

REPORT

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

PART 1 | OPPORTUNITIES



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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

The United States faces a critical infrastructure challenge: an electric grid built decades ago now under unprecedented strains from electrification, technology adoption and infrastructure deterioration.

Artificial intelligence is emerging as a transformative force in addressing this challenge. Today's AI systems help energy providers predict consumption patterns, balance complex power flows and maintain service reliability while managing distributed resources, virtual power plants and renewable installations. These capabilities mark a fundamental shift in how America could approach energy sector modernization and unlock previously unattainable advances.

This paper begins a three-part exploration of AI's role in the energy sector. Part one examines opportunities; part two will tackle challenges; part three will survey policy landscapes at the state and federal levels.

These opportunities are far-reaching. AI could transform grid operations, accelerate renewable adoption, and support decentralized architectures that boost system resilience. Benefits extend further to improving operational efficiency through waste reduction, sharper demand predictions and optimized storage utilization. With AI, energy providers have the opportunity to gain new tools to enhance service reliability, control expenses and meet sustainability commitments. By understanding these opportunities, policymakers and stakeholders can more effectively improve awareness of and track rapid technological advancements and support innovation while protecting constituents and the public. The opportunities for AI in the energy sector will be explored more fully below.

Background

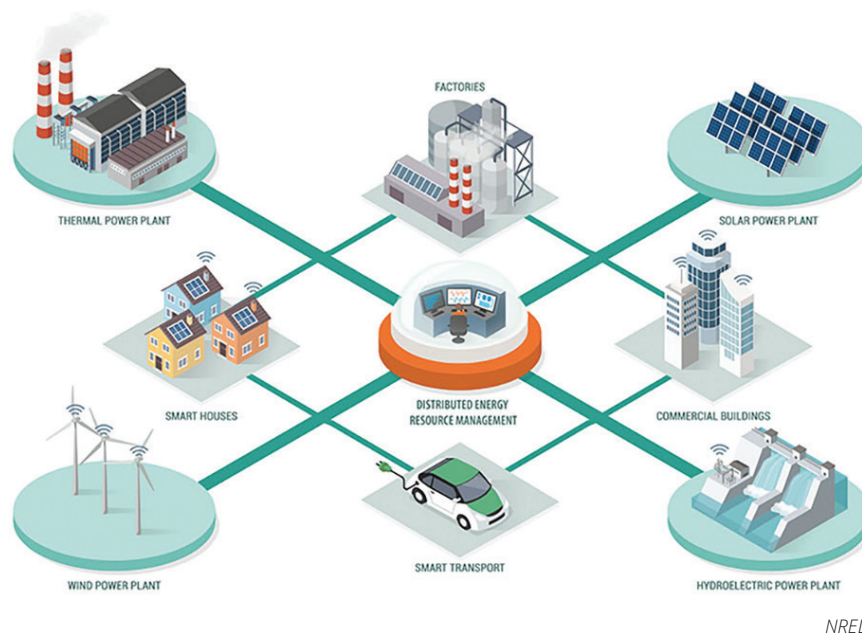
The American electric grid is large and complex. Much of it was constructed in the [1960s and 1970s](#) and some portions are even a century old. The result of such piecemeal construction is an aging grid that struggles to keep pace with modern demands. According to the [U.S. Department of Energy](#), the total grid capacity in 2024 was approximately [1,150 gigawatts](#) (GW) of electric generation. This falls far short of the DOE's forecasted need of [3,000-3,500 GW](#) by 2035 due to a growing urban population, increasing electrification, new energy-intensive technologies like electric vehicles and the huge increase in AI usage and need for AI infrastructure like data centers. Estimates by numerous sources forecast massive increases in energy consumption in the U.S. over the next few years. One such [report](#) by Grid Strategies, LLC found that by 2029 national electricity demand is expected to increase by a staggering 15.8%.

As the energy demands of everyday American life increase, the challenge of reliably supplying energy becomes more complicated and will require strategic investments in grid modernization. Some options grid

operators may use to improve reliability and efficiency in the grid include implementation of multidirectional energy flows, deployment of new infrastructure capable of integrating new intermittent power sources such as solar and wind, and enhanced real-time data monitoring for improved grid performance. AI is emerging as a critical tool to help manage this transformation and support the implementation of new options. AI has the potential to implement energy grid optimization, improve energy efficiency, balance the integration of renewable and traditional energy sources, and bolster overall resilience. New possibilities are now achievable because of AI.

