REPORT

Power Play: AI's Role in Energizing America's Energy Sector

PART 2 | CHALLENGES

NATIONAL CONFERENCE OF STATE LEGISLATURES

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Power Play: AI's Role in Energizing America's Energy Sector

Part 2 | Challenges

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The National Conference of State Legislatures is the bipartisan organization dedicated to serving the lawmakers and staffs of the nation's 50 states, its commonwealths and territories.

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- Promote policy innovation and communication among state legislatures.
- Ensure state legislatures a strong, cohesive voice in the federal system.

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Executive Summary

As artificial intelligence is integrated into the U.S. energy sector, it brings with it numerous possibilities and a chance to rethink America's approach to energy. However, transforming America's approach to how we generate, supply and secure our energy infrastructure is not and will not be simple. Integrating AI into the energy sector is accompanied by complex and wide-ranging challenges that policymakers, utilities and industry stakeholders must navigate to ensure reliability, security and sustainability.

This paper, the second in the series "Power Play: AI's Role in Energizing America's Energy Sector," examines the key challenges associated with adopting and deploying AI across the energy landscape. While Part 1 focused on the opportunities of AI integration, Part 2 highlights the technical, regulatory, ethical and environmental barriers that could slow or complicate AI's full potential in the sector.

Key Challenges in AI Deployment in the Energy Sector

The most important challenges for policymakers to consider include:

- **Increased Energy Demands:** AI data centers are consuming increasingly significant amounts of energy and straining grid capacity.
- **Grid Reliability:** Utilities and other energy sector entities face difficulties balancing demand with insufficient energy resources, which is compounded by aging and inadequate infrastructure.
- **Data Quality and Availability:** Fragmented systems and outdated technologies hinder access to consistent, high-quality data essential for AI performance and raise concerns about data accuracy, ownership and privacy.
- **Cybersecurity Risks:** Interconnected assets create new attack targets.
- **Scalability and Integration:** Legacy infrastructure, poor interoperability, specialized hardware and the need for major investments complicate AI deployment.
- **Innovation and Accountability:** Finding a balance between the need for transparency, explainability and resiliency, while allowing for technology innovation in energy sector AI-powered systems and tools.
- **Ethical and Regulatory Complexity:** Addressing AI bias, transparency and accountability challenges in a regulated sector.
- **Environmental Impact:** As AI technologies continue to advance, it is important to consider the environmental impact, including the carbon footprint, to ensure sustainable growth.
- **Workforce Shortages:** A lack of skilled professionals hinders AI implementation.

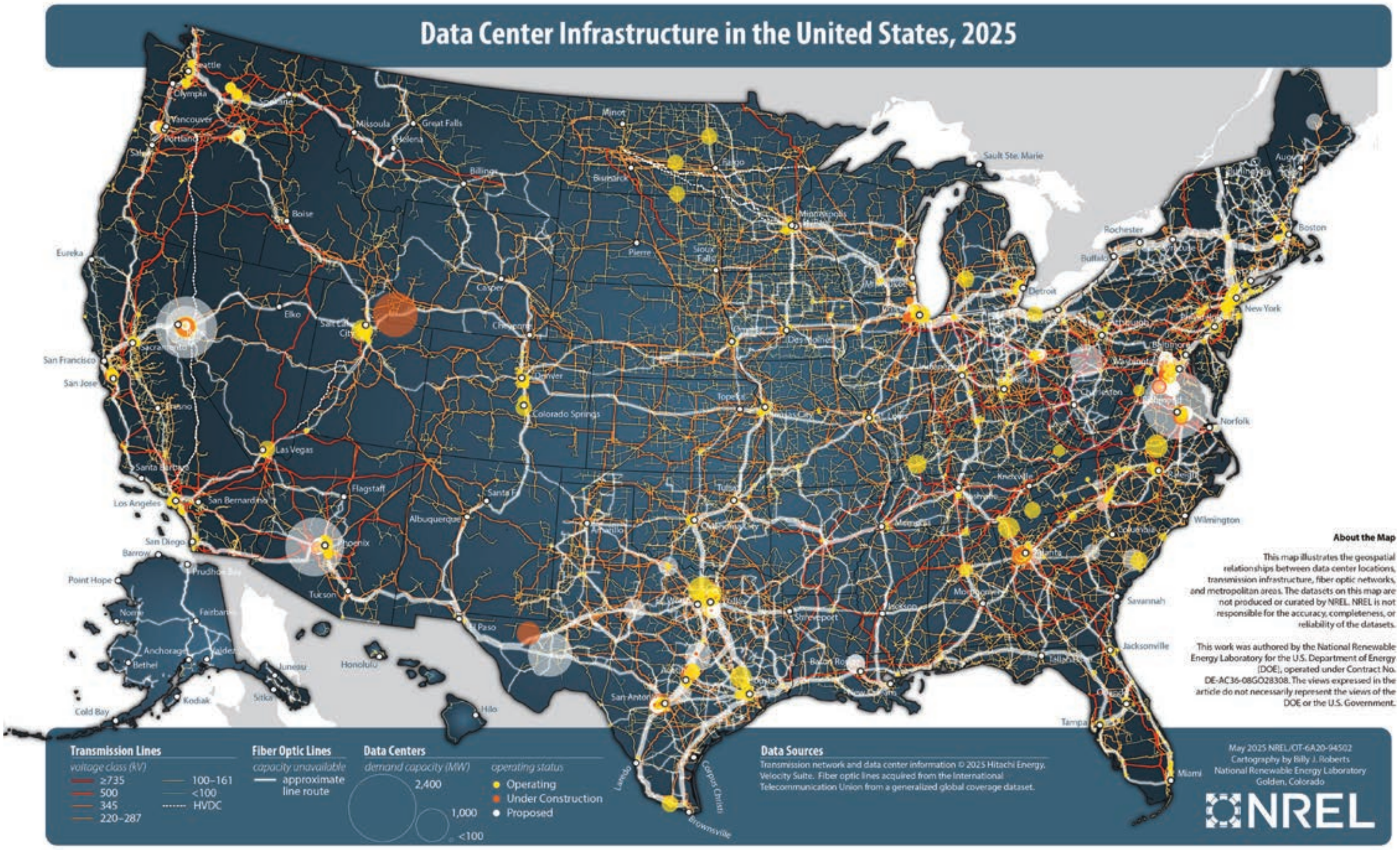
Together, these issues illustrate that while AI has the potential to modernize America's grid, see Part 1: Opportunities, its deployment should be balanced with solutions. By understanding these challenges, policymakers and stakeholders can more effectively develop solutions that enable innovation while protecting reliability, affordability and public interests. Each of the challenges will be discussed in further detail below.

