MAY 2024

Energy Infrastructure is Powering the Future of Artificial Intelligence

The rapid evolution of artificial intelligence (AI), from iconic fictional characters like the 1980's Star Wars droid C-3PO to modern-day avatars, signifies a profound transformation. Today, AI is deeply integrated into our daily lives, with virtual assistants like Siri and algorithm-driven platforms such as Netflix and Hulu shaping our experiences. The rise of ChatGPT has swiftly made waves, boasting 100 million monthly active users within just two months, marking it as the fastest-growing consumer application in history.

As Microsoft founder Bill Gates aptly noted at the World Economic Forum in 2023, the impact of AI rivals that of transformative technologies like mobile phones and the Internet. Indeed, AI holds the promise of unlocking endless opportunities and ushering in an era of unprecedented growth and prosperity.

> **Artificial intelligence is as revolutionary as mobile phone and the Internet**
>
> *– Bill Gates*

Moreover, the convergence of AI with energy and technology infrastructure is reshaping industries. The demand for low-cost, reliable, and secure energy supply is intensifying, driven by the burgeoning requirements of AI infrastructure and the need for advanced hardware like semiconductors. This symbiotic relationship forms the backbone of the AI infrastructure value chain, underscoring the indispensable role of energy in powering AI advancements. The illustration below illustrates the AI infrastructure value chain.

Artificial Intelligence Infrastructure Value Chain

ENERGY

Essential Energy

- Shale natural gas producers
- Uranium producers
- Oil field services
- Gathering & processing
- Natural gas pipelines
- Natural gas storage
- Electricity generation
- Electricity transmission
- Solar & wind generation
- Backup power supply
- Long duration energy storage

DATA CENTERS

TECHNOLOGY

Tech Hardware

- Semiconductor design
- Semi manufacturing
- GPU & CPU processing
- Servers
- Network cables & routing
- Memory and storage
- Liquid cooling
- Electrical components
- Uninterruptible power supply
- Cloud operators
- Cybersecurity

Source: Tortoise 2024

Data Centers Drive AI

Data centers are the backbone of AI infrastructure, providing the critical computational resources necessary for deploying complex machine learning models, large language models, and algorithms. In the United States alone, there are approximately 5,400 data centers, each playing a vital role in powering AI-driven applications and services.

These data centers typically consist of three essential components:

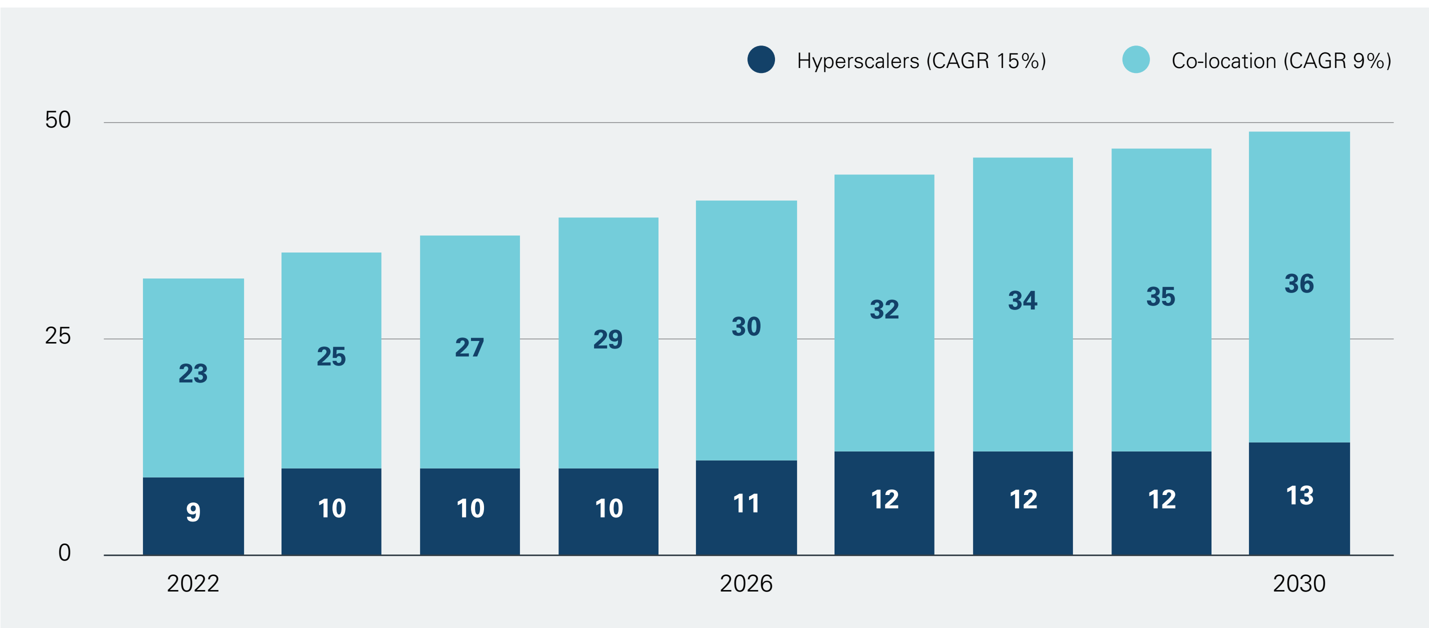
- **Computing Resources:** Servers that deliver processing, memory, local storage, and network connectivity for AI applications.
- **Storage Infrastructure:** Facilities housing valuable data storage essential for various operations.
- **Network Infrastructure:** Services ensuring seamless communication and data exchange with end-user locations.