Digging Deeper: Load Demand Predictions

Load demand prediction has become increasingly complex. Factors such as rising overall demand, reduced visibility of distributed generation, the growth of smart grid technologies and variable renewable energy make accurate forecasting challenging. Traditional grid management methods, which relied on consistent generation and historical trends, are less effective today, risking inefficiencies, wasted energy and supply shortages during peak demand.



NREL

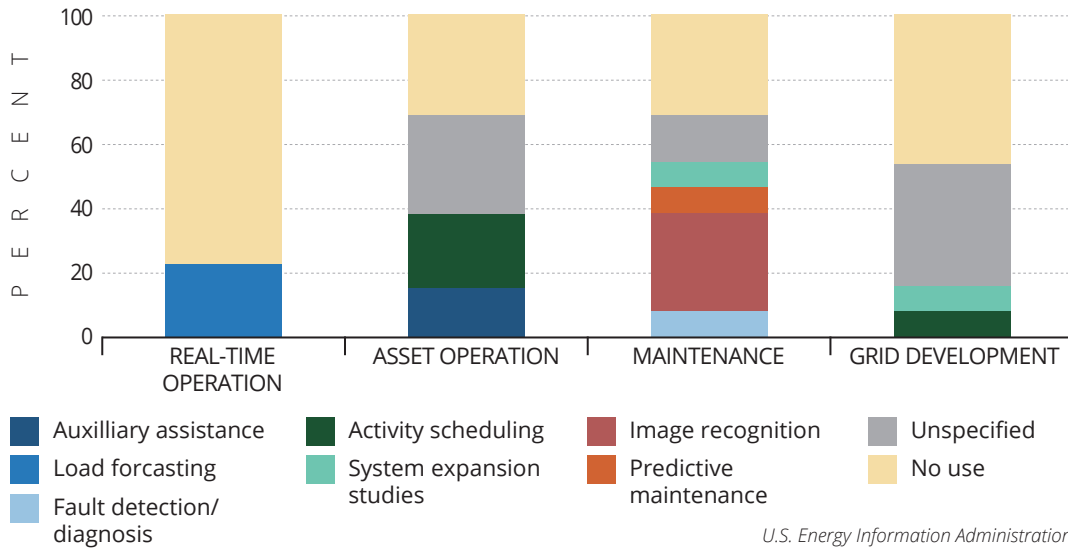
Opportunities for AI in Energy

Heightened interest among energy sector stakeholders in AI-driven solutions to address energy needs have helped highlight the five main areas ripe for AI usage in the energy sector—energy grid optimization; grid management; energy efficiency; decentralized energy systems; renewable energy integration. However, it is worth noting that the goals for and outcomes of AI usage in the energy sector may differ based on whether AI is used in a regulated or deregulated energy market, or whether it is being used by an energy generator or utility, etc. This paper is intentionally broad and is meant to provide an overview of some of the various opportunities for AI in the energy sector, though each opportunity may not be applicable or viable in every situation. The energy sector is complex and there is no one-size-fits-all situation, opportunity or solution.

Energy Grid Optimization

Predicting load demand and available supply has become a significant operational challenge for the modern grid. The DOE has found that AI-powered grid optimization offers operators a transformative solution by enabling real-time data analysis and predictive modeling. This ability can help anticipate and mitigate grid disruptions, improve resilience and maximize cost effectiveness. Furthermore, energy flows in the

Utilities Using AI Applications by Category, 2024



grid are neither uniform nor stable. AI has the potential to balance energy flows, improving distribution efficiency and reducing wasted energy.

One key application of AI in grid optimization is load mapping. For instance, during peak demand periods, AI-driven systems can anticipate supply constraints and activate reserve power sources before disruptions occur. Additionally, AI can help optimize the dispatch of DERs, such

as rooftop solar panels and battery storage, ensuring efficient use of decentralized energy production. AI-driven grid optimization can also enhance error recognition and outage prevention. This capability is especially valuable in mitigating natural disasters, supporting the resilience of buried power lines and minimizing energy waste and repair costs from damaged infrastructure. By continuously analyzing grid performance data, AI can identify anomalies and weak points before they lead to failures, reducing downtime and improving overall system resilience. This approach is especially critical as the energy sector adapts to more intermittent renewable power sources and increasing electrification demands. Similarly, AI use both upstream and downstream of the grid could offer similar optimization opportunities. The effect of current DER regulations and incentives at the local, state, regional and national levels on AI's ability to access and control parts of the energy system could be evaluated to fully leverage these optimization benefits.