AI Power Demand

The rapid expansion of AI data center deployment is placing unprecedented strains on the U.S. power grid, with AI-driven data centers emerging as major new energy consumers. While current conventional data centers sizes range from 10-25 MW. The energy consumption of a 100MW AI-focused data center is equivalent to that of about 100,000 households annually. As AI-focused data center capacity is expected to expand, energy consumption is also expected to rise, according to the U.S. Energy Information Administration's AI and energy report. The report estimates that the largest AI-focused data centers under construction in 2025, which will house 2,000MW of capacity, will consume the same amount of electricity as 2 million households on an annual basis.

Digging Deeper: Data Centers in the United States

The U.S. Department of Energy's National Laboratory of the Rockies has released an interactive version of the 2025 map shown below, "Data Center Infrastructure in the United States."



About the Map

This map illustrates the geospatial relationships between data center locations, transmission infrastructure, fiber optic networks, and metropolitan areas. The datasets on this map are not produced or curated by NREL. NREL is not responsible for the accuracy, completeness, or reliability of the datasets.

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Data Sources

Transmission network and data center information © 2025 Hitachi Energy. Velocity Suite. Fiber optic lines acquired from the International Telecommunication Union from a generalized global coverage dataset.

May 2025 NREL/OT-6A20-94502
Cartography by Billy J. Roberts
National Renewable Energy Laboratory
Golden, Colorado

A Berkeley Lab report estimates that data centers used 4.4% of all U.S. electricity in 2023. This consumption is only expected to grow, though estimates vary widely:

- McKinsey & Co., in a 2023 analysis, estimates electricity consumption by domestic data centers could reach 35 GW by 2030, a 105% increase from 17 GW of consumption in 2022.
- Deloitte, in a 2025 analysis, estimated data center energy demands could reach 176 GW by 2035.
- The Department of Energy, in a 2024 report, estimates energy consumption could reach between 6.7% and 12% of total production by 2028, largely due to AI server and data center development.
- Goldman Sachs, in a 2024 analysis, projects that data center power demand could increase by 160% by the end of the decade.
- The MIT Technology Review, in a late 2024 article, suggests that AI-related data center energy consumption could add the equivalent load demand of three New York Cities to the grid by 2026 and account for 9% of the U.S. grid load by 2030.
- The U.S. Energy Information Administration, in its Annual Energy Outlook 2025, expects commercial computing, largely driven by data centers, to surpass all other commercial end uses of electricity by 2050.

While large load demand will continue to rise, driven by data centers, advanced industrial manufacturing, oil and gas industry needs and increasing building and transportation electrification, accurately forecasting the scale and timing of future energy needs remains a challenge. Accurately identifying actual need is made even more complicated by the reported concerns of experts about the possible existence of an AI bubble, which in turn raise questions about investments, stranded assets, who pays, and who is ultimate responsible for the needed energy sector infrastructure buildout. This uncertainty can complicate infrastructure planning and regulatory decision-making. Understanding that future energy needs are unclear, and may even be unknowable, is particularly pertinent for lawmakers looking to address rapidly rising energy demands at all levels of government. The combined effects of these pressures may accelerate the need for new transmission infrastructure, advanced grid management technologies, regulatory adjustments, and permitting reform to balance demand with reliability.

Added to the challenge of rapidly rising and ultimately unknown levels of future energy demand, is the ongoing challenge of lagging infrastructure and new generation buildout which has existed for years. The Energy Information Administration's Short-Term Energy Outlook Report estimated that electricity generation was 4,410 billion kilowatt hours in October 2025, up just 2% from October 2024, when total generation from all sources reached 4,300 billion kilowatt hours. The EIA estimates that total electricity generation will grow by less than 3% to 4,530 billion kilowatt hours by October 2026.

Further complicating matters is the fact that consumption is not just about how much energy is being consumed, but when. Much of the energy demand caused by large load users is needed for 24/7 operations. However, other energy demands, those used by residential and smaller commercial users, typically peak at certain times of day. While these hours vary regionally, typically demand starts to rise in the morning and declines late in the evening. However, this changes during certain times of the year, typically the coldest

Digging Deeper: Grid Constraints

Several factors contribute to the nation's current grid constraints, including:

- Retirement of Baseload Resources: Numerous baseload generation sources are currently or scheduled to go offline in the neat future.
- Limited capacity: The grid has a maximum amount of electricity it can safely handle at any given time, especially given limits of outdated equipment, while also ensuring stability.
- Permitting: The current American permitting system is complicated and can cause long delays in the buildout of energy sector resources.
- Slow interconnection timelines.
- Rising electricity demand.
- Supply chain constraints.

