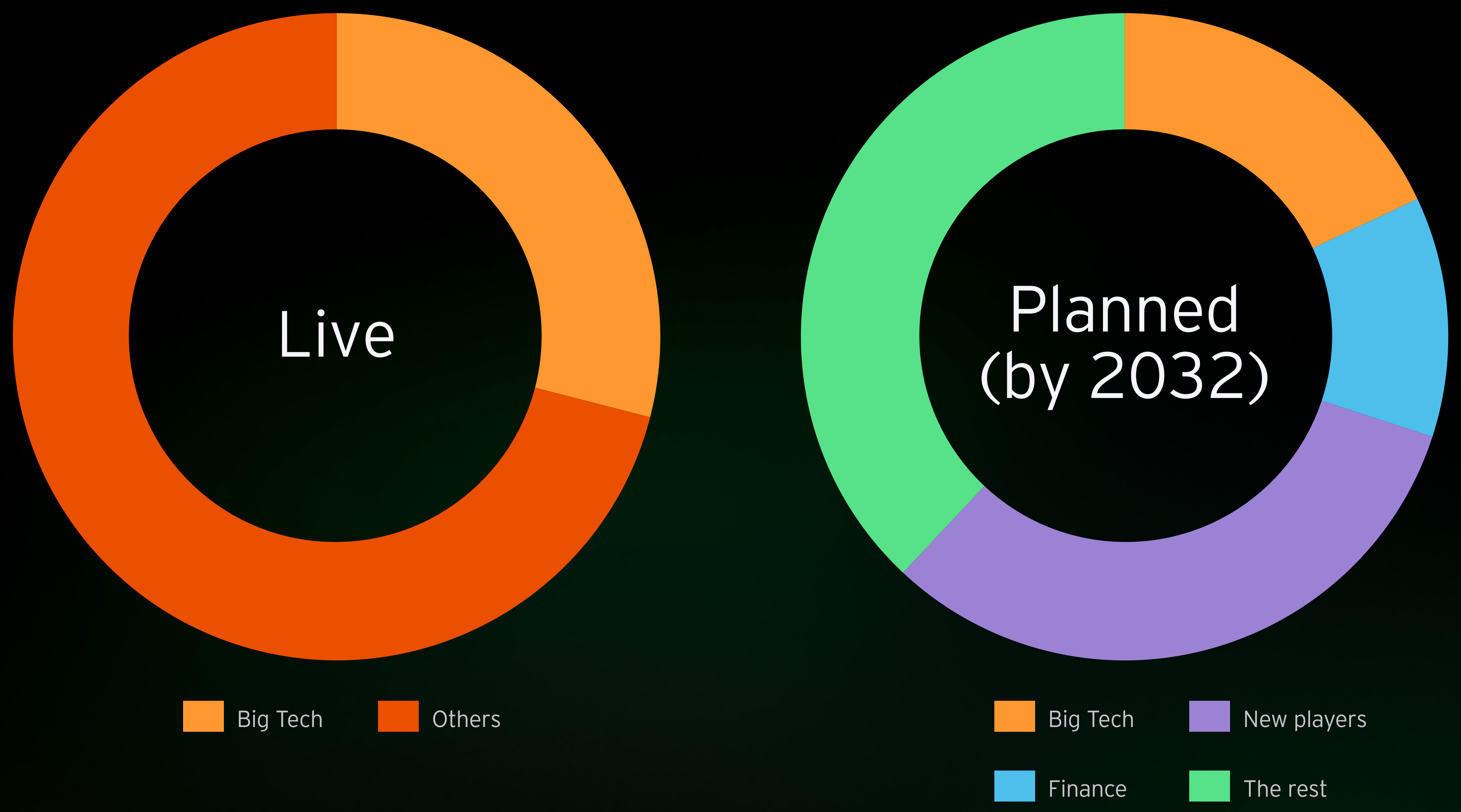
Big Tech companies have built most of today's large DC campuses and collectively control around one-third of global capacity. Over the medium term, however, their relative share of global computing power could decline as a broader set of players – increasingly drawn from financial markets rather than Silicon Valley – enters the space. Financial institutions and private equity firms alone have announced plans for more than 40 GW of new capacity across 33 countries, compared with roughly 7 GW currently in operation.

Alongside these investors, a growing number of new and nontraditional entrants are becoming active developers, including speculative players with limited prior experience in AI infrastructure. At the same time, existing operators – ranging from real-estate platforms and specialized infrastructure funds to technology startups and public-sector entities – are seeking to expand their DC footprints materially.[125]

Within this evolving landscape, neocloud providers are emerging as an important complementary layer rather than direct competitors to hyperscalers. Recent partnerships illustrate a model in which hyperscalers invest in neocloud expansion while retaining access to specialized capacity within their broader cloud ecosystems.[126]

Beyond these near-term dynamics, more experimental concepts are also being explored. Among them are proposals to locate DC infrastructure beyond Earth – including orbital or space-based data centers – aimed at addressing long-term constraints related to energy availability, cooling and land use. While such concepts remain highly speculative, they underscore the extent to which DC design and siting assumptions are being re-examined in the AI era.

DC market fragmentation: live vs. planned data centers



Sources: Bloomberg, DC Byte.

4.2

The widespread growth in data centers will require more power

Estimates of DC electricity consumption, particularly for AI-specific workloads, remain subject to significant uncertainty. In most jurisdictions, governments do not require comprehensive or standardized disclosure of electricity use by DC operators, and there is no globally consistent methodology for measuring or reporting consumption. In addition, hyperscalers rarely disclose the energy use of individual graphics processing unit (GPU) clusters or AI training runs, while limited access to proprietary operational data constrains efforts to measure consumption directly.

Emissions and electricity consumption reporting requirements by market

Country	National strategy	Reporting requirements	
		Emissions	Electricity consumption
Australia	+	+	+
Brazil	+	-	-
Canada	+	+	+
China	+	-	+
EU	+	+	+
France	+	+	-
Germany	+	+	+
India	+	-	-
Indonesia	+	-	-
Italy	+	+	-
Japan	+	+	+
Korea	+	-	-
Mexico	+	-	-
Russia	+	+	-
Saudi Arabia	+	-	-
South Africa	+	-	-
Turkiye	+	+	-
UK	+	+	+
US	+	+	+

+ National level + Subnational level only - No

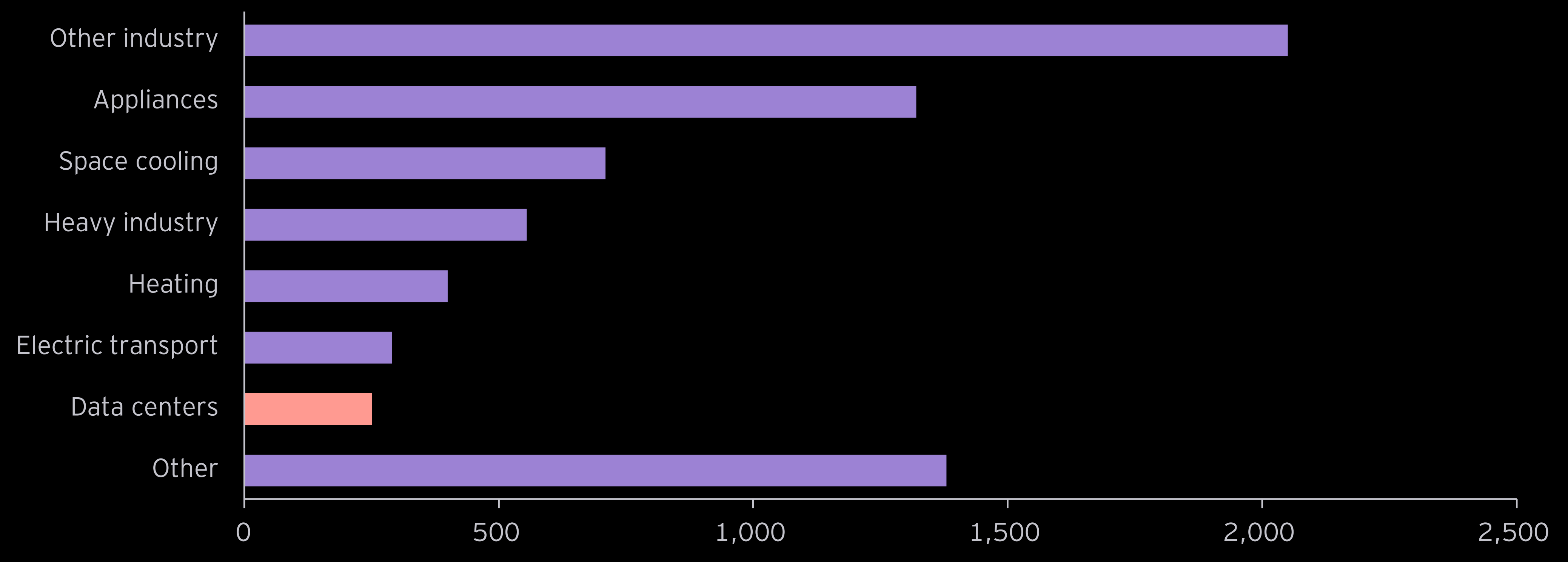
Source: IEA.

As a result, historical assessments of global DC electricity demand are largely derived from indirect estimates, combining partial disclosures, market sizing and modeling by third-party analysts rather than systematic reporting.

Despite these limitations, available evidence points to a meaningful and growing impact.

According to the IEA, data centers accounted for around 4% of global growth in electricity demand between 2014 and 2024. Over the past decade, growth in electricity consumption from data centers therefore increased by nearly as much as the transport sector, although it remained smaller than the contribution from appliance adoption in buildings and ongoing industrial electrification.[127]

Increase in electricity demand by sector in 2014-24, TWh



Source: IEA.

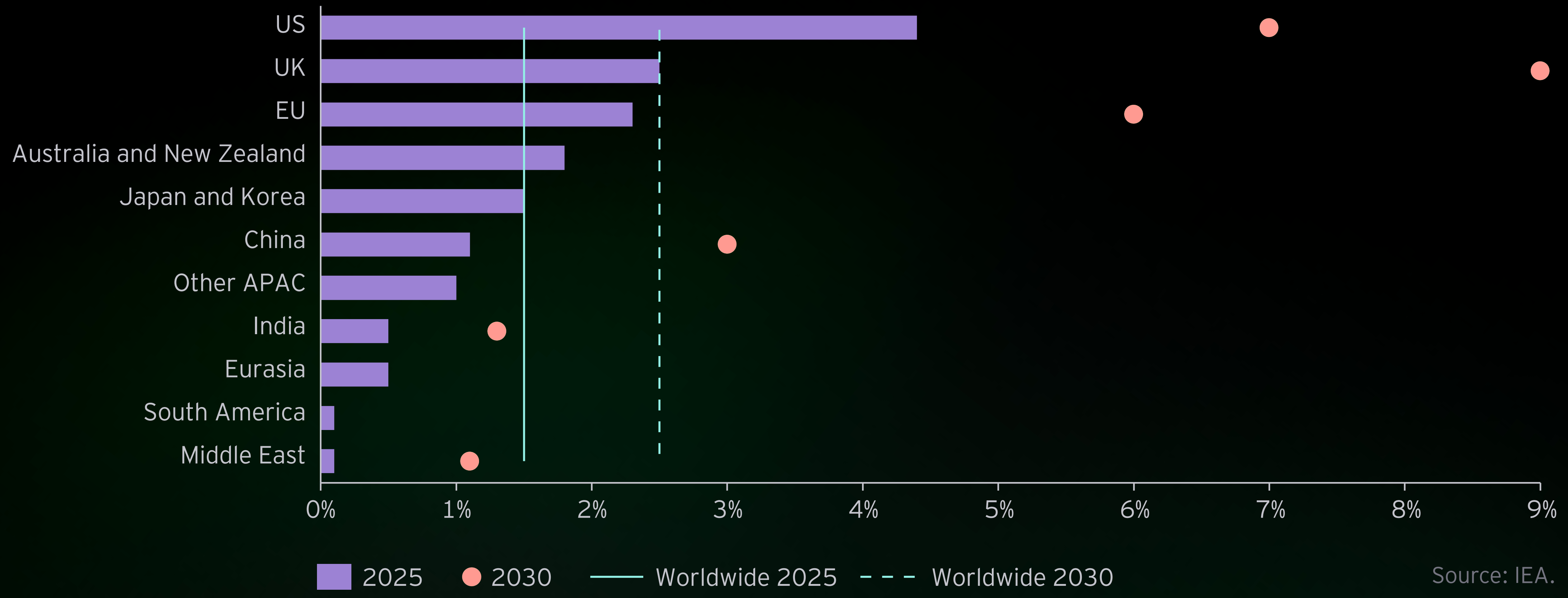
DCs accounted for around

4%

of global electricity demand growth during the past decade

Currently, DCs account for approximately 1.5% of global electricity consumption, though this share varies significantly by region and country. The highest penetration is observed in the US, where DCs represent nearly 4.5% of total electricity demand,[128] followed by the UK at around 2.5% and the EU at approximately 2.3%.[129] Within the EU, concentration is uneven: Ireland stands out with data centers accounting for around 22% of national electricity demand,[130,131] while the Netherlands, Germany and France record shares of roughly 5%, 4%, and 2%, respectively.[132, 133, 134] DCs in China use between 0.9% and 2.7% of the country's annual electricity, according to different estimates.[135, 136]

Electricity consumption from DCs as a share of total electricity demand by the market, as of 2025



Source: IEA.

