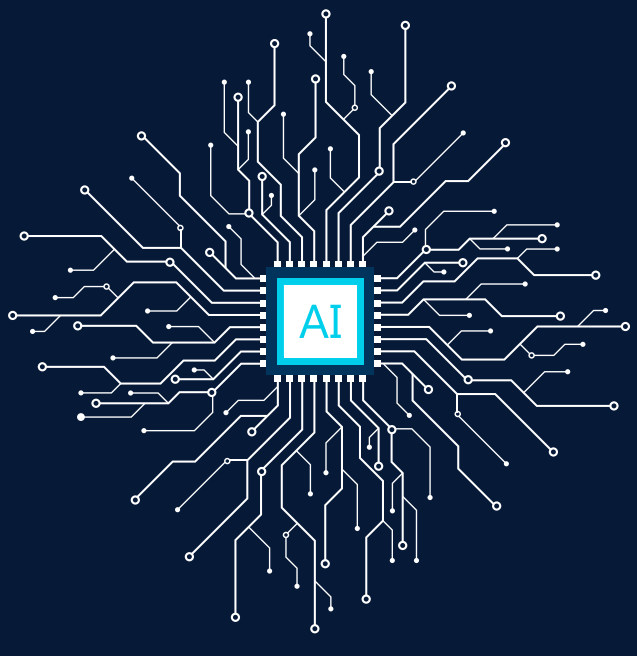
T.RowePrice

How AI innovations could help solve the U.S. energy problem



From the Field

Key Insights

- The rise of generative AI is increasing data center electricity demand expectations—focusing the U.S. on how to meet the needs of an electrifying and growing economy with clean electricity.
- Data centers require reliable electricity. While we expect demand for renewables to keep rising, natural gas-fired generation could also see increased demand, and planned shutdowns of coal-fired power plants may face delays.
- AI could offer transformative solutions to tackle U.S. energy challenges by enhancing grid efficiency, improving renewable energy integration, and optimizing energy storage systems.

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Demand for electricity has been steady since the mid-2000s in the United States, with demand growth about half a percent per year on average. This is down to a variety of factors, including the growth of less energy-intensive sectors in the economy (such as financial services), offshoring manufacturing to China and Southeast Asia, and improvements in energy efficiency.

Can we deliver the energy we need to power AI?

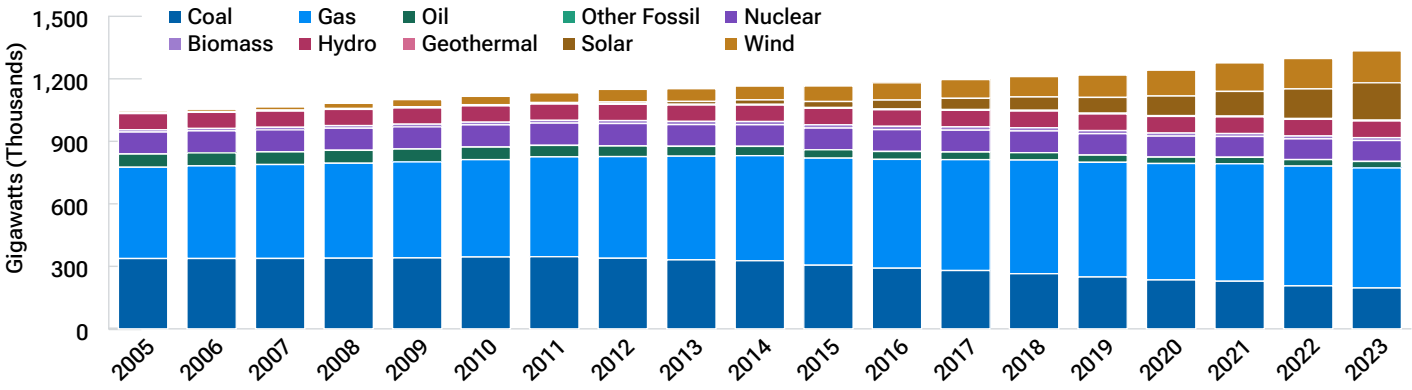
A continued shift toward electrification and the growth of data center infrastructure will drive a meaningful change in electricity demand. Energy demand estimates vary widely, but key variables include the pace of electrification, onshoring, and data centers. We expect that U.S. electricity demand could grow 2%–4% per annum over the next 10–15 years.[1]

Markets have been factoring a sustained uptick in electricity demand due to electrification, onshoring, and data centers, but the debut of ChatGPT in November 2022 marked a turning point for data center electricity demand expectations. Due to the increase in generative artificial intelligence (AI) model training and usage, we expect data center growth could be much higher than today's levels, increasing from 2%–4% of U.S. electricity consumption[2] to around 8% by 2035.[1]

[1] Analysis by T. Rowe Price.
[2] Source: International Energy Agency, Electricity Mid-Year Update—July 2024.

The total share of renewables and natural gas has increased as coal has decreased

(Fig. 1) Cumulative installed capacity of different energy sectors over time in the U.S.