Data centers come in three primary types:

1. **Enterprise-Owned Facilities:** These are relatively small facilities, typically spanning less than 20,000 square feet and housing fewer than 2,000 servers. With power demands ranging from 1 to 5 megawatts (MW), these facilities are exclusively owned and utilized by a single organization to meet its computing requirements.
2. **Co-location Data Centers:** Larger than enterprise facilities, co-location data centers allow multiple parties to rent space and equipment to supplement their own data center needs. These facilities range from 20,000 to 100,000 square feet and can accommodate up to 10,000 servers, consuming 5 to 20 MW of power annually.
3. **Hyperscale Data Centers:** These represent the pinnacle of data center infrastructure, boasting immense data capacity and power consumption. Hyperscale data centers house over 10,000 servers and consume between 20 to 100 MW of power annually. With their unparalleled scalability, hyperscale facilities are foundational in driving the next era of technological innovation. Currently, there are approximately 800 hyperscale data centers worldwide, with a significant majority located in the U.S.

It's no surprise that the rise of AI has catalyzed an increase in investment directed towards data centers. In the chart below, McKinsey projects a 5% annual increase in capital spending on data centers through 2030.

Data Center Construction Spending ($ billion)



Source: McKinsey & Company Investing in the rising data center economy January 2023. Projections on this page are shown for informational purposes only and no guarantee of future outcomes.