These constraints are costly in a number of ways, including:

- Delayed connection to the grid for new power generation, meaning longer timelines before projects become profitable.
- Loss of energy due to inefficient delivery, thus a loss of money.
- Basis risk, which is caused by price differences between trading hub level energy purchases and load zone settlements.
- An inability to meet higher demand with higher supply, resulting in higher energy consumption costs.

Solutions being pursued related to these constraints include:

- Infrastructure expansion: Largely focused on transmission capacity and construction of new generation sources.
- Congestion revenue rights: A financial instrument to help businesses manage and protect themselves from the uncertainty caused by grid constraints.
- Permitting reforms: Congress is currently considering new reforms at the federal level.

and hottest days see the most demand and they put extra strain on the grid. In the summer EIA estimates peak demand typically occurs between 5:00 – 6:00 p.m. due to increased air conditioning usage when the heat of the day reaches its highest point, while in the winter there is more likely to be a morning and an evening peak. Maybe counterintuitively, according to EIA weekends and holidays see less energy demand due to the typical closure of commercial offices. Understanding when energy is being used in addition to how much can help lawmakers develop effective energy policy.

Digging Deeper: Impacts of Changing Data Center Energy Needs

Counterintuitively, data centers and other large energy consumers suddenly going offline can trigger significant reliability issues with the grid similar to abruptly losing a power generation source. In an April 2025 report on grid reliability impacts, the North American Electric Reliability Corp. found that incidents in Texas and Virginia negatively affected supply-demand balance of the electric grid and thus its overall stability.

In addition to the rising energy demands, AI usage is rapidly growing. The Stanford Artificial Intelligence Index Report 2025 found that 78% of respondents reported using AI in their organizations in 2024, up more than 30% from 2023. The rapid integration of AI into a broad variety of workloads from tech to health has been a major driver of data center growth in recent years, and AI integration into everyday lives is only expected to accelerate. Dramatic increases in AI usage are tied to massive AI investments, which reached $252.3 billion in 2024 alone, according to the same report. These investments in turn have allowed for the construction of more and bigger data centers, which are fueling rising energy demands. AI models, especially large-scale machine learning systems, require continuous processing power, which translates into a constant demand for electricity. In AlphaStruxure's Before AI, After AI survey of 149 new American and Canadian data center projects, 48% reported average project sizes of over 100 MW. Massive hyperscaler data centers are also on the rise. McKinsey, in 2021, estimated that the data center industry will grow at an annual rate of 10% through 2030.

A DOE report from August 2024 forecasts data center expansion and rising energy demands through at least 2030. However, specific estimates about the growing number of data centers are unclear due to uncertainty about the power needs of new private sector AI model, speculative and duplicative requests for capacity from third-party vendors, and possible future technological breakthroughs that may reduce the energy and space demands of data centers. In particular, technological innovations to reduce energy consumption by data centers have been progressing in three categories:

- Data Center Operations: Day-to-day operations are being adjusted, from use of energy storage technology to building design, to improve the energy efficiency of certain data centers.
- Chip Design: Development in some chip designs, such as chip cooling advancements, have helped decrease energy consumption by some data centers.
- Algorithms: Some companies have improved algorithm creation and training to reduce energy needs.

The energy demand surge has raised concerns about grid reliability. The need for reliable power 24/7, 365 days a year means that while efforts to expand intermittent and other types of renewable energy are underway, traditional baseload power sources will continue to play a crucial role in balancing supply and demand. And ensuring adequate energy transmission capacity and grid resilience will be critical in sustaining AI's growth.

McKinsey has found that some data center companies are working to supply their own power through power purchase agreements or by building their own energy generation. Undertaking the self-generation "behind the meter" approach is one solution that data centers are pursuing to help avoid or mitigate their impact on the broader grid. This approach has the additional benefit of helping data centers avoid the potentially higher costs grid energy due to rising demand. Indeed, there is currently no federal regulation around colocation of large load users and new and existing generation, so large load users have the flexibility to pursue a variety of generation sources including, new and emerging technologies, such as tidal power or geothermal, or existing baseload power generation sources, such as nuclear or natural gas. Some facilities may also be exploring co-location with renewable generation projects or energy storage to help hedge against potential energy supply or price volatility in the grid.

Definitions

Hyperscaler

The DOE defines hyperscaler data center facilities in the report Recommendations on Powering Artificial Intelligence and Data Center Infrastructure as facilities that are 300 MW-1,000 MW or larger with construction lead times of one-three years.

Behind the Meter

Any energy generation sources that are run by a customer and supply energy only to that customer, much like solar panels on a homeowner's roof. Excess energy from this generation may sometimes be sold back to the grid.

Physics-Based

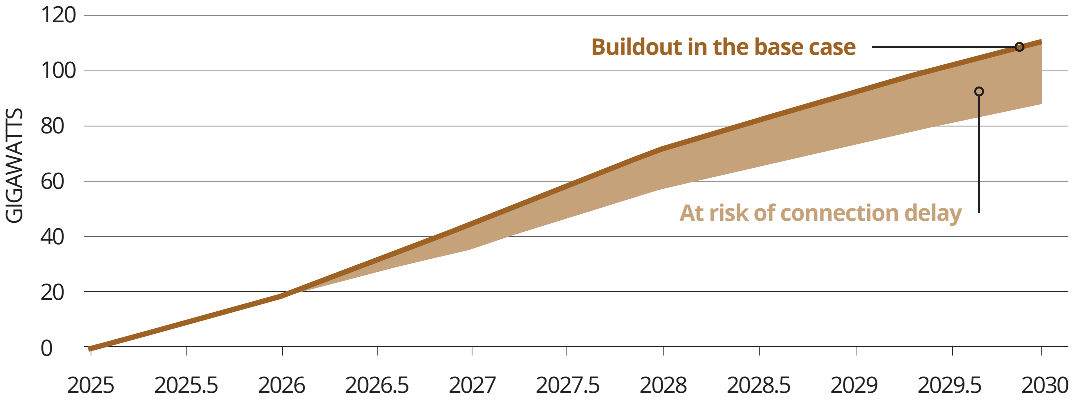
As it pertains to AI, the incorporation of real-world physics into AI models can help improve accuracy and reliability of results.