DCs account for around

1.5%

of global electricity consumption

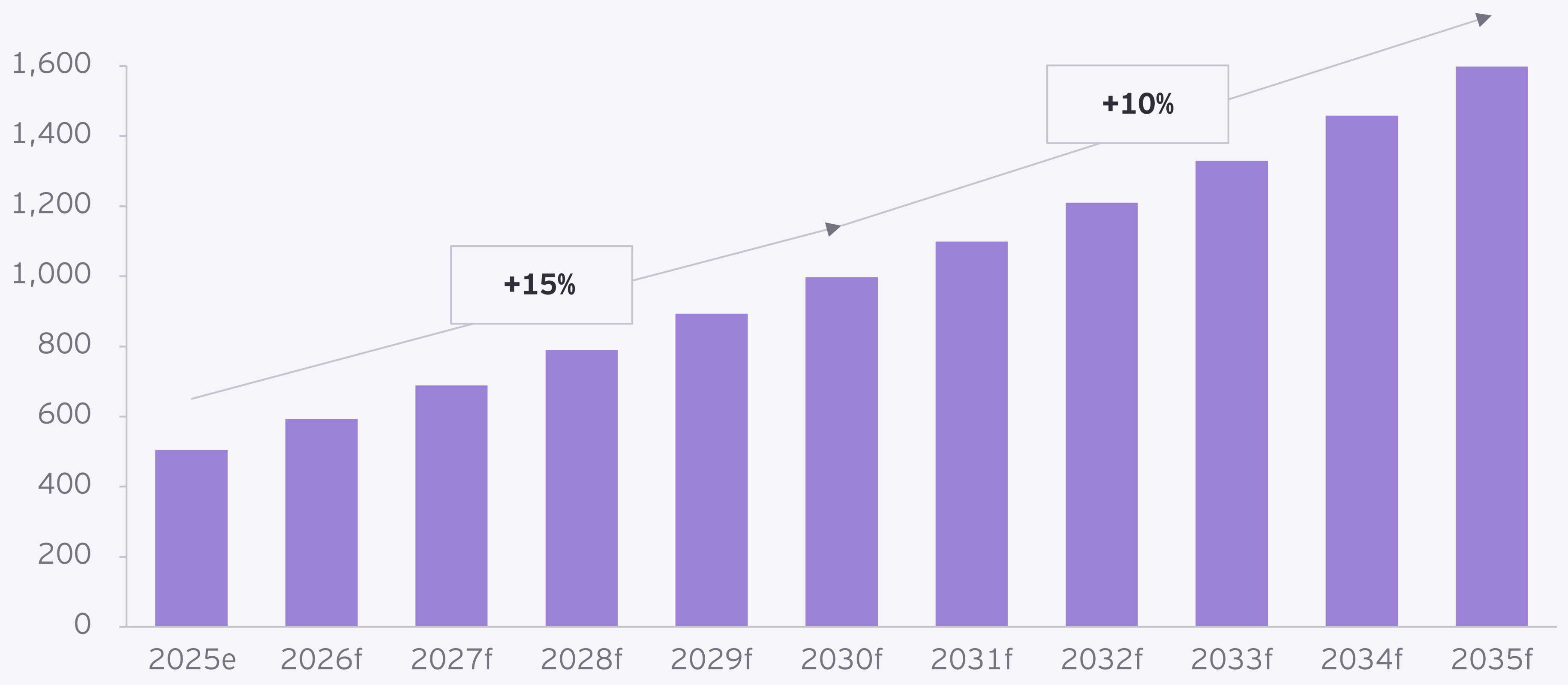
AI workloads are fundamentally reshaping DC power requirements. Traditional server racks typically draw 5–15 kW, whereas AI-focused racks equipped with high-performance GPUs operate at 40–60 kW or more. In some cutting-edge AI training facilities, individual rack power densities exceed 100 kW, driving significant changes in facility design, cooling systems, and power-delivery architecture.[137]

At the same time, isolating electricity demand attributable specifically to AI remains challenging. AI represents only one category of workload within DCs, and as AI capabilities become embedded across a growing range of digital services, the boundary between AI-related and non-AI-related consumption is becoming increasingly blurred.

Nevertheless, AI-driven expansion has elevated data centers to material actors in power system planning. Under the EY Energy and Resources Transition Acceleration (ERTA) model's "current trajectory" scenario, DCs are projected to account for approximately 2.5% of global electricity demand by 2030, broadly aligned with the IEA's base case estimate of around 3%.[138] By region, the share of electricity demand attributable to data centers could rise to around 7% in the US, 10% in the UK, 6% in the EU, and approximately 4% in China.[139]

Global electricity annual demand from DCs is projected to roughly double between 2025 and 2030, reaching close to 1,000 TWh under the EY ERTA model's "current trajectory" scenario, compared with approximately 946 TWh in the IEA's base-case estimate and between 1,580 TWh and 2,200 TWh across alternative projections.[140] Average annual growth in DC electricity demand is assumed to be around 15% through the end of the decade, before moderating to approximately 10% per year between 2030 and 2035 as deployment matures and efficiency gains partially offset expansion.

Annual electricity demand by data centers – "current trajectory" scenario, TWh



Source: EY ERTA.

DCs could account for approximately

7%

of global electricity demand growth by 2030

As a result, DCs could account for approximately 7% of global electricity demand growth between 2025 and 2030 and around 9% over the broader 2025–35 period.

However, significant uncertainty remains around the availability of adequate power supply. In the US – the world's leading market for DC expansion – the rapid escalation in compute intensity is creating particular strain. As next-generation models demand substantially more GPUs and energy, projections indicate the US could experience a power supply shortfall of up to 20% by 2028.[141, 142]

At the same time, projections of future DC electricity demand remain highly uncertain. Outcomes will depend on several interrelated factors, including access to grid capacity, availability of AI chips, efficiency improvements in hardware and models, speculative project announcements and shifts in the AI market itself.

Sustained geopolitical tensions is a layer of unpredictability, as they risk disrupting supply chains for critical components and reshaping market economics. Recent escalations in the Middle East, for example, have raised investor concerns that prolonged instability could tighten already constrained supplies of memory chips and storage devices.[143, 144]

Moreover, innovation is already delivering measurable efficiency gains, particularly in cooling, which has long been a major power constraint for DCs. Between 2007 and 2024, cooling related energy per server dropped from roughly 1.5×[145] to 0.6×, with best-in-class facilities pushing below 0.1×. The rapid emergence of more energy-efficient models – such as DeepSeek and o3-mini – highlights a central ambiguity.

Will efficiency gains curb total electricity consumption or will they lower costs and accelerate adoption, ultimately driving demand higher?

This dynamic reflects a modern manifestation of the Jevons paradox, where efficiency improvements could lead to increased overall resource use rather than reduction.

4.3

The energy system enablers of AI

Low-carbon power and grid access

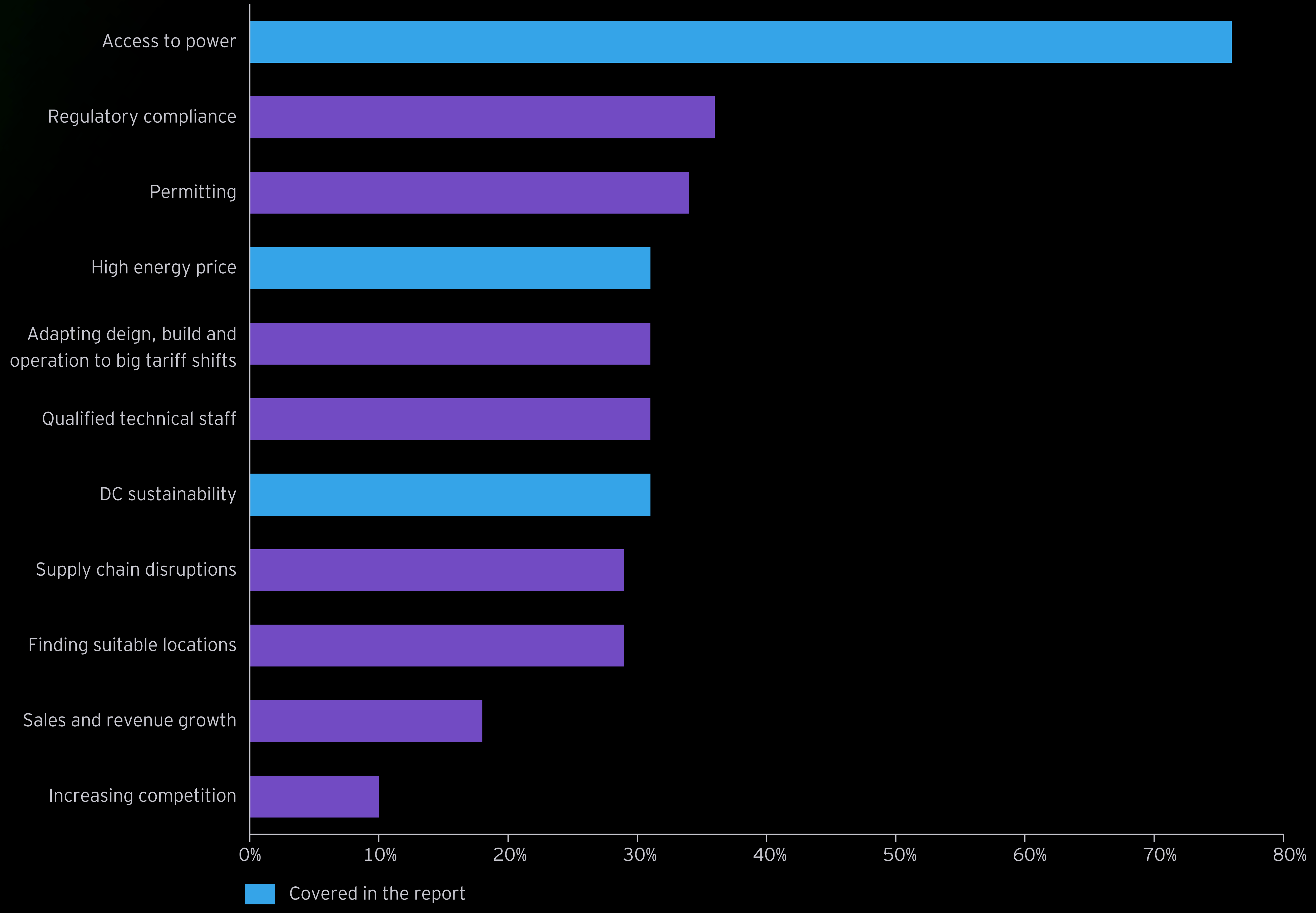
Despite uncertainty about the absolute level of growth in data center electricity demand, a few things are clear. The growth of DCs becomes conditional on two inseparable energy requirements: clean supply and deliverability.

Operators will need to secure low-carbon and cost-predictable megawatts to meet decarbonization commitments and manage price risk.

However, even the greenest megawatt could be unusable without grid capacity and timely interconnection: substations, transmission headroom and market frameworks that can connect large loads where and when they are needed.