AI is Boosting Electricity Demand

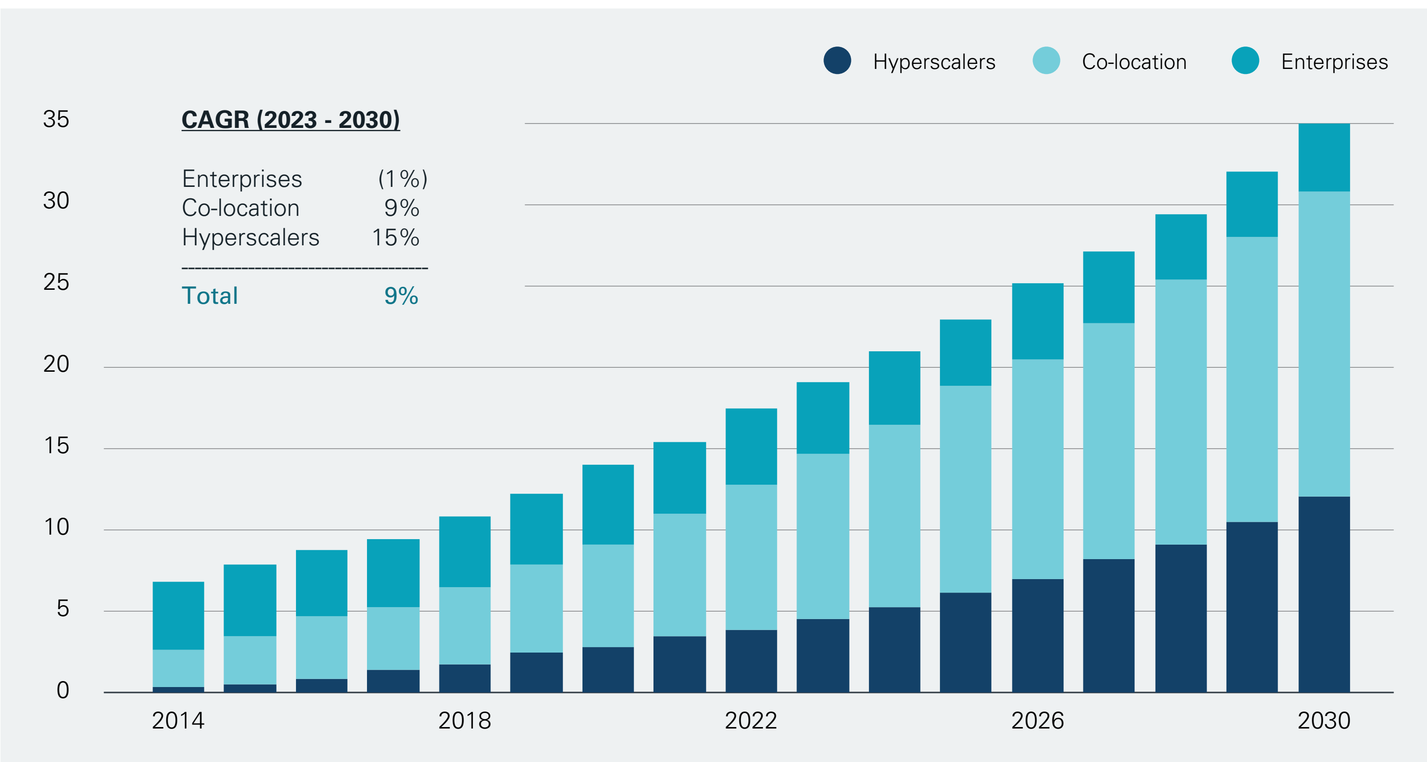
After decades of stagnation, U.S. electricity consumption is projected to deliver meaningful growth through 2030 as a result of several AI-related factors, including: the proliferation of data centers and the adoption of more power-intensive hardware, particularly GPUs for AI applications.

The expansion of data centers – both in quantity and quality – signals a growing digital infrastructure to support the increasing demand for cloud services, big data processing, and AI applications.

AI technology is rapidly evolving, with central processing units (CPUs) now incorporating graphics processing units (GPUs) —specialized circuits optimized for parallel processing and high-speed mathematical computations. This hardware integration reflects a strategic shift towards architectures tailored for AI workloads, enhancing processing efficiency.

As hardware evolves, newer generations of GPUs offer higher performance at the expense of increased power consumption. For example , the latest Nvidia H100 AI GPUs consume 700 watts of constant power, nearly 2x more than Nvidia's most popular A100 GPU. To put this into perspective, the average house in the U.S. uses 1,083 to 1,375 watts of power. This heightened power demand per GPU contributes to the overall electricity consumption of data centers, as depicted in the projected rise in U.S. data center electricity consumption through 2030.

Data Center Power Consumption by Provider (in gigawatts)



Source: McKinsey & Company Investing in the rising data center economy January 2023. Projections on this page are shown for informational purposes only and no guarantee of future outcomes.

McKinsey & Company estimates electricity demand from data centers to rise by 9% annually to 35 gigawatts by 2030. According to Boston Consulting Group, AI electricity consumption as a percentage of total U.S. electricity demand will surge to 7.5% in 2030, up from 2.5% today.

Energy Infrastructure Bridges Gap

The U.S. electric grid is like a large machine that provides crucial infrastructure for powering homes, businesses, and industries across the nation. It comprises a vast network of power generation facilities, transmission lines, and substations, all working together to deliver electricity reliably and efficiently. Individual companies operate highly regulated, essential generation and transmission infrastructure assets, while regional transmission organizations (RTOs) like PJM or ERCOT coordinate and monitor multi-state electric grids to maintain grid reliability. With an eye towards the future, RTOs are preparing for a significant surge in electricity generation.

As the landscape evolves, hyperscale data centers should emerge as the foremost consumers of electricity. Giants like Amazon and Meta are already taking steps to secure a reliable energy supply to meet their growing needs as they expand their operations to support advancements in AI.