AI Hallucinations

Instances where AI generates false or misleading information.

Global Data Center Capacity

Capacity additions in the base case and capacity at risk of connection delat due to grid constraints, 2025-2030.



Source: U.S. Energy Information Administration

This approach is particularly appealing for some as the AlphaStruxure survey cited grid constraints and the difficulty associated with connecting to the American electrical grid as key barriers to new data center development. The survey found that over 40% of the data centers faced wait times of more than four years to get power from a utility. Over half of the survey respondents indicated that they considered on-site generation as a potential solution to the grid constraint problem.

However, building a new power generation source for a single data center is not without its challenges and can negatively impact a strained grid. These agreements can prevent new power generation sources from helping alleviate multiple points of energy demand and instead divert that supply exclusively to one high-intensity demand center. Some data centers are working to address the downsides of behind the meter generation and large load demands by selling backup generation to the grid during times of need, exploring ways to increase data center flexibility to help reduce energy loads during periods of peak demand, train AI models across multiple data centers in different regions to help lower local energy demands, ad-

just connections to better utilize existing infrastructure or pay for infrastructure needs directly tied to their interconnection to the grid. These and future adaptations have the potential to help improve energy sector reliability. Policymakers could consider ways to help ensure this potential solution is beneficial and supports grid stability when possible, including the impact it may have on grid stability and consumer rates. Considerations about power and grid availability could help guide ideal data center locations. Policies and regulations that either restrict or incentivize energy generation types will also impact large load users. Policymakers should consider such situations carefully. It should be noted that co-locations are only being pursued by some data centers. Many data centers choose to purse direct grid connection. Some of these data centers may work with their local utilities to examine options to avoid adding additional strain to the grid.

Reliability

The electric grid faces several reliability challenges. The North American Electric Reliability Corp., or NERC, which oversees the U.S. power grid, highlighted the risk of blackouts during extreme temperature events in a December 2024 report. The report pointed to "resource adequacy challenges"—meaning concerns about whether the grid can supply enough electricity to meet demand—over the next decade. The DOE's July 2025 Resource Adequacy Report also found grid reliability concerns. Though much of the energy generation being retired by 2030 is expected to be replaced, the report estimates that only 22 GW of the expected 209 GW will come from "firm baseload generation sources," causing concern about sufficiency.

AI is both a driving force and a possible solution to these adequacy challenges. While it can never solve all the current and expanding hardware needs, AI could be used to optimize and improve the reliability of existing resources. However, AI's own reliability and trustworthiness can act as a barrier to widespread adoption. Until AI can consistently deliver trustworthy, physics-based results, and until a solution is found for AI hallucinations, human fact-checking will remain necessary. This process can be laborious, time-consuming and ill-suited for dynamic, rapid-response situations. However, enabling AI to check, display and explain its own reasoning could help accelerate verification.

Additional challenges to using AI include external limitations such as inadequate development and the slow integration speed of new energy generation, the need for new and improved transmission, and the rapid retirement pace of existing generation, which complicates this effort even further. As addressed in further detail in Part 1: Opportunities of this series, AI can be used to help alleviate these challenges by assisting with and improving energy grid management and development.

Data Quality and Availability

Data quality and availability present significant challenges for the effective use of AI in the energy sector. AI models rely on vast amounts of accurate, real-time data to optimize grid operations, forecast energy demand and enhance efficiency. However, it is not uncommon for energy systems to have fragmented, incomplete or outdated data due to the diversity of energy sources and hardware, inconsistent data collection methods and isolated infrastructure. Gaps in data can lead to unreliable predictions, inefficiencies and suboptimal decision-making. Additionally, integrating AI across different energy networks requires standardized data formats and improved data-sharing mechanisms to ensure interoperability and maximize the benefits of AI-driven solutions. Concerns around data privacy and security further complicate the issue, as utilities must balance transparency and information sharing while protecting sensitive operational data from misuse or cyberattacks. Moreover, real-time data transmission often depends on advanced communication networks such as 5G, which may not yet be universally deployed or equitably accessible across rural or underserved regions. Without addressing these issues, the full potential of AI in energy management will likely remain unrealized.