These areas are among the biggest challenges faced by DCs by the end of the decade.[146]

Biggest challenges faced by the DCs for the next three years



Source: European Data Association survey (December 2024).

4.3.1

Low-carbon power procurement is needed to meet tech's decarbonization commitments

The challenge posed by DCs extends well beyond their rapidly rising electricity consumption to the carbon intensity of the power they rely on. Without access to low-carbon generation, continued expansion risks locking in significant CO_2 emissions, undermining both corporate decarbonization commitments and broader climate objectives.

To reconcile ambitious emissions targets with the need for reliable, cost-predictable power, DC operators are deploying a diversified portfolio of clean-energy strategies.

While renewables remain the fastest-growing source of new generation capacity, their inherent intermittency limits their ability to support continuous, high-load AI training and inference workloads. Solar output, for example, can decline by nearly 45% within an hour in some regions, with photovoltaic ramp-down rates of between 70% and 80% over just five to ten minutes during cloud events, volatility that dense AI clusters cannot absorb without buffering.[147]

These constraints are accelerating the adoption of hybrid clean-energy architectures. Smoothing second-to-minute fluctuations, capturing excess renewable output, and, in some cases, replacing diesel generators for short-duration backup increasingly requires deployment of battery energy storage systems (BESS). For longer-duration resilience, hydrogen fuel cells are emerging as a clean, low-noise option capable of delivering continuous power. Many operators expect such hybrid systems (renewables, BESS and fuel cells) to provide reliability comparable with legacy fossil baseload plants. According to the European Data Centre Association, planned adoption of hydrogen fuel cells could rise from around 3% today to nearly 19% within the next two years, while we expect BESS deployment to increase from 3% to 28% over the same period.[148]

Layering renewables with batteries for balancing and fuel cells for extended backup enables hybrid systems that approach the reliability of traditional baseload generation, while preserving the decarbonization benefits of clean energy. Yet even well-designed renewable-plus-storage configurations struggle to fully meet the 24/7 load profiles required by large-scale AI workloads. As a result, hyperscalers are increasingly turning to firm, low-carbon baseload options, notably next-generation nuclear and geothermal technologies.

Small modular reactors (SMRs) – factory-built units typically delivering up to 300 MW per module with capacity factors of up to 95%[149] (compared with roughly 14% for solar, 30% for onshore wind, and around 50% for offshore wind) – are gaining traction as scalable, high-reliability power sources for large AI campuses. Globally, up to 25 GW of SMR capacity has been announced with explicit links to DC supply.[150] Most projects, however, remain at an early stage and are unlikely to contribute materially by the end of the decade.

In parallel, enhanced geothermal systems (EGS) are moving from concept toward early commercial deployment. With capacity factors close to 90%, geothermal offers round-the-clock, carbon-free power well-aligned with AI duty cycles, while also providing opportunities for direct cooling.[151] Its applicability remains geographically constrained, but momentum is building. For example, one of US developers has raised nearly US$0.5 billion, including investment from Big Tech, to advance a 500 MW geothermal project in Utah, with the first phase targeted for commissioning in 2026.[152, 153]

Even well-designed renewable-plus-storage configurations struggle to fully meet the 24/7 load profiles required by large-scale AI workloads.

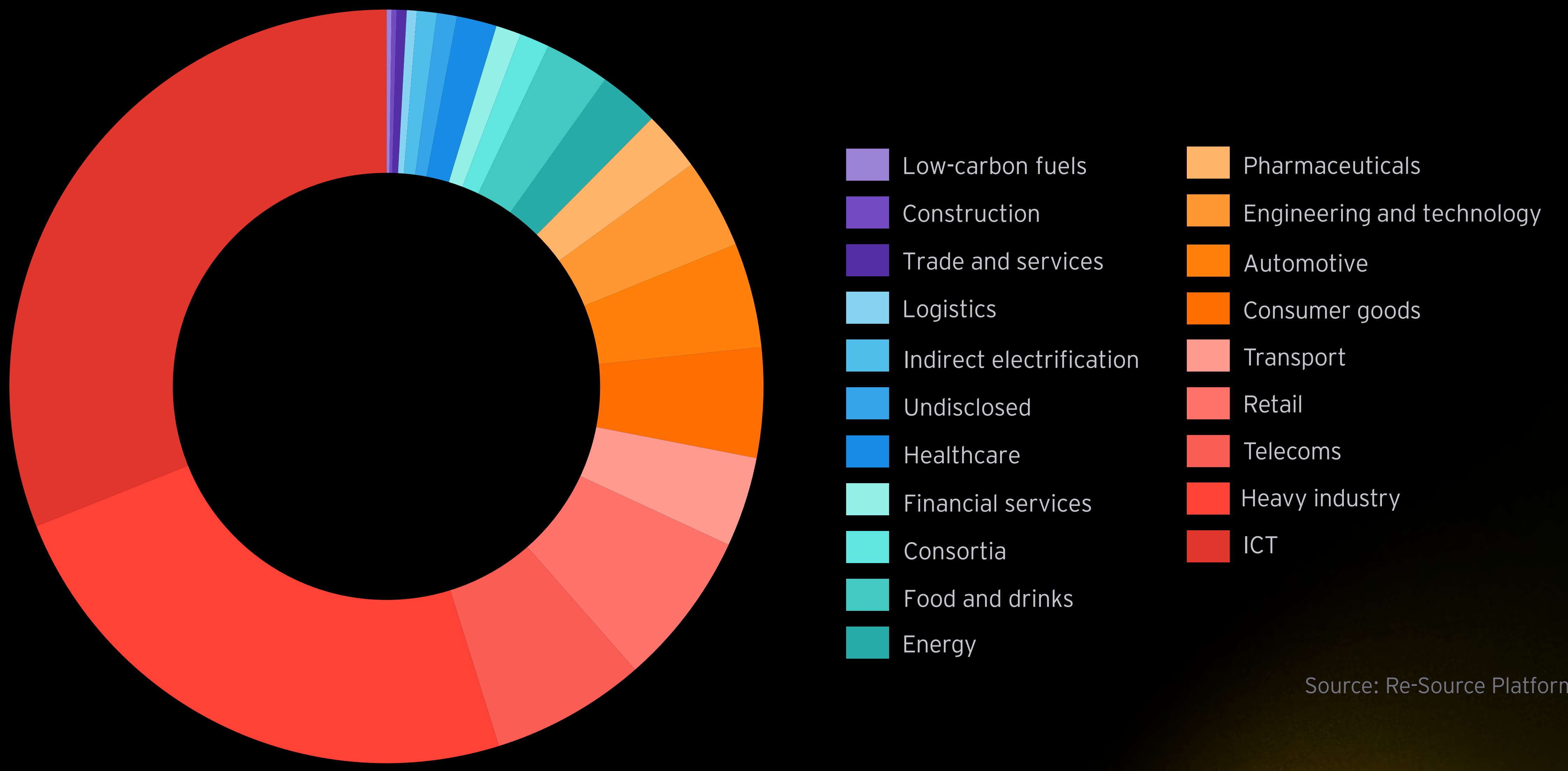
SMRs and EGSs provide near-baseload performance (90%–95% capacity factors), versus much lower utilization for solar and wind.

Gas infrastructure, when paired with carbon capture and storage (CCUS), can play a transitional role in enabling near-term DC deployment where firm low-carbon alternatives such as SMRs or geothermal are not yet available.

Beyond generation, operators are also rethinking energy flows within and around DC campuses. Hyper-dense AI facilities generate substantial volumes of waste heat – an often overlooked by-product that Northern European markets are increasingly capturing and feeding into district heating networks. This circular approach converts a thermal liability into a community asset and illustrates the system-level integration required to align AI infrastructure growth with broader energy transition.

Finally, long-term power purchase agreements (PPAs) have become a cornerstone of DC energy strategy. By contracting directly with power producers, operators can secure reliable electricity while accelerating the deployment of new cleaner generation. In Europe, data centers have emerged as one of the largest drivers of renewable PPAs, accounting for around one-third of total contracted volumes.[154] Between 2020 and 2025, the information and communications technology (ICT) sector contracted approximately 14.5 GW of renewable capacity – surpassing even heavy industry, which secured around 11 GW over the same period.[155]

PPA market structure in Europe, by industry (2020-25)



Source: Re-Source Platform.

As operators seek firm, low-carbon baseload to complement intermittent renewables, nuclear PPAs are also beginning to enter the market, indicating that companies are starting to explore more diversified, long-duration clean-energy procurement options aligned with the emerging power needs of the AI era.

2025 nuclear power initiatives for DCs in Europe

Country	Nuclear power capacity	Applications
Multiple locations	Up to 500 MW	Powering co-location data center portfolio across multiple European locations.[156]
Netherlands	Up to 250 MW	Powering AI data centers in the grid-constrained Dutch market with SMRs.[157]
n/a	300 MW per unit	Exploring the use of the AP 300 SMR to provide clean power for Data 4's future data center campuses.[158]
UK	300 MW	Developing Europe's first co-located SMR and data center campus on a 250-acre site.[159]
Sweden	n/a	Exploring the construction of Sweden's first nuclear-powered data center in Nyköping.[160]
Poland	n/a	Creation of a national roadmap for deploying SMRs to power Poland's data center market.[161]
UK	n/a	Formally exploring dedicated nuclear energy for special data center districts, backed by a £12 billion investment.[162]
France	n/a (leveraging existing national fleet)	Expanding national AI computing capacity, explicitly powered by its nuclear backbone, with an initial €10 billion investment.[163]

4.3.2

Power grid queues force data center operators to revise strategies and locations

Despite the rapid build-out of new clean-energy capacity, connecting new projects to the electricity grid has resulted in a major bottleneck. Power grids in many countries have not kept pace with recent shifts in demand and investment. Transmission networks are increasingly congested, connection queues are growing longer, and utilities often lack the capacity to accommodate large, continuous 24/7 loads, such as data centers.

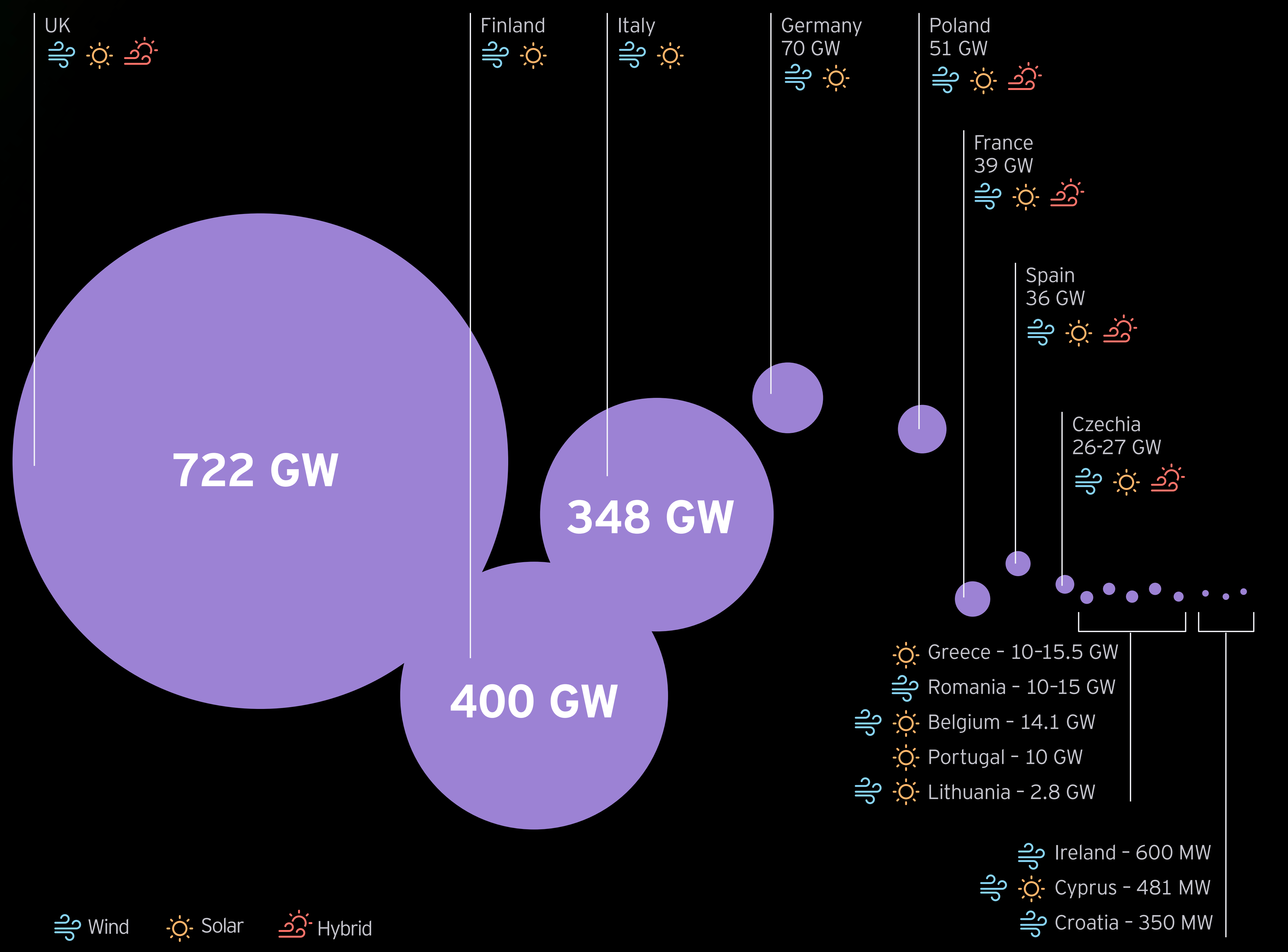
The surge in connection requests has coincided with insufficient expansion of transmission infrastructure. Over the past decade, the rate of increase in new high-voltage transmission lines has slowed, even as demand for grid access has accelerated. While new transmission projects are planned, bringing a major line from design to operation can take up to a decade,[164] due to lengthy siting, permitting and construction processes. As a result, many energy projects are technically ready to operate but remain unable to connect to the grid.