As of January 2025.
Source: BloombergNEF.

Generative AI and data center growth are focusing the U.S. on this broader challenge of how to meet the needs of an electrifying and growing economy with clean electricity, while also driving down greenhouse gas emissions. Concerns about electricity scarcity amid technological advancements are not new. There was concern in the early 2000s and with the emergence of cloud computing, for example. Over the past two decades, energy efficiency has outpaced electricity demand growth in advanced economies (including digitalization, heat, and mobility).

According to the International Energy Agency (IEA), the absence of efficiency improvements would have resulted in 1.6% electricity demand growth instead of 0.3%.[3] Since 2010, the number of internet users worldwide has more than doubled, while global internet traffic has expanded 25-fold.[4] Rapid improvements in energy efficiency have, however, helped moderate growth in energy demand from data centers and data transmission networks.

To achieve something similar with AI, there are several levers throughout the AI supply chain that could reduce electricity consumption while still meeting demand. These include continued improvements in AI training (as seen recently with Chinese AI company DeepSeek) and AI algorithms, the energy efficiency of information technology equipment, liquid cooling technology, data center design and modularization, and clean power adoption. However, it will take time for these levers to have an effect, so we expect AI-related energy demand will likely have a negative impact on decarbonization in the near term.

Will AI derail decarbonization?

While virtually all the largest hyperscalers[5] in the U.S. have longstanding decarbonization targets in place, they are now planning for notably higher energy requirements. Data centers require firm and reliable electricity, meaning intermittent power sources like renewables will not adequately meet their needs. Although we expect the demand for renewables and storage to keep rising, we also expect that natural gas-fired generation will see increased demand, and the scheduled shutdowns of coal-fired power plants may face delays. Wind and solar energy will need battery storage and/or natural gas peaking capacity to provide round-the-clock reliability.

The U.S. power sector has shown a steady decline in carbon (CO_2) emissions for two decades[6] thanks to renewables and natural gas growing their share of the generation fuel mix. Solar deals have dropped from $5/megawatt to $1/megawatt, and the cost of capital for both solar and wind have declined meaningfully, which has made these technologies more attractive investments.[7]

How can AI help address U.S. energy constraints?

AI offers transformative solutions to tackle energy challenges in the U.S. by enhancing grid efficiency, improving renewable energy integration, and optimizing energy storage systems.

AI algorithms can improve smart grid management by predicting power demand fluctuations, enabling utilities to adjust supply proactively and prevent blackouts, and accessing surplus energy between energy grids. By analyzing vast amounts of data from smart meters and sensors, AI helps balance load distribution and manage energy storage effectively.

[3] Source: International Energy Agency (IEA), "The mysterious case of disappearing electricity demand," February 14, 2019.
[4] Source: IEA, iea.org/energy-system/buildings/data-centres-and-data-transmission-networks, July 2023.
[5] Hyperscaler is the term usually given to mega-cap technology companies that occupy AI data centers.
[6] statista.com/statistics/204879/us-carbon-dioxide-emissions-by-sector-since-1950/
[7] Source: BNEF (bnef.com/interactive-datasets/2d5d59acd9000006); commercialsolarguy.com/cost-of-solar-power-capital-down-69-strong-economy-and-learning-curves-abound/

Data centers can turn to a range of different options to boost energy efficiency

Software and Management Systems
- Virtualization
- Data center infrastructure management software
- Dynamic power management

Cooling Infrastructure
- Direct liquid cooling
- Immersion cooling

Hardware Components
- Servers
- Solid-state drives
- Fans
- Chip design

Power Infrastructure
- Transformers
- Uninterruptable power supply systems
- Battery energy storage systems

For illustrative purposes only.

Renewable energy forecasting can be improved through AI, enhancing the predictability of renewable energy sources by analyzing weather patterns and historical data—allowing for better scheduling and dispatch of power. This ideally leads to more efficient use of renewables and reduces reliance on fossil fuels.

Energy storage can also be improved through AI optimizing charging and discharging cycles of energy storage systems, ensuring that excess renewable energy is stored efficiently and released when needed.

Green(er) data centers: Improving energy efficiency

Companies throughout the AI supply chain are hyperfocused on improving energy efficiency, which is why we believe the AI sector's carbon intensity could reduce over time. We expect emissions from the data center industry to increase in the short term (5–10 years) and begin to decrease in the medium term (10–20 years). This is because the advanced clean technologies being invested in today (such as nuclear, geothermal carbon capture and storage, and long duration storage) are expected to be at scale between the mid-2030s and 2040s.

Ultimately, there are many levers that data centers can use to reduce energy consumption through improvements in energy efficiency. These include hardware components, software and management systems, cooling infrastructure, and power infrastructure.

Final thoughts

Today, a pressing question is precisely how to deliver the energy the world needs to power growing economies and new economic activities. This growth puts pressure on the entire supply chain to find solutions that enable scalable deployment of new and existing technologies that can improve energy efficiency and reduce energy intensity for the industry.

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– Ashley Hogan
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