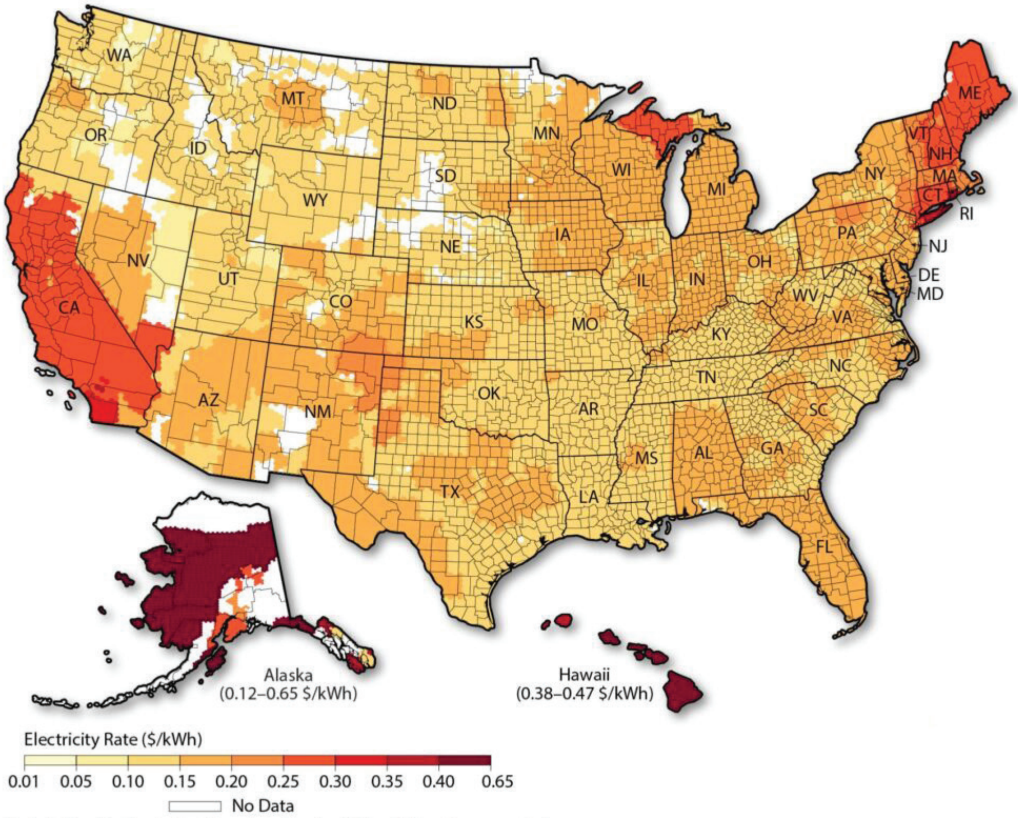
Scalability

As AI use expands and data centers proliferate nationwide, the scalability of AI-driven energy solutions becomes increasingly critical. Infrastructure for transporting energy, connecting energy generation to the grid or generating the energy itself can be built, operated and maintained by utilities, private companies or a combination thereof. Minimizing associated costs is a typical goal of the infrastructure manager. AI presents opportunities to scale energy infrastructure more efficiently, reduce burdens and optimize related costs.

According to a 2024 National Laboratory of the Rockies (NLR) report, AI could accelerate grid expansion by developing rapid, cost-effective planning models, optimizing energy storage deployment and enhancing real-time grid management. Yet, the very technology that promises to strengthen the grid is also driving demand for electricity. The rapid growth of AI-driven applications, especially large-scale data centers, has become a key contributor to rising energy consumption. Balancing AI's potential to improve grid efficiency with its substantial power needs will require careful coordination among grid operators, policymakers and other stakeholders to prevent affordability challenges for all consumers.

Residential Electricity Prices

Maximum blended rate, 2023



For clarity, blended utility rates by utility service territory from EIA Form 861 have been summarized to a uniform 25km grid, and the highest blended rate is shown where multiple territories overlap. Rate data has been overlaid with state and county boundaries for reference.

Source: National Laboratory of the Rockies

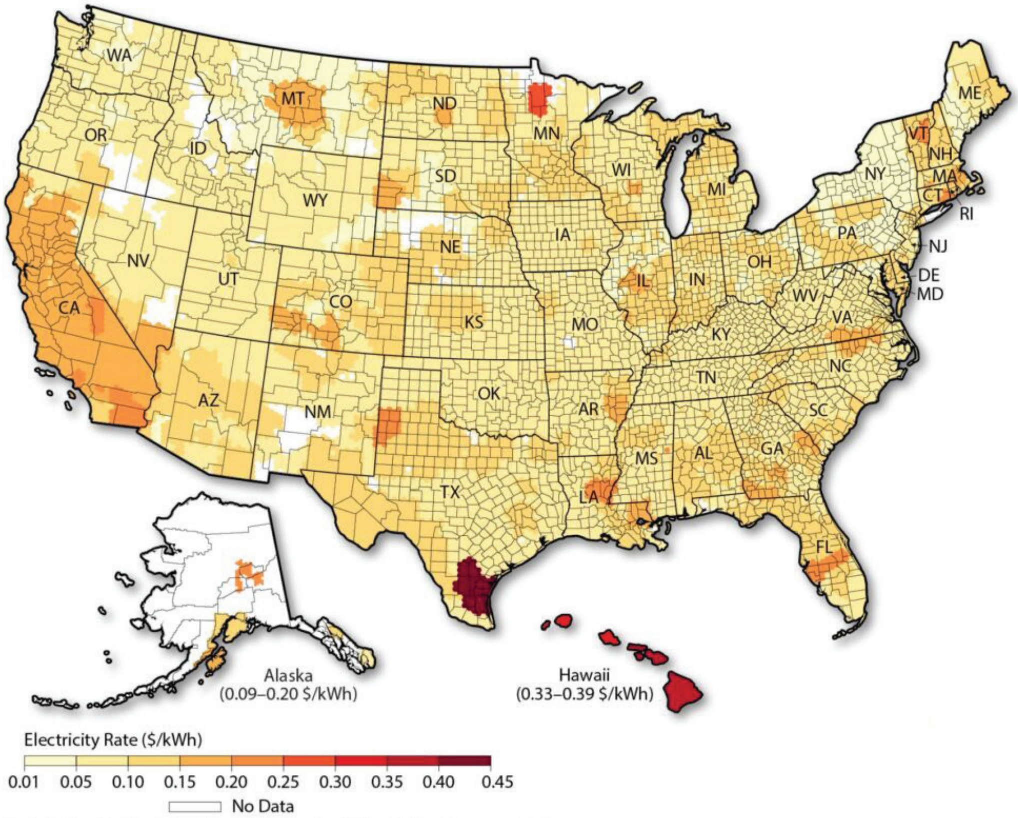
The NLR report also indicates that the rising electricity demand from AI adoption and large-scale data centers can lead to increased expenses for all utility customers. However, it should be noted that other factors and policies, such as, regulatory bottlenecks or an overreliance on one energy generation source, can also contribute to rising energy prices. Generally, electricity costs for renters and homeowners are rising more rapidly than for businesses. According to the Bureau of Labor Statistics' August 2025 consumer price index, electricity prices rose by 6.2% over the previous 12 months. Seven states —Arizona, Nebraska, New Mexico, North Dakota, Oregon, Texas and Virginia —saw annual energy demand and load growth increase by at least 2% between 2019-2023, driven largely by the rapid expansion of data centers and cryptocurrency mining, along with increasing electrification needs such as electric vehicles. Data center AI-driven energy consumption has already responsible for more than 10% of energy use in six states, with the largest share of 25% in Virginia, according to the IEA's AI and energy report.