Globally, more than 3,000 GW of renewable energy capacity is currently waiting in grid connection queues – over five times the amount of solar and wind capacity added in 2022 alone – with roughly 1,500 GW already at advanced stages of development.[165,166]

In Europe, the challenge is particularly acute: over 1,700 GW of renewable and hybrid projects are stuck in interconnection queues across multiple countries, constrained by network congestion and procedural delays.[167] In the UK, for example, before grid-connection reforms introduced in late 2025 unlocked around 283 GW of generation and storage, the connection queue exceeded 722 GW – roughly four times the capacity required to meet national power needs by 2030.[169, 169]

As a result, DC developers are increasingly facing multiyear delays simply to secure grid connections. While a new DC campus can typically be designed and constructed in around four years, the development of new transmission infrastructure in advanced economies can take 10 years, making grid access – rather than construction – the critical limiting factor.[170, 171, 172] This is not just a problem of permitting and construction; supply chains for grid equipment are also showing strain – the price index for power transformers has increased one and a half times since 2020.[173]

Grid connection queues for renewable and hybrid projects in Europe, GW (mid-2025)



Note: The UK unlocked 283 GW of generation and storage in late 2025.
Sources: Beyond Fossil Fuels, Ember, E3G, Institute for Energy Economics and Financial Analysis.

Reported connection queues for new DCs in selected markets

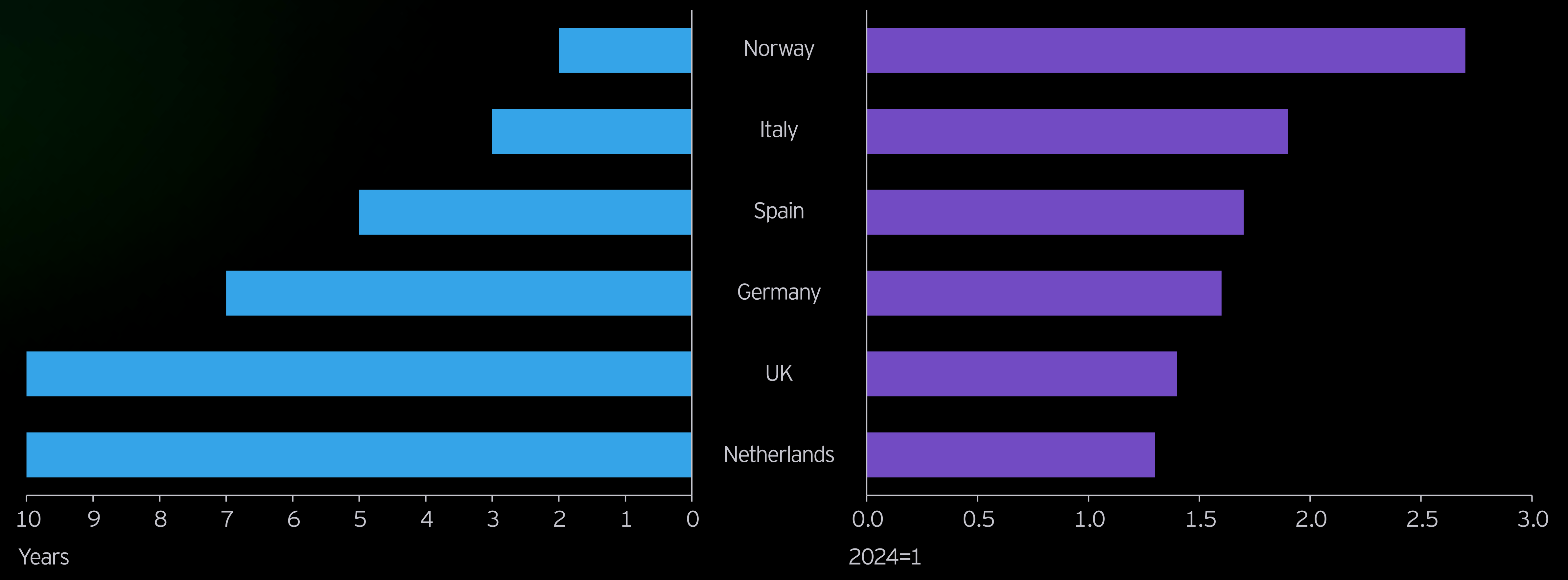
Country	Average time in queue, years
US average	1-3[174]
North Virginia (US)	Up to 7[175]
California (US)	3[176]
Germany	Up to 7[177]
UK	Up to 10[178]
Netherlands	Up to 10[179]
Kanto (Japan)	Over 5[180]
Malaysia	Up to 3[181]
Queensland (Australia)	Over 2[182]
Italy	Up to 3[183]
Norway	2[184]
Spain	3-5[185]
Poland	3[186]
Hungary	Approximately 5[187]
Finland	2-3[188]
Ireland	Up to 3[189] (the pause on new grid connections for some DC projects in 2021-25)

As a result, countries with long grid-connection queues are increasingly losing out on DC investment, while growth is shifting toward markets whose power systems are better prepared to accommodate large, continuous loads. Today, countries with half the connection time of major hub markets are positioned to attract more DC growth by 2030.[190]

These constraints are forcing operators to rethink how they secure power.

Unable to wait years for traditional grid connections, hyperscalers are increasingly pursuing co-location strategies, placing data centers directly adjacent to power plants and bypassing the transmission network altogether. This approach, however, comes at a cost: pricing for co-location arrangements has risen by around 20% in power-constrained markets.[191]

The correlation between years in grid connection queue and DCs expansion growth rate for 2024-30



Sources: ICIS, Ember, EY Europe Central Energy Center analysis.

It also introduces new reliability considerations. Co-location can also raise reliability concerns: when a DC relies on a single on-site generation source in an off-grid setup, it departs from traditional redundancy models – unlike conventional cloud regions with dual utility feeds and network-wide fallback, co-located sites often function as isolated power islands.

In parallel, some developers are adopting a "bring your own power" (BYOP) strategy, securing their own power supply instead of relying solely on the grid. This model provides greater cost control, flexibility to participate in energy markets and improved resilience during grid outages.[192] This shift is starting to blur the line between energy and digital infrastructure investors, as DC funds begin co-owning renewable plants or storage projects. In the future, we could even see energy-backed DC securities emerge to hedge price and load risks. BYOP is paving the way for a new asset class – "compute-integrated energy" – in which returns depend not just on rack utilization, but also on the efficiency of power production.

Despite these innovations, grid interconnection remains the fundamental constraint. Network bottlenecks could delay around 20% of global DC capacity planned for construction by 2030,[193] and supporting anticipated AI-driven growth may require up to US$720 billion in grid investment by the end of the decade. Until delivery of such investments, power availability – not computing capacity – will remain the primary factor shaping the pace and geography of AI infrastructure expansion.[194,195]

05

Europe's data center rebalancing

Power constraints push growth toward the Europe Central region

As of late 2025, Europe hosts more than 3,000 data centers, though their distribution across the continent remains highly uneven. Germany, the UK, France, the Netherlands and Ireland together account for around 55% of all European facilities count.[196, 197]

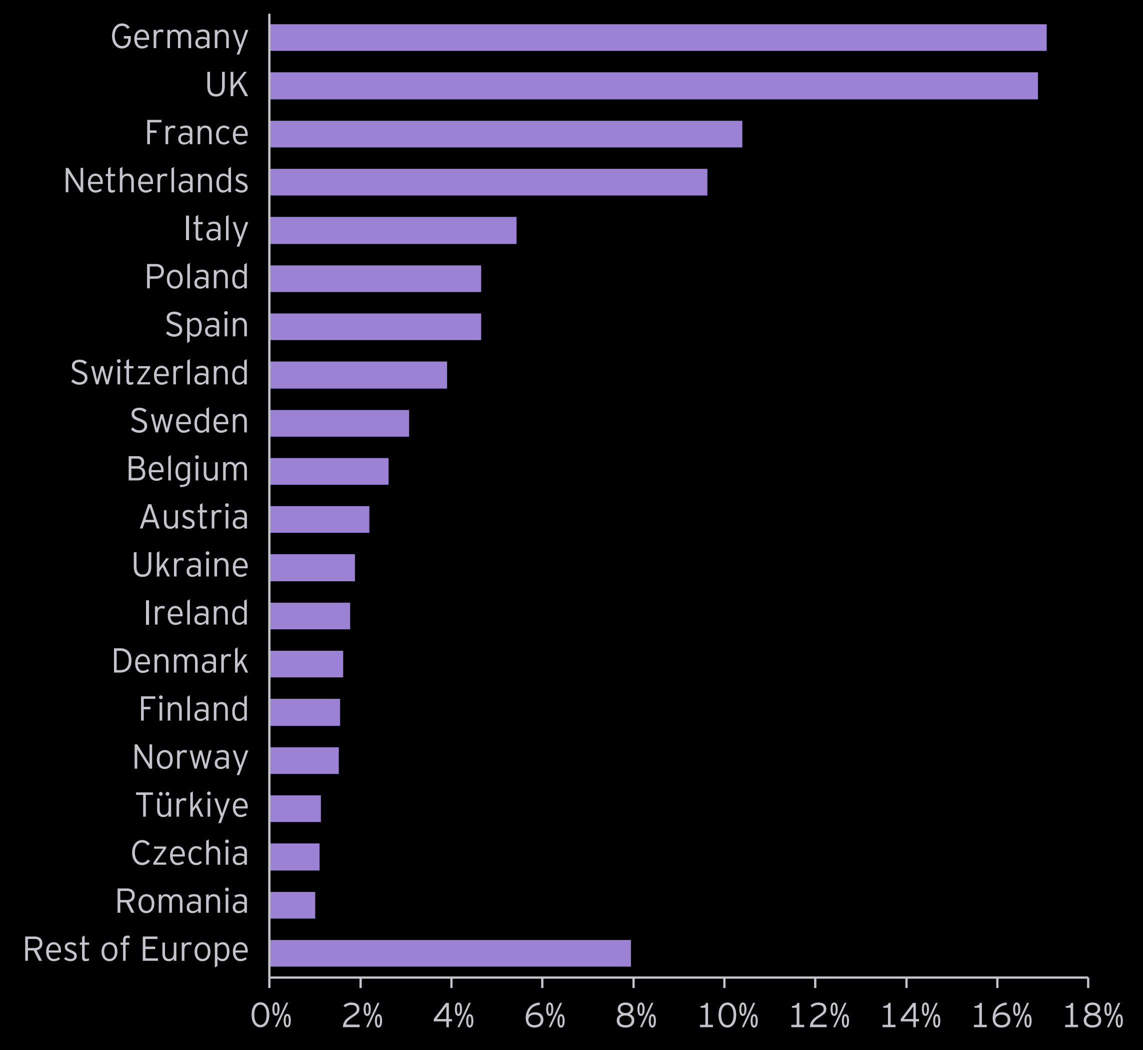
Within this landscape, the FLAP-D markets – Frankfurt, London, Amsterdam, Paris and Dublin – have long dominated Europe's co-location DC ecosystem, serving as the region's primary hubs. Their combined installed capacity expanded from approximately 2 GW in 2020 to around 4.6 GW by early 2025, representing over 60% of total European data-center capacity.[198, 199, 200]

Frankfurt, London, Amsterdam, Paris and Dublin represent over

60%

of total European DC capacity

Share of DCs in Europe (by number)



Source: EY Europe Central Energy Center's analysis of CloudScene and Cargoson.

