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Energy And AI: Key Issues And Future Challenges

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Artificial intelligence promises new technological advantages for the energy industry. But it is also responsible for vast, and growing, energy consumption — driven by the computers powering much of AI.

AI technologies, particularly those involving machine learning and large language models, are extremely energy-intensive. For instance, a single generative AI query requires nearly 10 times more electricity than a traditional internet search.

Per the Electric Power Research Institute, data centers account for approximately 4% of all electric power usage in the U.S. By 2030, that figure could rise as high as 9%.

However, this usage is unevenly distributed, with some states, such as Virginia, potentially seeing nearly half their electricity used by data centers by 2030. These large figures underscore the need for innovative solutions to manage and optimize energy consumption.

This article explores the critical issues at the nexus of AI and energy use in the U.S. — including using AI to improve energy reliability and resilience, the potential of different energy sources to power AI, the infrastructure requirements needed to support this growth, financing and procurement issues, cybersecurity concerns, and the regulatory landscape that will shape these developments.

Using AI to Improve Energy Reliability and Grid Resilience

Within the energy sector, utilities are increasingly leveraging AI to enhance system reliability and grid resilience, driven by operational needs and financial incentives. For example, investments in AI can be a boon for utilities, if they are considered capital investments by state regulators, in addition to reducing operational and maintenance expenses.

Currently, AI is being deployed in several key areas of utility operations to improve reliability and operational performance.

Day-to-Day Operations and System Planning

Utilities must manage their energy supply from numerous sources and address complex customer interactions, including various rate options and bidirectional energy flows with customers generating their own power.

As an example, AI could help improve forecasting by analyzing real-time weather data to predict customer consumption, enabling better management during peak periods.

Operations and Maintenance Investments

In addition to monitoring the status of electric generation, transmission and distribution assets, AI can predict abnormal performance of those assets, and automatically generate work orders when it identifies pending equipment failures.

It can also assist field workers, by providing access to comprehensive service manuals and performance data, enhancing efficiency in addressing maintenance issues. And AI may help control machines that assist with tasks related to the physical installation, operation and maintenance of power projects.

Customer-Facing Applications

AI can support customer service agents, by pulling customer data to create personalized energy profiles and identify issues more efficiently. During emergencies, AI could help manage increased call volumes by providing personalized recommendations and support through utility chatbots.

System Monitoring and Security

AI is being combined with surveillance and sensor systems to automatically detect and analyze anomalous activities affecting the cyber systems that make up a utility's operational technology and information technology infrastructure — including assets such as energy management systems, relays and remote terminal units.

This capability is crucial for both physical security and cybersecurity, helping identify threats faster and enabling responses that preserve system integrity or minimize the disruption of assets.

In the context of grid resilience, the focus shifts from preparation to minimizing the duration and impact of disruptions and enhancing recovery capabilities. AI can play a key role in achieving these goals, due to its proficiency in improving response time and efficiency. It can enhance situational awareness by providing operators with real-time information about grid status.

Effective resilience planning also involves leveraging available resources, especially when some may be unavailable during an event. AI can help improve modeling and resource integration, which will become more important and complex as the grid evolves to include more dispersed power sources.

AI could even be used to autonomously control critical energy systems, enhancing the speed and efficiency of resilience responses. Of course, this raises cybersecurity concerns, especially when operations are migrated to the cloud, which is discussed further below.

Utilizing Renewables and Nuclear to Power AI

Renewable energy sources like solar and wind are crucial for sustainable AI development, but face intermittency issues. This can be addressed by combining the use of renewables with gas facilities and long-duration energy storage — an approach in which AI can be used to help optimize the performance and efficiency of battery storage systems.

AI can also assist in the permitting and environmental review processes for new renewables projects, including optimizing project siting while reducing operational costs.

Nuclear energy, with its ability to provide a continuous power supply, addresses the reliability issue posed by renewables. Nearly 20% of the U.S. power supply comes from nuclear power plants, providing continuous, carbon-free energy.

While there are few challenges for using existing nuclear plants to power data centers and AI, and a few such projects are already moving forward, there are more challenges to consider with yet-to-be-built advanced nuclear reactor designs. These challenges include regulatory hurdles, colocation logistics, and the uncertainty of new reactor technologies and related fuel procurement.

Looking ahead, small modular reactors, advanced reactors and microreactors — all currently in various stages of design and licensing — promise to be positive developments for the energy landscape for AI data centers.

Financing New Energy Infrastructure for AI Growth

Traditional sources of capital may be insufficient to develop the new energy infrastructure that will be needed to support AI.

In the U.S., trillions of dollars will be required for clean energy investments, supported by debt financing, equity and tax equity. The Inflation Reduction Act aims to address some of these financial challenges by creating new methods for monetizing tax credits.

However, further investment and innovative financing mechanisms will be necessary to meet future demands. This being the case, new financing sources are emerging to address this need. Alternative lenders and even life insurance companies are increasingly entering the energy sector, creating deeper financing markets.