Like the brain, the control room receives numerous data points, processes that data, makes a decision based on that data and transfers needed data to other parts of the system. A 2024 National Renewable Energy Laboratory (NREL) [report](#) states that as AI use grows, certified transmission operators could increasingly rely on AI to deliver faster, physics-based decisions, providing critical support, particularly in control rooms that may lack advanced technological tools. Current control room systems were designed for an older, more stable grid with single-direction power flow, making them less effective in managing today's dynamic, and often weather-dependent energy landscape. AI has the opportunity to help bridge this gap, if deployed responsibly within a system.

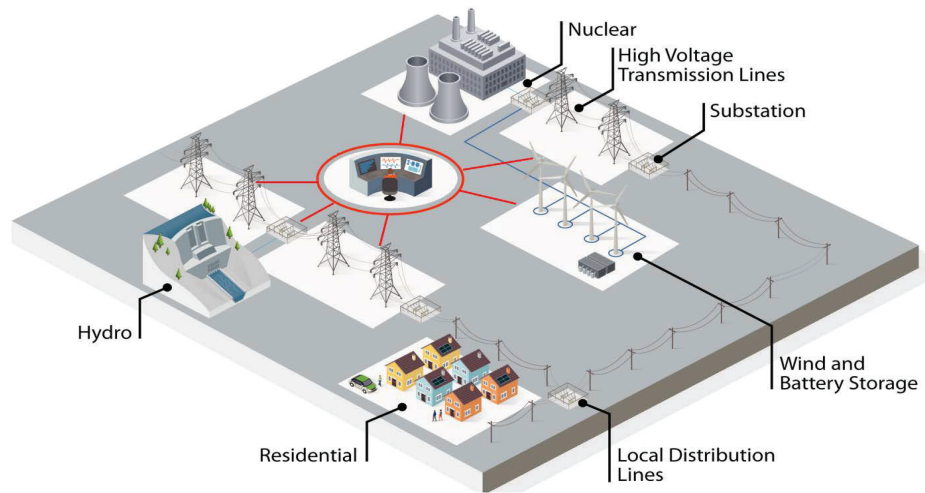
While AI can help grid operators manage the evolving energy landscape and reduce both the time and cost associated with technology upgrades, operators are ultimately responsible for ensuring accuracy and reliability. Some items that could be considered to help bolster accuracy and reliability include:

Definition: Load Mapping

Load mapping is the process of using AI to analyze and predict electricity demand, energy production volume, location and timing across different grid locations to help optimize power distribution, reduce inefficiencies and provide a more complete picture of the entire system and its needs. This knowledge enables operators to identify gaps and adjust the energy production mix, bringing reliable power sources online during high-demand periods.

Balancing the Grid

Power grid control room as the operational “brain” of the grid to balance supply and demand.



Christopher Schwing, NREL

- Evaluating the cyber-attack surface of systems and evaluating the security of deployment.
- Evaluating the transparency of how AI systems are making decisions and how that transparency is communicated to stakeholders.
- Evaluating interoperability within legacy systems/technology that was not designed with modern security in mind.
- Evaluating fail-safes and human oversight of AI operations.
- Evaluating the security of data libraries from manipulation, theft and other malicious access.

A 1979 IBM training manual is famously quoted for the line, “A computer can never be held accountable; therefore, a computer must never make a management decision.” Regulation can help find the appropriate balance of human and AI decision making, however they also tend to lag behind technology deployments. Keeping regulations broad enough to be applicable to emerging technologies, while also flexible enough to allow for additional growth and innovation could be considered to help utilities and other industry stakeholders keep up with modern standards of operating procedure and security.

Digging Deeper: eGridGPT

The NREL is working to develop an underlying platform for a trustworthy AI that can be used in a grid operator control room. Specifically, it anticipates the development and deployment of an AI tool that will:

- Use both machine learning and large language models to assist grid operators with tailored responses.
- Evolve and adapt to changing needs.
- Act as a virtual assistant by answering operator queries and prompts.
- Empower analysis of grid conditions by augmentation of digital twins and analytical tools.
- Translate recommendations from the tools into a digestible format.

More specific additional information about this model can be found in the [NREL eGridGPT: Trustworthy AI in the Control Room report](#).