Power and transmission constraints are most acute in the leading FLAP-D markets, where data centers already account for an estimated 30% to 80% of total local electricity demand. This level of concentration highlights the growing difficulty these hubs face in accommodating further expansion over the coming years.[201]

A combination of limited land supply, severe grid congestion and lengthy connection queues, which in some cases extend seven to ten years increasingly constrain FLAP-D markets. These pressures are further compounded by stringent sustainability and permitting requirements, raising development costs, lengthening project timelines and increasing investment uncertainty for both operators and capital providers.

Percentage of all power demand consumed by DCs in FLAP-D cities, 2024

Source: Eight International.

While FLAP-D markets will remain critical to Europe's DC ecosystem, their rate of expansion is expected to slow, accelerating the shift of new capacity toward less constrained regions.[202]

As a result, Europe's DC landscape is entering a transformative decade, shaped by both a significant expansion in capacity and a fundamental shift in geography. Faced with land and power constraints in traditional hubs, operators and investors are increasingly looking beyond the established FLAP-D markets toward new locations that offer greater grid headroom, available land and lower operating costs. This trend is particularly pronounced for remote, training-oriented data centers supporting machine-learning workloads, where proximity to end users is less critical, while cost efficiency, power availability, and scalability become the primary drivers (see Box 2).

Europe's DC landscape is entering a transformative decade, shaped by both a significant expansion in capacity and a fundamental shift in geography.

BOX 2. Latency and inference

During AI model training, latency is far less important, as training workloads involve large, batch-based computations that do not require real-time user interaction.

For decades, DC location decisions followed a simple rule: closer is faster. Facilities were typically built near large population centers to help reduce latency – the time it takes for a server to respond to a user's click, request or data query. In this model, geography directly determined performance, making proximity to users a critical design constraint.

AI is reshaping this logic. During AI model training, latency is far less important, as training workloads involve large, batch-based computations that do not require real-time user interaction. As a result, the infrastructure used for training can be located far from major cities, allowing operators to prioritize access to lower-cost land, abundant power and scalable infrastructure. These remote training facilities are then connected to urban centers through high-capacity fiber-optic networks.

Latency becomes critical again once models are deployed for real-world use in a phase known as inference, when AI systems interact directly with users and applications. To support fast response times, inference workloads are often placed closer to end users, driving renewed demand for data centers in or near population hubs. Over time, this distinction is leading to a more distributed architecture, with large, remote sites designed for training and smaller, strategically located facilities supporting inference.

Countries outside Europe's traditional DC hubs are expected to capture a growing share of new development, with the Europe Central region[203] among the strongest beneficiaries. The region's power mix is already around 65% supplied by reliable low-carbon sources, including renewables, nuclear and hydropower,[204] providing a structural advantage for energy-intensive DC growth.

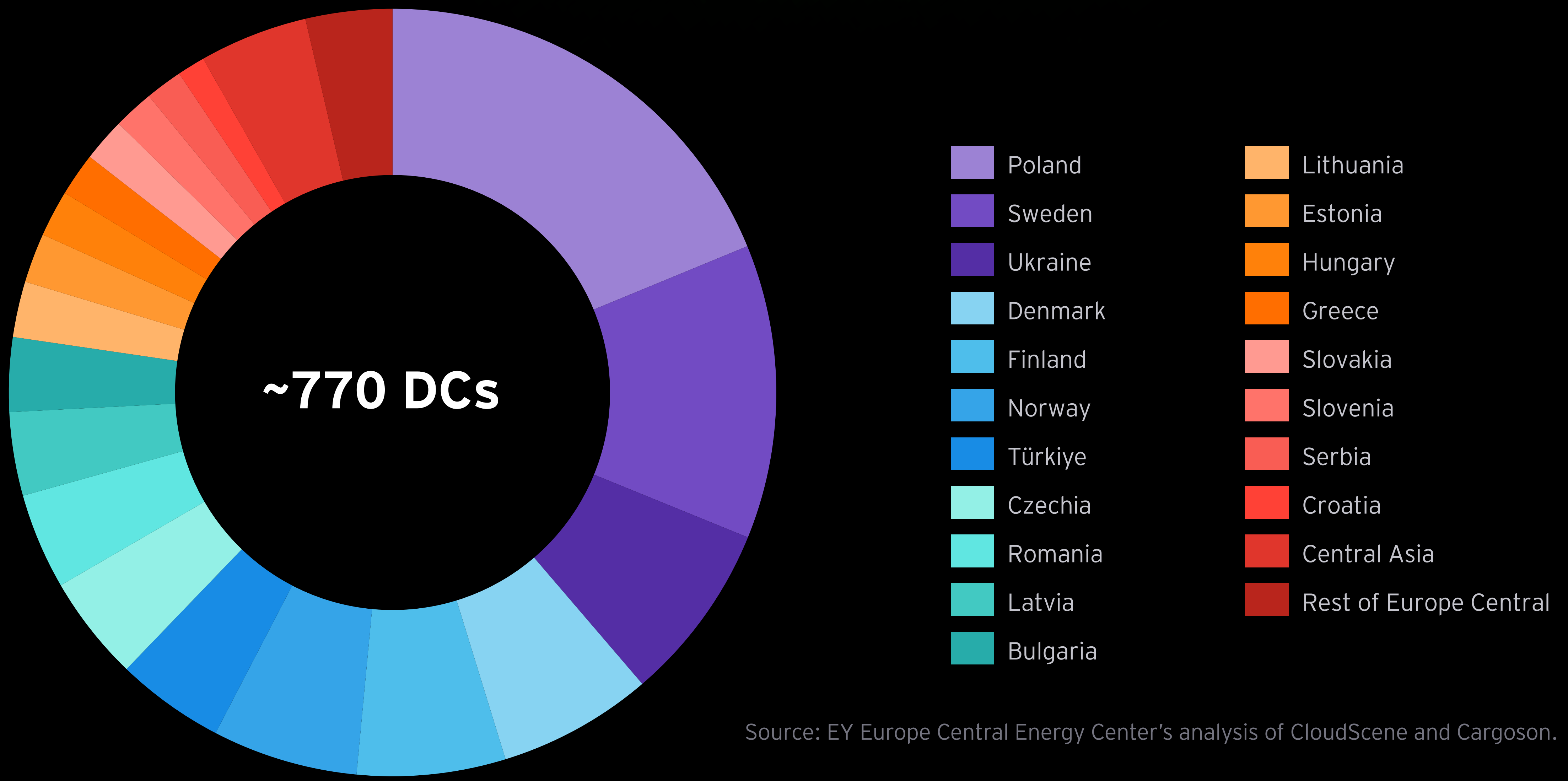
By the end of 2025, Europe Central (EC) accounted for approximately 25% of all data centers in Europe. Capacity within the region is concentrated primarily in Poland, the Nordic countries, Türkiye, Czechia, and Romania, which together host around 63% of Europe Central's DC facilities.[205]

Poland, the Nordic countries, Türkiye, Czechia, and Romania, host around

63%

of Europe Central's DC facilities

DC market structure in Europe Central, end of 2025 (by number)



Source: EY Europe Central Energy Center's analysis of CloudScene and Cargoson.

Nordic countries

The Nordic countries – Sweden, Norway, Finland, and Denmark – stand out for their combination of highly stable, low-carbon power systems, competitive electricity prices and naturally low cooling requirements driven by cold climates, albeit alongside relatively high labor costs. A distinctive feature of the region is its leadership in waste-heat recovery, with DC operators increasingly integrating excess heat into local district-heating networks. Sweden, for example, has articulated an ambition to develop a DC industry in which no waste heat is lost, while in Finland a data center in Mäntsälä recovers approximately 20,000 MWh of heat annually, sufficient to supply heating for around 2,500 homes.[206, 207, 208] Underscoring this momentum, a €1.2 billion long-term partnership has been established to develop an AI-specialised data-center complex in Borlänge, Sweden – a move that further consolidates the Nordics' position as a strong hub for AI infrastructure.[209]

Beyond energy advantages, the Nordics benefit from strong broadband penetration, extensive fiber-optic networks and highly reliable electricity grids, enabling low-latency connectivity for global operations. The region is well connected to Europe, North America and Asia through multiple high-capacity undersea cable routes, while also offering ample land availability and continued access to renewable energy and natural resources.

These structural advantages are attracting a growing pipeline of large-scale "super-projects." Notably, Norway is set to host European data center, with a Stargate-branded AI campus in Narvik expected to begin operations in late 2026 at an initial capacity of 230 MW, powered entirely by renewable energy and designed to expand by an additional 290 MW.[210, 211, 212]

Poland

Despite lower current penetration of clean energy and relatively higher electricity prices, Poland [213] – an economy experiencing strong growth within the EU – is emerging as an increasingly important player in Europe's DC landscape. The country offers substantial land availability and benefits from one of the lowest average ambient temperatures outside the Nordic region (around 10 °C in Warsaw, compared with 9 °C in Stockholm and 11 °C in Frankfurt),[214, 215,216] which helps reduce cooling costs. Poland is also beginning to advance waste-heat recovery initiatives. In late 2024, for example, a new project on DC waste heat reuse was announced in Poznań, integrating digital infrastructure more closely with local energy systems.[217]

Further credibility is provided by ongoing investment in grid infrastructure, including provisions in the national high-voltage grid investment plan to support up to 1.2 GW of DC capacity by 2034. This is complemented by rapid growth in renewable generation and ambitious nuclear power plans, with a pipeline of approximately 16.2 GW of small and large nuclear reactors under development. Together, these factors strengthen Poland's position as a long-term host for energy-intensive digital infrastructure. Looking ahead, Poland's DC capacity – serving not only domestic demand but also pan-European AI-training workloads – could reach around 500 MW by 2030 and up to 1.2 GW by 2034, placing the country among the most scalable growth markets in Europe.[218]

Romania

Romania stands at a pivotal moment to position itself as one of Europe's leading emerging DC hubs. The country combines strong connectivity to both Western and Central Europe with significantly lower land, construction and labor costs than markets such as the Nordics, the Netherlands or Ireland. Its logistics advantage is reinforced by the Port of Constanța (Black Sea) and navigable inland waterways, while substantial headroom remains to expand fiber networks, grid capacity and renewable generation. Looking ahead, emerging nuclear capabilities – particularly fourth-generation SMRs – could provide stable, carbon-free baseload power to support large-scale DC growth. The country is now developing its Black Sea AI Gigafactory project (up to €5 billion) for AI accelerators at the Cernavodă nuclear power plant and the planned SMR in Doicești. The computing hub would be powered by 1.5 GW including renewable electricity.[219, 220]

Greece

Greece is also gaining traction as a DC destination for both domestic and international investors, driven by its strategic position at the crossroads of Europe, Asia and Africa. This location makes Greece a natural hub for international data traffic. Submarine cables – critical but often invisible infrastructure – are central to this role, and in recent years Greece has become a landing point for several major systems, including the IONIAN cable linking Italy and western Greece[221] and the India-Europe-Xpress[222] connecting Mumbai to Crete.[223] While the outlook is positive, further growth will depend on timely grid upgrades, well-structured connection agreements and careful engineering and site planning to manage higher electricity and cooling costs as well as seismic risks.