Cybersecurity Risks

While AI has the possibility to transform the energy sector, AI-initiated cybersecurity risks remain a critical challenge. As demonstrated by the graph below, cyberattacks against energy organizations have been steadily rising. The energy sector, and energy grids in particular, are prime targets for cyberattacks due to their reliance on significant amounts of sensitive data and their pivotal role in national security and daily operations. Moreover, AI faces vulnerabilities from a variety of sources, including corrupted data inputs, algorithmic manipulation and flawed automated decision-making. Left unaddressed, these weaknesses could lead to inefficiencies or even grid instability. As AI takes on more autonomous roles in managing microgrids and virtual power plants, these risks become more significant and highlight the need for robust model validation, explainability and human oversight to ensure grid stability and reliability.

Industrial Electricity Prices

Maximum blended rate, 2023



For clarity, blended utility rates by utility service territory from EIA Form 861 have been summarized to a uniform 25km grid, and the highest blended rate is shown where multiple territories overlap. Rate data has been overlaid with state and county boundaries for reference.

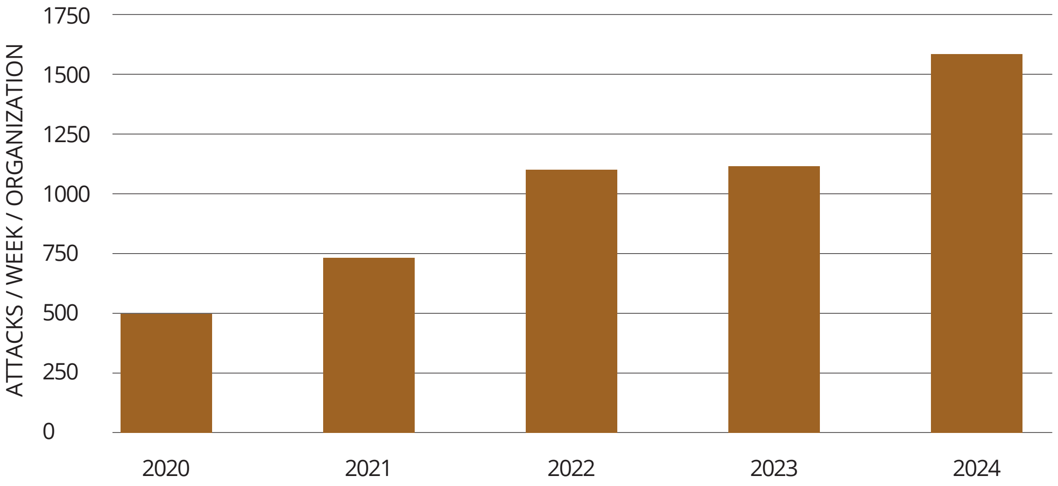
Source: National Laboratory of the Rockies

As AI advances, the security landscape will grow even more complex, requiring ongoing research and the development of sophisticated countermeasures to safeguard energy infrastructure from evolving threats. Policymakers could consider incentives for AI-specific security innovation, standards and frameworks that encourage mandatory testing, cross-sector engagement and resilience planning for AI models deployed in critical energy environments.

AI systems can also be vulnerable to adversarial attacks specifically designed to exploit the model's weaknesses. Unlike traditional cybersecurity threats that target the infrastructure itself, adversarial attacks can manipulate AI models in subtle ways, leading to incorrect decisions or system failures. These types of attacks prove that defending AI-powered energy systems requires a specialized approach different from traditional cybersecurity methods and may include requiring strong encryption, access controls and continuous monitoring.

As AI applications in the energy sector expand, cybersecurity concerns surrounding AI hardware and software are also growing. AI applications may contain built-in code, firmware or embedded software that could be exploited or manipulated to disrupt operations, compromise data integrity or create backdoor access points. These vulnerabilities, whether intentional or unintentional, pose potential risks to the reliability and security of future energy systems that depend on AI technologies. Protecting AI-powered energy infrastructure will require secure software and data handling, resilient chips and trusted supply chains. Furthermore, the various security risks associated with the use of AI developed outside the U.S., especially in electric grid operations, need to be taken into account. Foreign AI systems, like DeepSeek AI, may be attractive to grid operators and other stakeholders due to improved speeds or reduced resource needs. However, cybersecurity vulnerabilities like those mentioned above and other unknown factors necessitate careful risk evaluation before using these foreign-developed models in the energy sector.

Cyberattacks Per Week Per Energy Organization, 2020-2024



Source: U.S. Energy Information Administration

Case Studies

■ Colonial Pipeline Ransomware Attack

The 2021 attack on Colonial Pipeline disrupted fuel supplies across the southeastern U.S. by exposing critical vulnerabilities in a portion of the domestic energy infrastructure. The hack was initially caused by a compromised virtual private network, or VPN, password. However, with the increasingly widespread use of AI by the public and malicious actors, cyberattacks using AI can identify weaknesses faster, create more sophisticated attacks, adapt tactics in real time, and target multiple systems simultaneously.