Grid Management

AI can also play a key role in grid management and operations, according to the NREL, where it may be able to help optimize grid performance and improve supply use. AI virtual assistants could help operators make informed proactive decisions that enhance the overall efficiency, reliability and resiliency of the grid and related energy infrastructure. AI could also be used as a tool to help prevent brownouts or blackouts. For example, AI models could be used as a predictive assistant by continually running gap analyses and alerting

operators when a shortage is expected, thereby providing additional time to deploy other energy resources to prevent disruptions in service. This could be particularly beneficial for small operators by providing affordable on-premises support.

Furthermore, AI could be used to help prevent damage to energy and other ancillary infrastructure, especially buried infrastructure, while hardware like sensors could be used to relay when damage occurs, AI software could be used by developers to predict the location of buried infrastructure and avoid encroachment or damage.

Definition: Grid Management

Grid management refers to the process of monitoring, controlling and optimizing the flow of electricity across the power grid from generation to distribution to end users.

Energy Efficiency

As with AI's impact on grid management, operation and optimization, its potential to enhance energy efficiency presents another transformative opportunity. AI can revolutionize the understanding of energy consumption patterns by identifying inefficiencies, like excessive line loss, using advanced data analytics, machine learning algorithms and real-time monitoring. This enables more efficient consumption, reduces energy waste and ultimately lowers operational costs. Similarly, energy producers and consumers could use AI to help increase energy efficiency. By optimizing energy usage and minimizing environmental impacts, AI can be a powerful tool for driving smarter, more sustainable energy practices. Authorizing the use of AI verified by human operators could help leverage efficiencies in the energy sector.

AI also offers significant opportunities for optimizing energy storage, transmission and consumption. Energy storage, in conjunction with baseload generation, plays a crucial role in balancing supply and demand. By determining the optimal times for storing and releasing energy, AI's predictive capability could assist operators with planning to help secure energy availability when it is needed most, while minimizing waste and helping to create a more resilient and efficient energy infrastructure. The development of energy storage capacity, including improved batteries, depends on existing policy barriers and incentives. With AI offering an opportunity for improved use of energy storage, policy options that expand energy capacity across all energy sectors, while also improving stabilization of the grid during peak demand could be explored. Similarly, AI could be used to increase the capacity of transmission lines by helping reduce wasted energy that is needed to meet demand.

Case Study: Austin Energy

Smart meters are being used by [Austin Energy](#) to enhance grid efficiency by collecting real-time data that is then analyzed by AI systems to understand how and where energy is being consumed. AI analyses are then able to help lower costs, identify anomalies or outages, improve load forecasting, reduce demand during peak hours and achieve sustainability goals by providing customers with household-specific recommendations.

Other utilities are even gaining customer permission to view behind the meter usage to make energy efficiency recommendations or, in some cases, manipulate household devices such as HVAC systems, lighting and appliances to reduce customer consumption during times of peak demand in return for financial compensation.

Case Study: Florida International University's Microgrid

Florida International University, through a collaborative project with Florida Power & Light, has developed an [AI-controlled microgrid](#) on the engineering campus. This system integrates solar panels, battery storage and advanced forecasting tools to predict grid instabilities. When potential issues are detected, the AI system can autonomously "island" the campus, ensuring uninterrupted power supply to approximately 10,000 students and faculty. The microgrid employs grid-forming inverters, allowing it to operate independently from the main grid, and can provide up to 24 hours of backup power for critical circuits.

Furthermore, AI capabilities may be used to increase efficiency in energy production. Various generation facilities, including gas and coal plants, could adopt learning algorithms to predict the best times to purchase inputs, decrease costs and anticipate periods of high demand to expand capacity and deliver additional energy more effectively.

When it comes to energy consumption, AI can optimize how energy is used through technologies. Some examples include:

- **Smart meters:** These provide real-time energy consumption data.
- **Advanced analytics:** AI uses advanced analytics to analyze usage patterns and identify opportunities and provide recommendations for efficiency improvements.