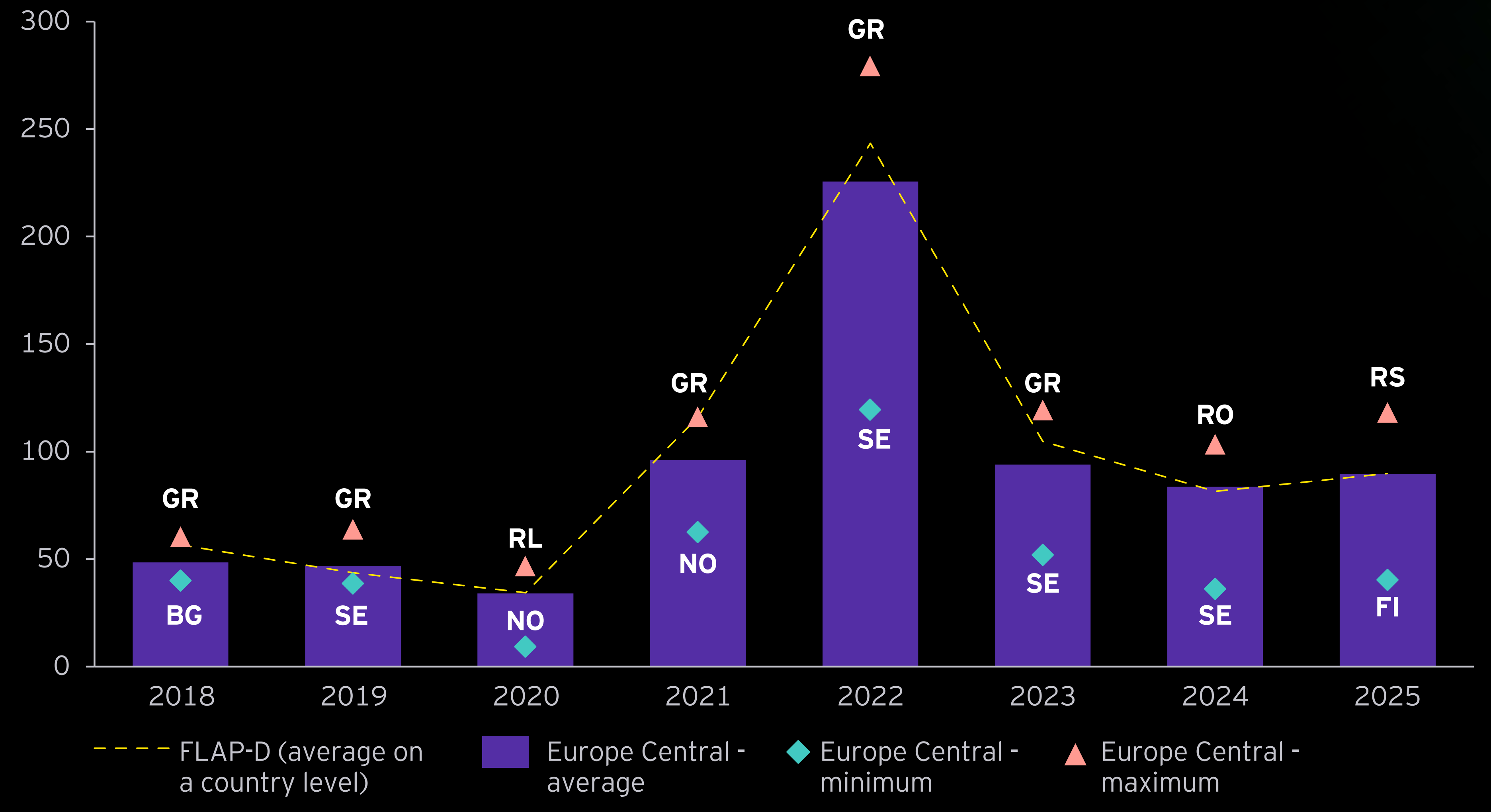
Türkiye

Türkiye represents another strategically important market, leveraging its position at the intersection of Europe, Asia and the Middle East to serve as a natural interconnection point between them. Rapid expansion of submarine cable infrastructure is strengthening Türkiye's role as a low-latency traffic exchange hub for Europe and Asia. A notable milestone is the agreement to establish Türkiye's first hyperscale regional data center – significantly enhancing the country's digital-infrastructure profile.[224]

Across Central Europe, each country brings its own strengths to DC development. Some offer cleaner power mixes, others benefit from lower operating costs, favorable climates that reduce cooling needs or large areas of available land.

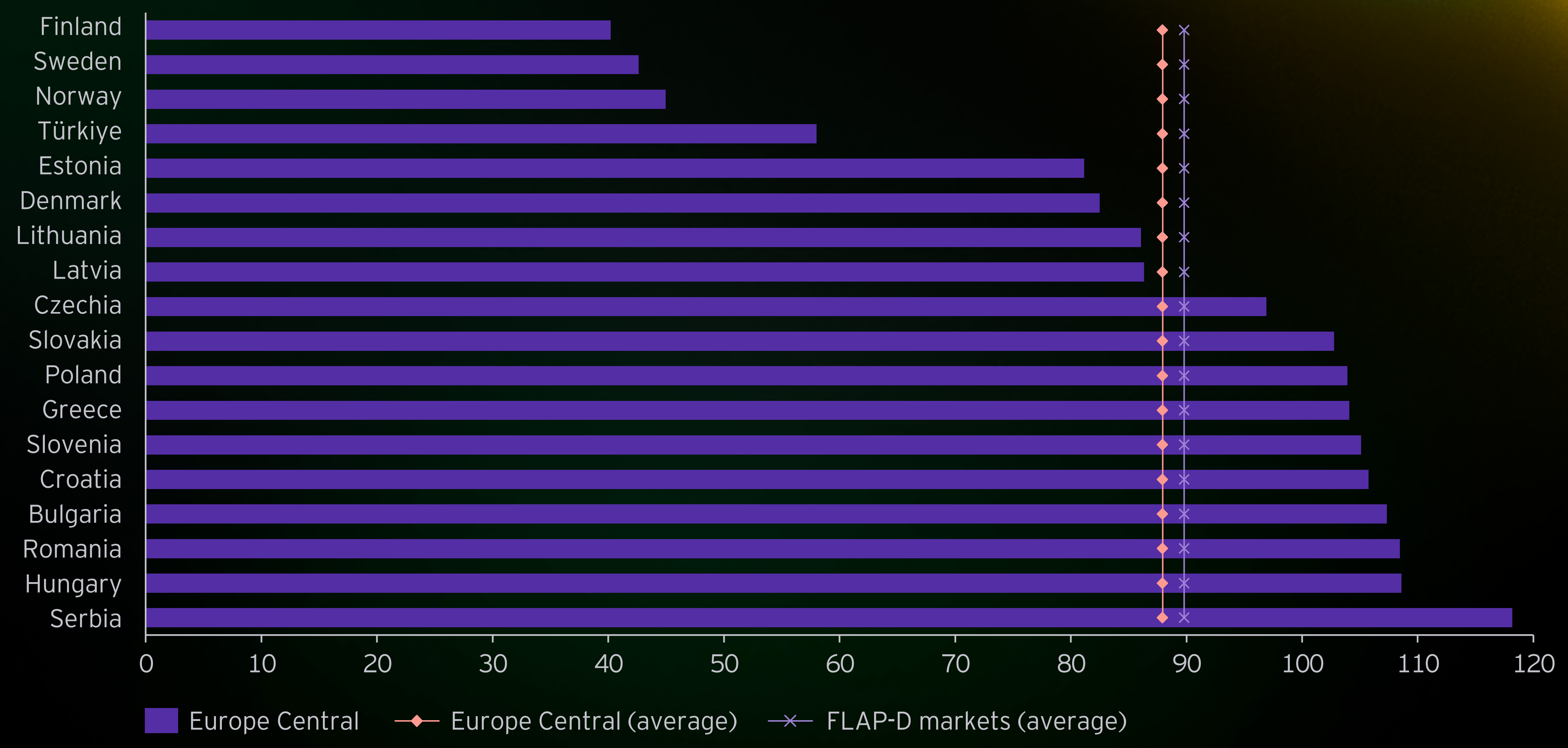
Together, these varied advantages make the region increasingly attractive for new DC and AI-infrastructure investments.

Wholesale electricity prices in Europe Central vs. FLAP-D nations, €/MWh



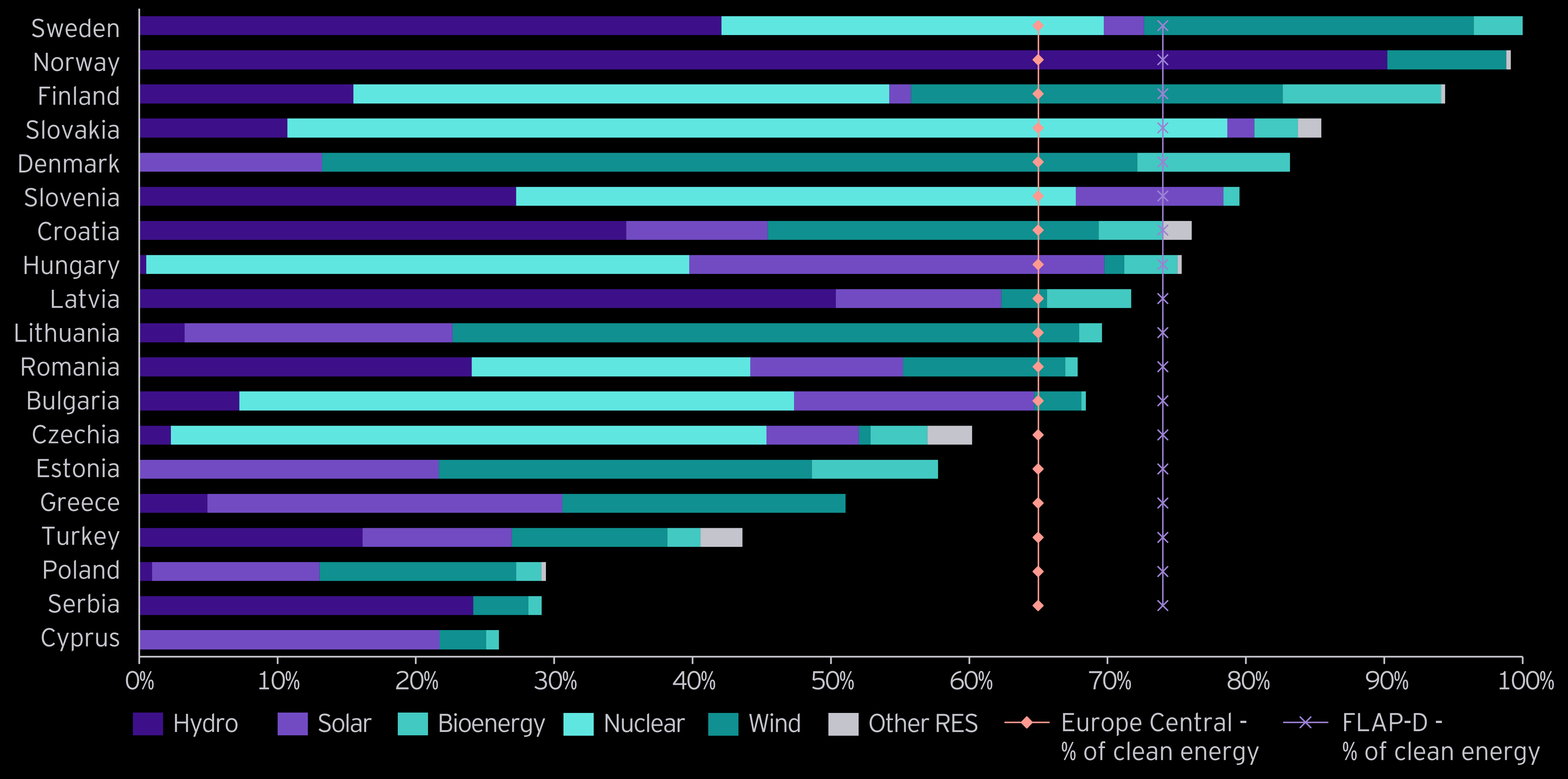
Sources: Ember, EY Energy Center's analysis.