Meta's strategic move in appointing John Arnold, an esteemed energy industry expert, to its board in February 2024 underscores its commitment to address energy-related challenges and opportunities. Similarly, Amazon's acquisition of a 960 MW data center campus from Talen Energy, strategically located next to the Susquehanna nuclear power plant, highlights its efforts to secure reliable power sources for its operations. Moreover, the interest shown by tech companies in sourcing natural gas directly from producers, such as the CEO of the largest U.S. natural gas producer, Toby Rice, hints at a potential shift towards leveraging energy sources for future data center operations.

Collectively, these developments illustrate the increasing synergy between the technology and energy sectors. Companies are actively seeking to ensure a reliable power supply to support their evolving business needs.

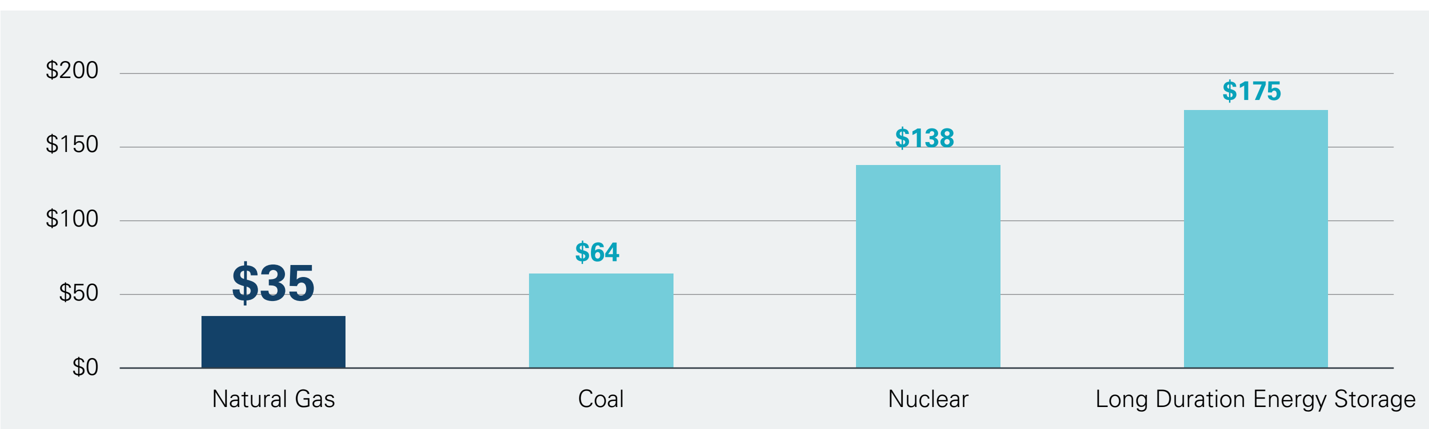
Natural Gas is Fueling the AI Boom

As the primary source of energy for U.S. electricity generation, natural gas has seen a steady rise in prominence over the past decade, claiming the largest share of energy supply in 2023 at 43%. This rise can be attributed to several factors, including its relatively low cost, abundant domestic supply, and lower carbon emissions compared to coal.

Maintaining a continuous and reliable power supply is crucial for uninterrupted data center operation. While renewable energy sources such as solar and wind have gained traction in recent years due to their environmental benefits, they do present challenges in terms of intermittency. Solar panels only produce electricity during daylight hours, and wind turbines can only generate power when the wind is blowing at the right speed.

In contrast, natural gas is often seen as a reliable alternative due to its flexibility and availability. Natural gas power plants guarantee a consistent electricity supply, further bolstered by its affordability, as illustrated in the chart below.

Cost of Electricity ($/megawatt-hour)