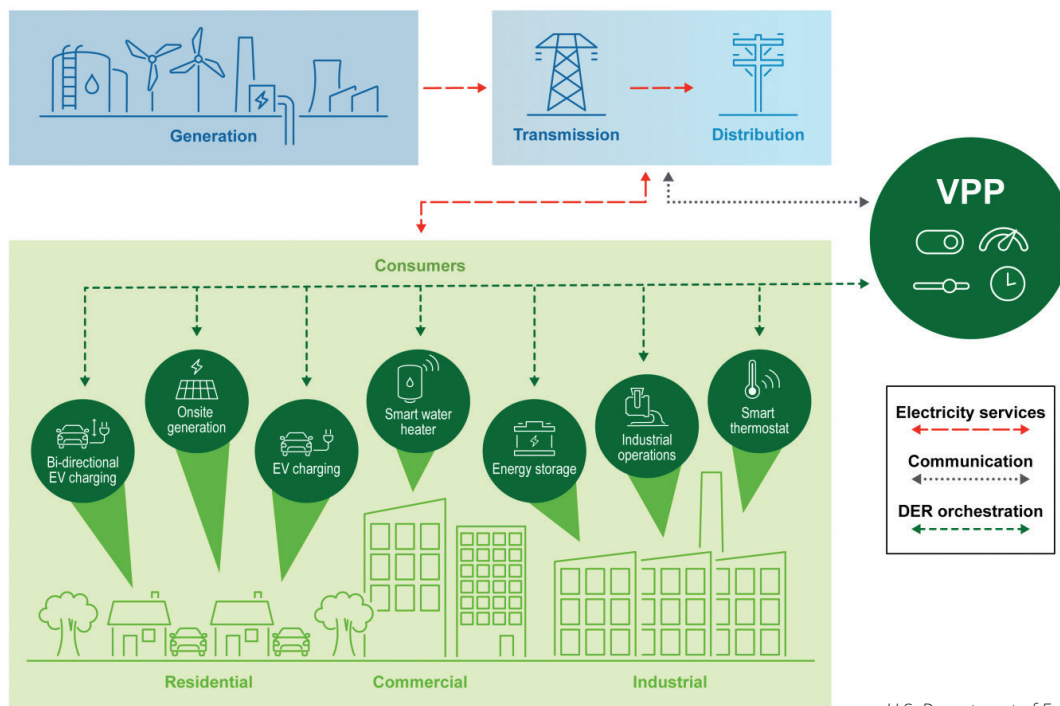
Definition: Virtual Power Plant

A VPP is a network of DERs such as solar power, wind turbines, batteries, and demand response programs that are aggregated and optimized using AI-driven algorithms. These systems use real-time data analysis and predictive modeling to balance supply and demand, enhance grid stability and maximize energy efficiency.

AI can improve energy efficiency and grid reliability, while also enabling VPPs to forecast energy flows and quickly respond to grid fluctuations. It does, however, raise certain privacy and cybersecurity concerns for consumers and operators. These issues will be discussed in part two of this series.

Renewable Energy Integration

Like with DERs, grid operators could consider and incorporate the increased connection and deployment of renewable energy as a new variable into effective grid operation. The inherent variability of certain renewable energy technologies, primarily wind and solar, and the ability to account for and address known and unknown dips in production is the main challenge of this variable. For example, a forecasted thunderstorm could reduce solar generation or wind output could drop due to changing atmospheric conditions. Hydropower and nuclear power can also present their own challenges. Generation by hydropower can be put at risk by flooding and other extreme weather events, during which nuclear energy cannot be started or shut down rapidly, so it often serves as a base load energy source. Additionally, nuclear power plants can take years to be fully brought online due to stringent regulations and costs. AI can be used to manage these difficulties by analyzing forecasting data and incorporating it into energy production estimates to forewarn grid operators and help ensure 24/7 energy sector reliability.



U.S. Department of Energy

As with DERs, grid operators could alter current grid operations by increasing the connection and deployment of renewable energy. The expansion of wind, solar, hydropower and nuclear power offers an opportunity to diversify the energy mix. These resources, when effectively integrated, can serve as both flexible and foundational elements of the nation's energy portfolio. AI can be leveraged to maximize these benefits by analyzing forecasting data and incorporating it into energy production estimates, enabling grid operators to optimize system performance, support 24/7 reliability, and ensure communities benefit from affordable and sustainable energy.

Conclusion

The integration of AI into America's energy infrastructure represents the ongoing major transition from concept to actualization. From optimizing power flows to integrating renewables and improving efficiency, AI is already helping modernize critical infrastructure. These advances are not just about technology, they are about building an energy system that is smarter, tougher and more responsive to what communities need.

But it is just getting started. How policymakers and industry leaders guide AI adoption in the next few years will determine whether early progress turns into lasting benefits for consumers, the environment and the economy. And that requires clear rules, smart investments and a commitment to innovation done right.

This paper has outlined the major opportunities. The next paper in this series examines the challenges that come with using AI in the energy sector, setting the stage for a balanced discussion on how to maximize benefits while managing risks. For a detailed look at challenges, see part two. For an overview of the current AI in energy policy landscape and detailed information on state and federal actions, see part three.

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