Wholesale electricity prices in Europe Central by country (2025), €/MWh



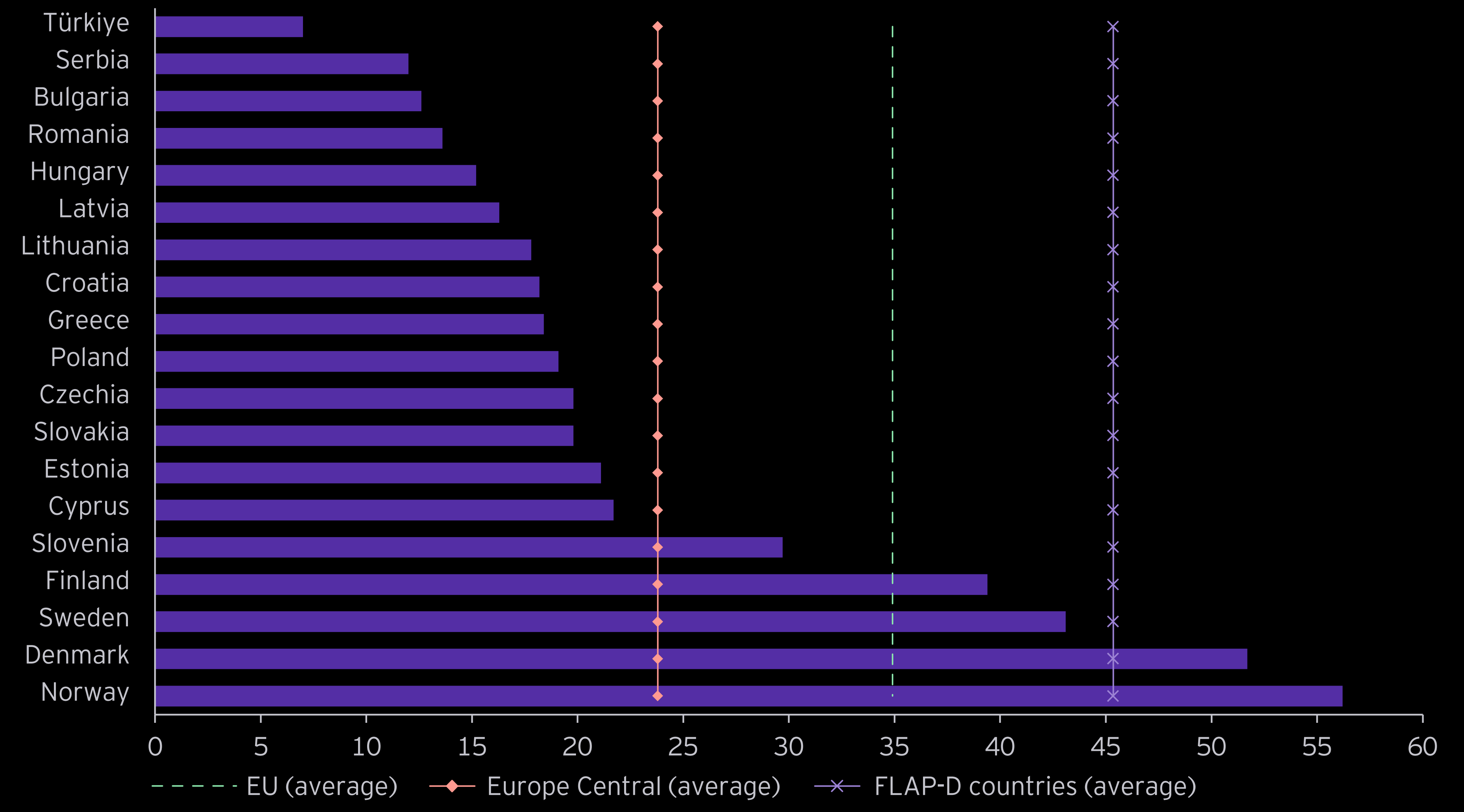
Sources: Ember, EY Energy Center's analysis.

The share of clean energy sources in the power mix in Europe Central (2025)



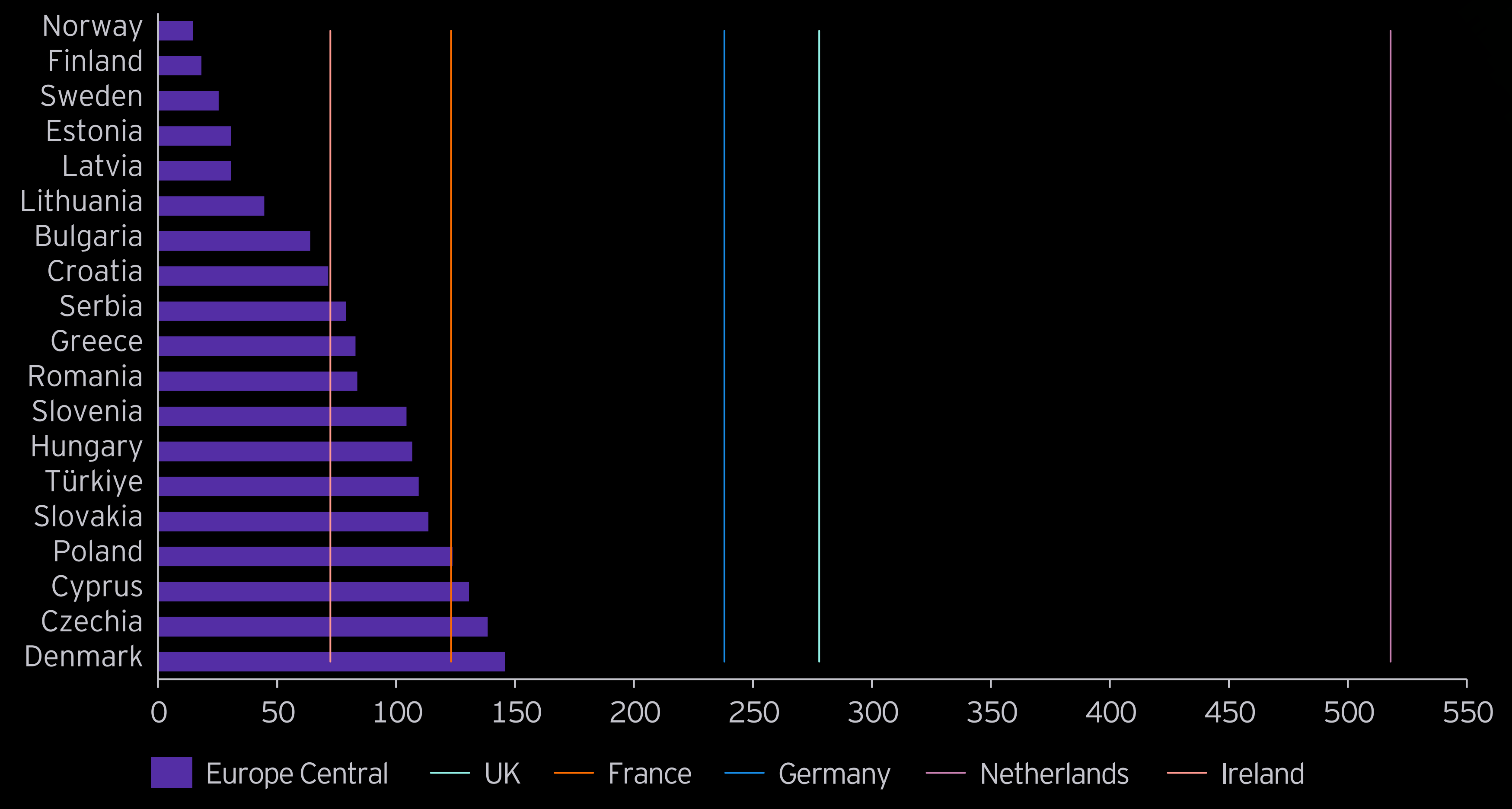
Sources: Ember, EY Europe Central Energy Center's analysis.

Labor costs in Europe, €/hour (2025)



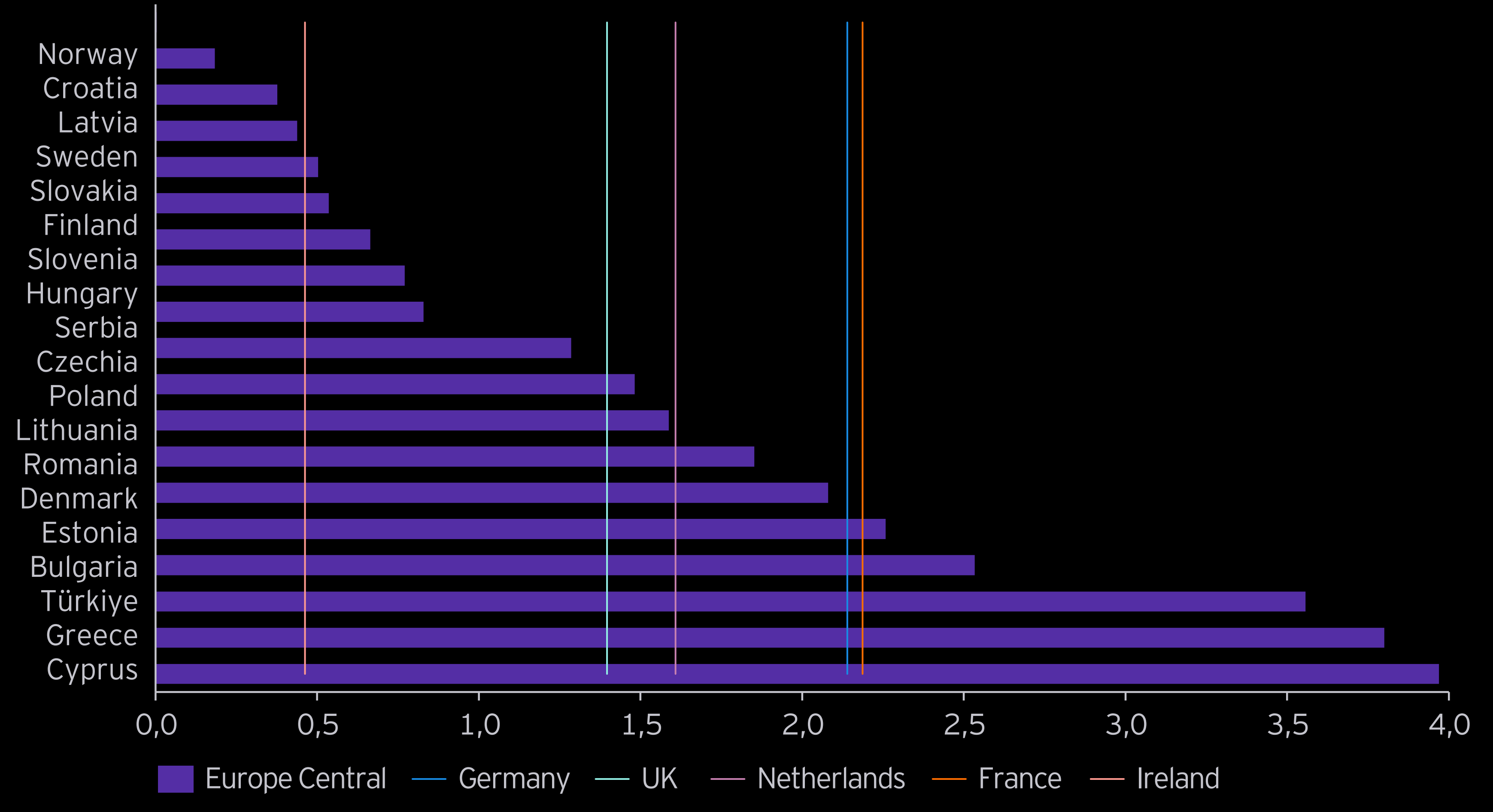
Sources: Eurostat (2024), EY Europe Central Energy Center's estimations for Turkey.