■ DeepSeek

DeepSeek is an AI model developed in China that, unlike current counterparts, is specially designed to consume less energy while using more affordable and widely available computing components, thus setting a new benchmark for efficiency in AI development. While the model is largely untested and its use will likely be restricted in the U.S. due to country-of-origin concerns, the DeepSeek model could still influence U.S.-based AI developers in their efforts to create more energy-efficient systems. If its innovations can be studied and adapted, they may drive a shift toward more sustainable AI models, reducing reliance on power-intensive infrastructure. However, regulatory restrictions, intellectual property concerns and differences in computing ecosystems may pose challenges to directly integrating these advancements into U.S.-based AI frameworks.

Despite their advantages, AI-powered virtual power plants also face significant challenges. The integration of multiple decentralized energy resources requires robust data security and interoperability standards, as different distributed energy resources often operate on various platforms. Additionally, AI-driven automation raises concerns about system vulnerabilities, including cybersecurity threats that could disrupt the domestic energy supply chain. Furthermore, regulatory frameworks are still evolving to accommodate AI-driven energy management, which could pose barriers to widespread adoption. These frameworks may need to include protective measures to address potential system vulnerabilities, while also avoiding burdensome operational barriers. While AI enhances the capabilities of decentralized energy systems, careful oversight and continuous technological advancements are necessary to ensure long-term sustainability and security.

Regulatory Concerns

The energy grid, and the energy sector more broadly, is generally highly regulated in the United States. While DOE is the cabinet level agency responsible for the energy sector and federal energy policy, the Federal Energy Regulatory Commission (FERC) and NERC are the primary federal entities that oversee energy sector reliability and transmission. Broadly, they develop, establish and enforce protocols, requirements and regulations that grid operators must adhere to. Regional, state and local entities also have their own standards. While AI deployed on the electric grid must comply with all relevant standards, it can also assist operators with regulation compliance by helping them reduce errors and meet standards more efficiently. Given this, policymakers seeking to ensure the protection, safety and well-being of constituents and community assets, could consider consolidating or streamlining standards, accounting for the speed of technological innovation and the degree of oversight needed.

AI Workforce Gaps

A workforce capable of addressing the increasingly prevalent and likely applications of AI in energy infrastructure is a growing priority for a multitude of stakeholders. AI professionals will need specialized training in securing machine learning models, managing AI-driven risk assessments and implementing protective measures against cyber threats targeting the energy sector. Additionally, workforce development initiatives must prioritize ethical AI use, regulatory compliance and resilience planning to mitigate risks associated with AI deployments. Addressing these workforce challenges will be critical to ensuring that AI enhances rather than endangers the reliability and security of the U.S. energy sector.

Ethical Considerations

An obvious ethical consideration for AI technology is its trustworthiness. An NLR report cites the definition of trustworthy AI used by the National Institute of Standards and Technology: “valid and reliable, safe, fair, and bias is managed, secure and resilient, accountable and transparent, explainable and interpretable, and privacy-enhanced.”

Another ethical consideration is the implicit bias built into AI models. The Artificial Intelligence Index Report 2025 found that even large language models designed specifically to be unbiased still demonstrate implicit bias and reinforced racial and gender biases in decision-making, for example favoring men for leadership roles. The report finds that despite improvements, AI model bias remains a pervasive issue.

Trust among the public and other stakeholders in AI technology, products and services could be considered when developing AI legislation and regulations. A Stanford University report found that globally, trust that AI systems are free of bias fell to 47% in 2024 from 50% in 2023.

Environmental Considerations

AI’s potentially significant environmental impacts could be examined when considering the use of AI in the energy sector. In addition to the aforementioned energy consumption, AI data centers consume significant amounts of water to cool the servers used to store data and provide computing services. Data centers also have large footprints, in part because of the space needed to ventilate and cool equipment. According to the DOE, while data centers have historically allocated about 37% of their energy use to cooling and noncomputational functions, emerging green data center innovations and other efforts are being made to improve water efficiency by deploying advanced technologies like direct-to-chip and immersion liquid cooling, as well as implementing closed-loop systems that recirculate water for cooling, minimizing water needs for operational cooling. The industry is also exploring other solutions to address the environmental toll of AI—including renewable energy, battery storage, nuclear and geothermal technologies, and leveraging AI for thermal management and grid optimization. Continued collaboration between the technology and energy sectors will be crucial for achieving sustainable progress.

Data centers equipped with back-up power in the form of diesel generators may also be contributing to air pollution if used frequently. These generators and other similar equipment can be loud, noisy and disruptive for neighboring homes and businesses.

Case Studies

■ Microsoft's AI Data Center Water Usage in Iowa

One of Microsoft's Iowa data centers, which is used to train OpenAI's GPT-4, consumes roughly 700,000 liters of water in just two weeks. The water is mainly used to cool servers during intense AI model training. This contributed to a 34% increase in Microsoft's global water usage between 2021 and 2022. The high water demands of data centers have raised environmental concerns in Iowa and throughout the U.S..

■ Project Natick

Microsoft has been exploring several ways to cool data center servers in a more resource-efficient manner. Experiments have included submerging a waterproof steel pressure vessel, or an underwater data center, at the bottom of the North Sea in 2018. The experiment yielded improved data center functionality and lower resource and time costs, with minimal environmental impacts.

Indirect and direct carbon emissions due to AI training are a rising concern. In the Before AI, After AI survey, 35% of respondents reported that since 2023 their carbon emissions have increased. The Stanford Artificial Intelligence Index Report 2025 found that compared with the 18 tons of carbon an average person emits in a year, training for new AI models can emit more than 8,500 tons a year.