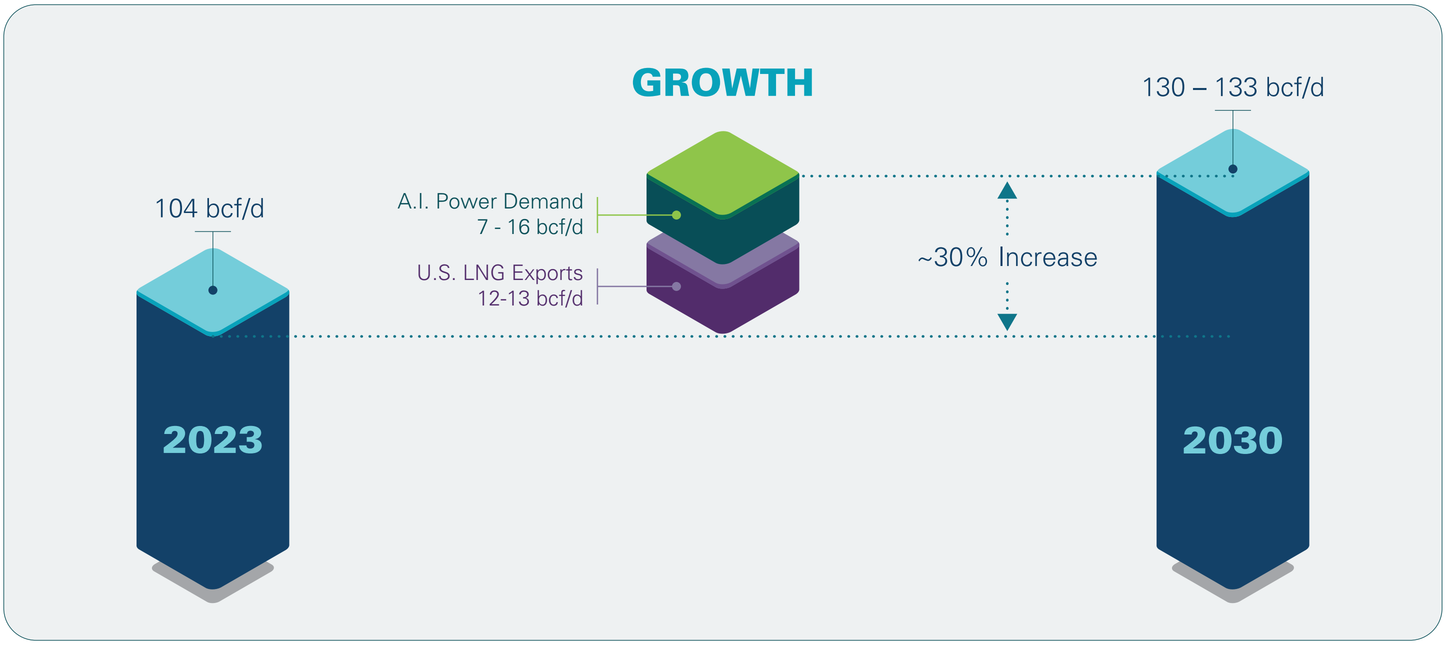


Source: McKinsey & Company, September 2023 and Lazard LCOE study, April 2023

As environmental concerns drive the phase-out of coal, nuclear power faces its own challenges due to its high construction costs and lengthy permitting processes. While solar and wind show promise, their reliability hinges on long duration energy storage solutions, such as batteries, which have yet to prove cost-effective on a large scale despite decades of development efforts.

With all these considerations, we believe natural gas emerges as the best supply source to deliver low cost, reliable electricity as AI advances. Indeed, the burgoing AI sector presents another source of growth to the already robust U.S. natural gas industry. The illustration below shows how U.S. natural gas production could grow by almost 30% between 2023 and 2030.

U.S. Natural Gas Production



Source: EIA and Tortoise estimates. Projections on this page are shown for informational purposes only and no guarantee of future outcomes.

Currently, the U.S. produces around 104 billion cubic feet (bcf/d) of natural gas, with nearly 80% originating from domestic shale formations. Shale gas production is already slated to grow by 12 – 13 bcf/d as the U.S. LNG exports double by 2030. AI power demand growth could require an additional 7 to 16 bcf/d of U.S. natural gas production to meet electricity demand from data centers. To facilitate this heightened demand, the expansion of natural gas infrastructure is imperative to ensure safe and cost effective distribution. Notably, infrastructure operator Williams Companies recently underscored the challenge, citing a 43% increase in U.S. natural gas demand since 2013, outpacing the growth of interstate pipeline and storage delivery capacities by 25% and 2%, respectively.

Summary

AI has undeniably emerged as a transformative technology, paralleling the impact of the Internet, as influential figures such as Bill Gates have pointed out. Not surprisingly, the development of AI infrastructure, namely data centers, is crucial to support its rapid evolution in the coming years. As data centers drive up electricity demand, the energy infrastructure sector is expected to play a vital role in providing secure, reliable, and low-cost fuel to power these facilities. We believe natural gas emerges as the not so obvious beneficiary of these converging trends, offering a strategic advantage for both natural gas producers and infrastructure operators poised to capitalize on the escalating AI-driven demand in the years and decades ahead.

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