Land availability (people per sq. km of land area) in Europe Central



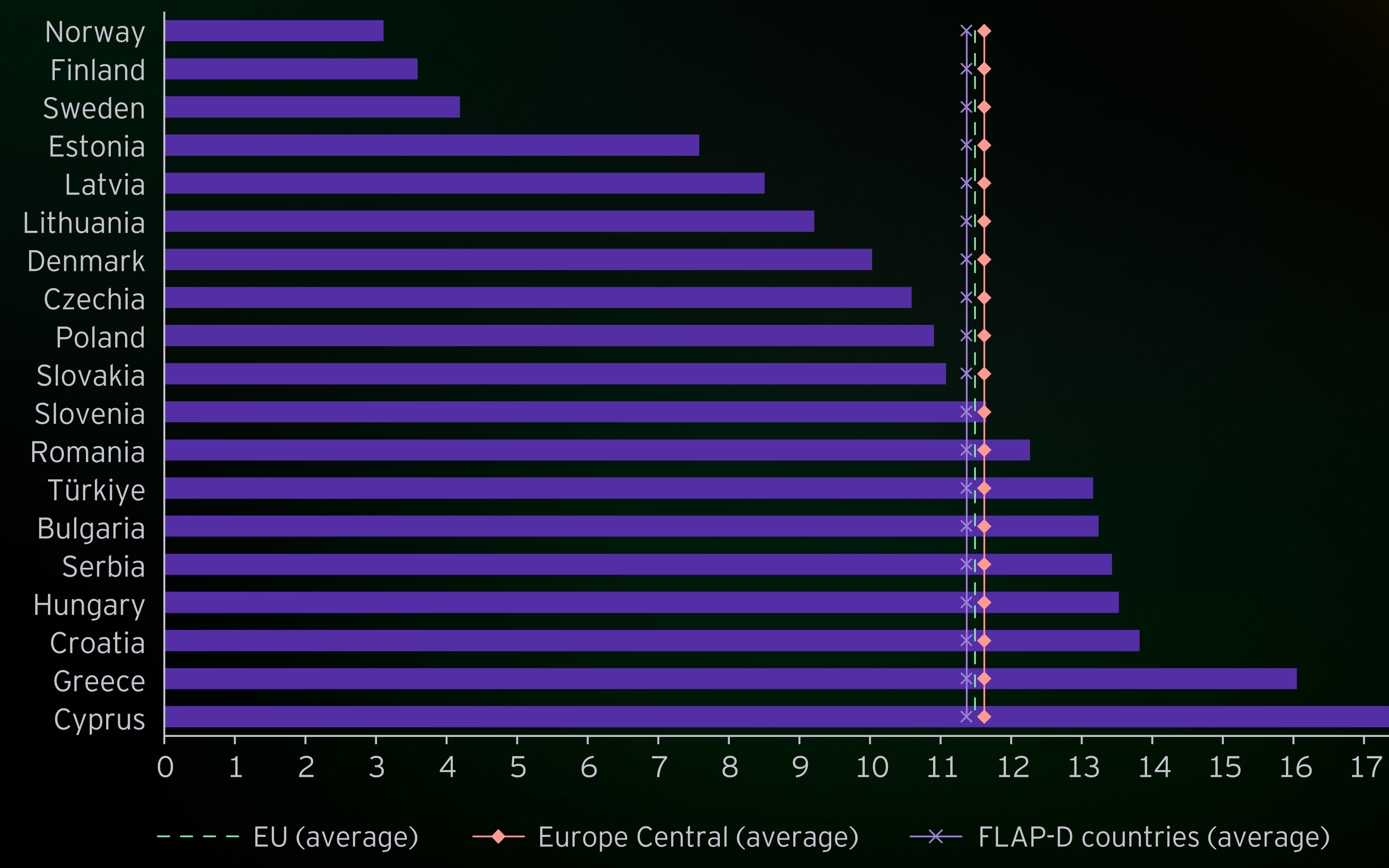
Sources: Index Mundi.

Water stress index in Europe Central



Source: Resource Watch.

The average temperature in Europe Central, °C (2024)



Sources: Statista.

Nordic countries combine strong clean-energy penetration, competitive power prices and favorable climatic conditions, offset by the highest labor costs in the Europe Central region.

Coastal countries benefit from stronger cross-border digital connectivity, driven by proximity to submarine cable landings and strategic network location.

Competitive analysis of DC locations within the Europe Central region

	Power prices	Clean energy	Labor costs	Land availability	Natural conditions for cooling	Water stress	Cross-border connectivity
Finland	▢	▢	■	▢	▢	▢	▢
Sweden	▢	▢	■	▢	▢	▢	▢
Norway	▢	▢	■	▢	▢	▢	▢
Türkiye	▢	■	▢	■	■	■	▢
Estonia	▨	▨	▨	▢	▢	■	▢
Denmark	▨	▢	■	■	▨	■	▢
Lithuania	▨	▨	▢	▢	▢	▨	▢
Latvia	▨	▨	▢	▢	▢	▢	▢
Czechia	▨	▨	▢	■	▨	▢	▢
Slovakia	■	▢	▢	■	▨	▢	▨
Poland	■	■	▢	■	▨	▨	▢
Greece	■	▨	▢	▨	■	■	▢
Slovenia	■	▨	■	■	▨	▢	▢
Croatia	■	▨	▢	▨	■	▢	▨
Bulgaria	■	▨	▢	▢	■	■	▢
Romania	■	▨	▢	▨	▨	■	▢
Hungary	■	▨	▢	■	■	▢	▨
Serbia	■	■	▢	▨	■	▢	■
Cyprus	n/a	■	▨	■	■	■	■

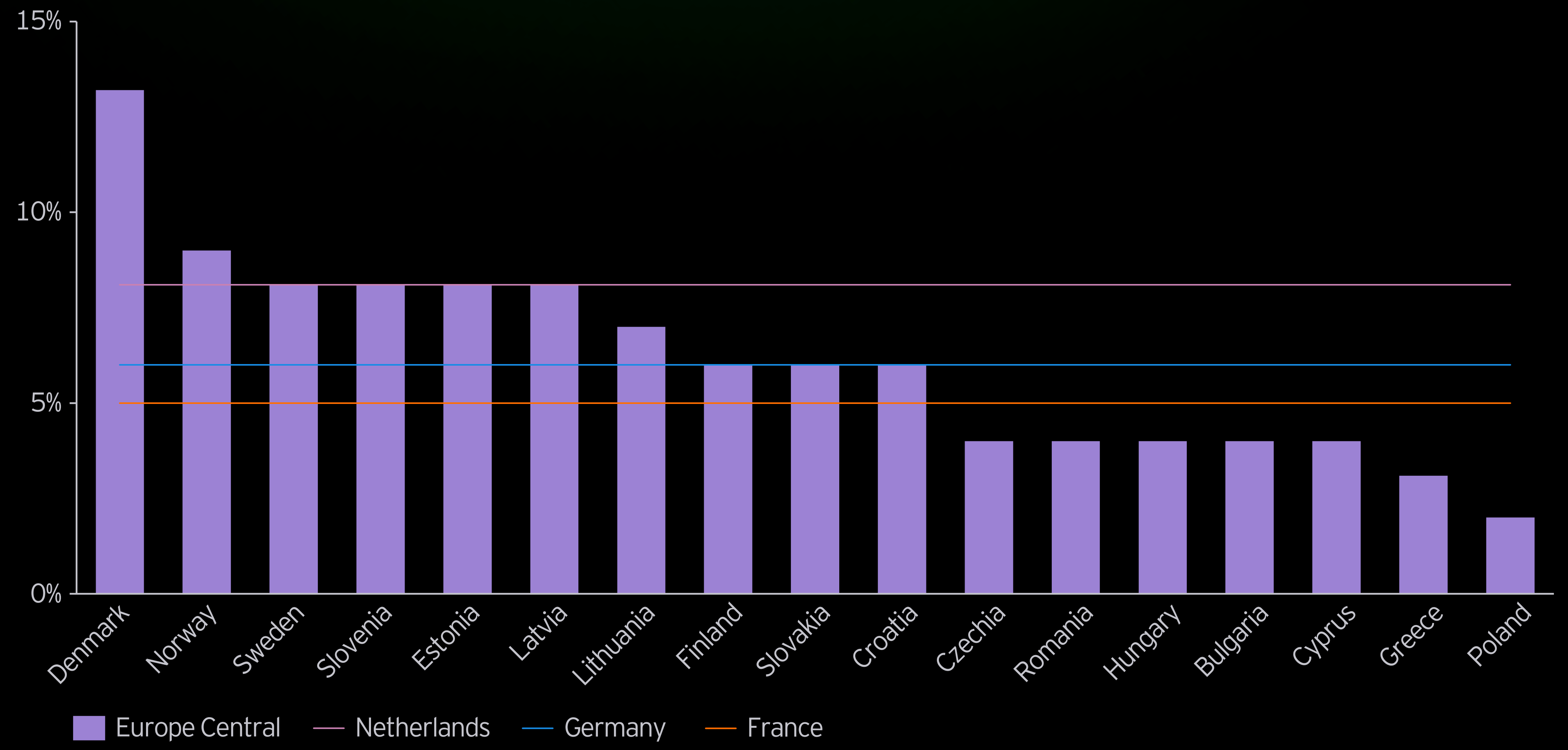
▢ >15% more positive than the average of Europe Central

▨ +/- 15% of Europe Central average

■ >15% less positive than the average of Europe Central

Considering the increasing geographic dispersion of data centers across the Europe Central region, the share of DC electricity consumption in national power demand could rise to between 2% and 14% by 2035, with the highest concentrations expected in the Nordic countries. In Norway, data centers could account for around 9% of total electricity demand. In Denmark, the share could rise to around 13%, while in Sweden it may grow to more than 8% over the same period.[225]

Potential share of DC in total national power demand in Europe Central (2035)



Source: ICIS.

06

A shared future

Coordinated actions to unlock AI energy synergies

The analysis throughout this report points to a clear conclusion: AI and energy can no longer be treated as separate agendas.

AI is becoming a core capability for improving energy systems, supporting greater efficiency, reliability and integration of low carbon resources, while simultaneously emerging as a material driver of electricity demand and infrastructure investment. From data center build outs to grid congestion and clean power procurement, the growth of AI is now directly shaping energy system outcomes.

Conversely, the ability to scale AI itself is increasingly constrained by power availability, grid access and regulatory frameworks.

This mutual dependence marks a shift from experimentation to system level coordination. The limiting factor is no longer technology readiness, but the alignment of incentives, infrastructure and governance across stakeholders. Unlocking AI-energy synergies at scale therefore requires coordinated action across three dimensions:

- Aligning planning between digital and energy infrastructure
- Designing systems that are both AI-ready and energy-aware
- Modernizing regulatory and investment frameworks

AI infrastructure and energy systems have historically been planned on different timelines and under different assumptions. That mismatch is now becoming costly. Large, continuous AI loads require visibility into grid capacity, interconnection timelines and clean-power availability, while grid operators and policymakers need earlier and more transparent signals from AI and DC developers. Shared planning frameworks, improved disclosure and more integrated scenario analysis can reduce uncertainty, avoid bottlenecks and support more efficient capital allocation across both sectors.

Scaling AI for energy requires robust data foundations, secure architectures and governance models that meet the requirements of critical infrastructure. At the same time, scaling energy for AI requires digital infrastructure to become more flexible, efficient and aligned with power system constraints. This includes prioritizing energy efficient hardware and models, enabling workload flexibility where feasible, integrating storage and demand response capabilities and embedding carbon and cost awareness into AI infrastructure decisions. The goal is not simply to add capacity, but to improve how AI workloads interact with energy systems.

Regulation and market design will play a decisive role in determining whether AI accelerates or strains the energy transition. Grid connection processes, permitting timelines, power procurement rules and standards for AI deployment in critical infrastructure all influence the pace and geography of both energy and AI investments. Faster grid build out, clearer rules for large loads and frameworks that support low carbon, firm power solutions, while maintaining safety, reliability and public trust, are essential. At the same time, innovative investment models are emerging, blurring the boundary between digital and energy infrastructure and pointing toward new forms of shared risk and value creation.

Taken together, these actions underscore a simple reality: the future of AI and the future of energy are inseparable. A coordinated approach, involving both energy and tech companies as well as regulators, is essential.

Those who act early to coordinate across sectors, align infrastructure planning and modernize governance will be best positioned to capture the productivity gains of AI while supporting an affordable, reliable and low carbon energy system.

And as AI and energy systems become increasingly interdependent, the human element becomes even more critical.

A shared human-AI operating model allows organizations to scale judgment, creativity and operational experience across far more complex systems. AI automates routine activities, but people remain central, shaping decisions, ensuring safety and driving innovation. This is not a “do more with fewer people” story, but a “do more with the same people” story, enabled by AI-orchestrated workflows.

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