Many data center developers and other stakeholders are already working on solutions to reduce these emissions. The Before AI, After AI survey found that most data center projects and companies are continuing to pursue sustainability goals in a variety of areas, including carbon neutrality, water use and net-zero emissions. Some are exploring new, more sustainable building materials. However, continued consideration of community concerns, resource use, land use and zoning regulations could be beneficial when considering the integration of AI into the energy sector.

Integration Complexity

Integration complexity is a major challenge to deploying AI solutions within existing energy infrastructure. In addition to the advanced age of most of the power grid, much of it relies on legacy systems that were not designed to accommodate AI-driven automation. This creates interoperability issues when attempting to merge new technologies with aging hardware and software. AI applications require seamless data exchange and real-time communication between various grid components, yet differences in protocols, proprietary systems and outdated equipment can hinder this process. Retrofitting existing infrastructure to support AI capabilities often demands significant investment in new sensors, control systems, and data management tools. Additionally, ensuring compatibility across a diverse energy landscape—including traditional power plants and renewable and distributed energy resources—adds complexity. Ongoing efforts to develop industry-wide standards and best practices for interoperability can help streamline AI integration into existing energy infrastructure, unlocking new efficiencies and reducing costs. Improving standardization across relevant systems could be an option to help mitigate these concerns.

AI Hardware

AI hardware is another crucial aspect of optimizing energy generation, distribution and efficiency. High-performance computing systems, specialized AI chips such as graphics processing units and tensor processing units, and edge computing devices enable faster data processing for grid management, predictive maintenance and renewable energy forecasting. These technologies allow utilities to analyze vast amounts of real-time data, improving energy load balancing and reducing operational inefficiencies. AI-driven hardware is also being integrated into smart grid technologies to enhance automation and responsiveness in energy distribution while minimizing waste.

AI hardware can also be added to external tools, like drones, to help improve energy sector maintenance and reliability. The traditional approach to energy sector maintenance for equipment, such as substations and transmission lines, has relied on a predictable, calendar-based routine. By leveraging AI powered tools, like drones, energy sector operators can shift from reactive to proactive maintenance in order to increase efficiency, reduce costly downtime due to equipment failure, and boost the lifespan and reliability of vital infrastructure. Previous slow, manual and subjective inspection methods, such as helicopter flyovers or contractor patrols, can now be replaced by AI powered tools that can be implemented and monitored from a central command center enabling faster, safer, higher-quality inspections during routine and disaster response operations. Autonomous drone missions, for example, can reduce inspection time by 50–90%, cut labor requirements by 1–2 full-time equivalents per inspection cycle, and capture up to 10× more imagery with consistent framing and angles. This accuracy and repeatability can dramatically improve data integrity and give managers a clearer baseline of an asset's condition. In high-fire-risk regions, these tools can help utilities execute dense inspection cycles and rapidly monitor assets after wind events in order to help prevent wildfires.

Digging Deeper: AI Chips/Semiconductors

AI chips are specialized processors designed to accelerate AI tasks like machine learning and deep learning. They are built from semiconductors, the basic material used to make all computer chips, that have been specifically optimized for handling complex AI computations quickly and efficiently.

Despite its transformative potential, AI hardware in the energy sector faces significant challenges, particularly in power consumption, scalability and integration with existing infrastructure. High-performance AI chips, although beneficial, require substantial amounts of electricity, burdening the already strained energy grid. As AI-driven applications become more widespread, the need for more efficient computing hardware is critical to preventing excessive energy demand and reducing the environmental footprint of AI operations. Additionally, many energy systems still rely on legacy infrastructure that was not designed to support AI-driven analytics and automation, making seamless integration a costly and complex process. Upgrading these systems requires significant investment in both hardware and software, as well as retraining personnel to manage and maintain AI-enhanced energy networks. However, AI hardware is becoming 40% more energy efficient and overall prices are decreasing by 30%, according to Stanford's Artificial Intelligence Index Report 2025.

Another major challenge in advanced AI hardware is the supply chain and material constraints. The production of AI chips depends on rare materials like silicon and gallium, which are subject to executive orders, geopolitical risks, tariffs, trade agreements and supply chain disruptions. Additionally, some specialized AI hardware must operate in harsh environments, such as offshore wind farms or remote power plants, where durability and reliability are critical. Ensuring that AI devices function reliably under these conditions and managing frequent maintenance needs present major engineering challenges.

Future Uses

Companies and organizations continue to experiment with AI in the energy sector and explore its possibilities. For example, Google has announced a partnership with Tapestry and the grid operator for PJM to improve the operation of PJM's electricity system across 13 states. Specifically, the partnership intends to use new AI tools and technologies to address backlogs and improve and manage all project planning and interconnection within PJM's jurisdiction.

Other companies are beginning to use AI to identify, assess and respond in real time to physical threats, such as wildfire or extreme weather, to various assets in the energy sector. In some instances, AI is even being used to detect potential grid and energy manufacturing and equipment irregularities, anomalies or damage that, if not identified and addressed, could prove to be fire or safety hazards, or cause economic loss or power outages. These are just a few examples of theoretical AI applications currently deployed in the energy sector.

There are of course many unknowns with respect to future uses of AI in the energy sector. Advancements in technology, like the potential for quantum computing, as well as new policies and regulations, could drastically shift this growing and changing sector.

Conclusion

As AI integration into the energy sector continues to evolve, it will bring with it both significant opportunities and complex challenges. Policymakers and industry leaders can proactively address these challenges to help harness the revolutionizing potential of AI to bring about a more efficient, resilient and sustainable American energy future.

While Part 1 and Part 2 have outlined the key opportunities and challenges for AI in the energy sector, these barriers are not insurmountable. The next and final part of this series will examine the current landscape of state and federal actions on AI in the energy sector, providing additional context and a foundation for a balanced discussion on the path forward.

For a deeper exploration of specific opportunities and policy options, see Part 1 of this series.

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