The IRA has significantly affected the market by enabling the transfer of tax credits — which has facilitated the creation of a new market for these credits. This transferability significantly expands the market for tax credits, from a relatively small and sophisticated group of tax equity investors to nearly any corporate entity that is a taxpayer.

This will help to avoid bottlenecks associated with the traditional tax equity market. And as insurance products develop that will wrap the tax credits, the IRA is expected to create a larger, more accessible market, attracting new sources of capital.

The emergence of these new financing mechanisms is crucial for meeting future energy needs — including for AI — while aligning with environmental goals, ensuring that the demand for clean and renewable energy is met effectively.

Infrastructure Needs and Regulatory Challenges

Supporting an AI data center buildout involves significant — often underestimated — electrical demands, and a robust infrastructure. In addition to generating additional power, it is also essential to efficiently transport this power from its production site to the data centers where it is consumed to meet demand, given the limited storage options available on most electric systems.

This will require substantial infrastructure upgrades, which can be expensive and complex. It will also require developing a long-term transmission plan that ensures the necessary capacity on the transmission system to accommodate the additional load.

The regulatory environment governing the intersection of AI and energy includes Federal Energy Regulatory Commission regulations, for transmission planning and generator interconnection; the Federal Power Act, for wholesale power sales; and various state-level regulations, for transmission and generation siting.

There is also a significant federal overlay involving regional transmission planning, which can replace local projects with larger, more cost-effective regional projects. This can lower costs for ratepayers, but may affect timing and involve a complex selection process.

State-level approvals further complicate the process, while projects that cross federal land or waterways can raise environmental issues and become litigious, leading to unpredictable delays.

The goal for AI companies will be to navigate this regulatory and legal landscape efficiently, to ensure that the necessary infrastructure is ready on time for new data center operations. They can achieve this by establishing proactive partnerships with local distribution utilities. Engaging early with a local utility provider will provide insights into the state regulatory landscape, reasonable project time frames, and rate structures.

AI companies should also actively participate in the broader transmission planning process. Historically, large load customers like data centers have not been as involved in these processes.

But given the substantial load and financial investment that data centers represent, these companies should increase their level of involvement. This will ensure the infrastructure required for data centers is considered and planned for, facilitating smoother project execution.

Renewable Energy Procurement for AI Data Centers

In some cases, AI data centers can secure renewable energy through utility "green tariffs." However, utilities are facing significant increases in projected demand, and the renewables market is competitive. Utilities may not be able to meet the renewables demand of all of their customers.

AI data centers can also contract directly with renewables developers to enter into physical power purchase agreements, in which they purchase the energy generated by a renewable energy project. Or they can enter into virtual power purchase agreements, in which they purchase the climate-friendly attributes generated by a renewable energy project.

However, AI data centers will be competing in a renewables market where securing the necessary land use approvals and interconnection rights to construct large-scale projects can be challenging — especially in the PJM region and the northeastern U.S. This is leading some AI data centers to explore development in new markets where project development may be easier.

Energy storage is also likely to play a critical role in AI data center development, as energy storage can be paired with existing or new solar and wind projects to address the inherent intermittent nature of these sources of generation.

Pairing energy storage with wind and solar projects will allow them to meet the 24/7 demand of AI data centers. This will add to the complexity of offtake agreements, which will need to be deftly navigated to ensure sufficient and efficient energy procurement for the growing number of data centers expected in the coming decades.

Cybersecurity Concerns

AI offers numerous capabilities to enhance cybersecurity operations in the energy industry, such as its ability to detect anomalous activity on energy networks. AI can automate the identification and assessment of suspicious activities — processes which currently rely heavily on human operators.

This automation can improve the detection of both known and novel malicious activities, allowing for faster and more effective responses.

Additionally, AI can streamline the reporting of cybersecurity incidents. Energy companies are subject to multiple overlapping cyber incident reporting requirements from federal and state agencies. AI can help those companies redirect human resources to focus on incident response and recovery, while still meeting their legal reporting obligations.

However, the use of AI in cybersecurity is not without risks. For instance, AI can produce unpredictable results if it is trained on biased or inaccurate data.

Another concern is the potential for AI to be harnessed for malicious purposes. AI-driven autonomous malware poses a significant threat, and could lead to more sophisticated and widespread cyberattacks.

The electric utility industry has long-standing mandatory requirements for cybersecurity. As AI is integrated into the energy industry, these existing regulatory frameworks will likely adapt and expand, especially as lawmakers monitor its development.

This scrutiny could lead to the introduction of more specific rules and regulations for AI, and possibly new regulatory bodies dedicated to overseeing its use in the energy industry.

Biden's AI Executive Order

President Joe Biden's October 2023 executive order on AI is expected to significantly influence the implementation of AI in the energy sector.

The order emphasizes core principles that are likely to shape federal regulatory actions, and assigns a leading role to the federal government in managing AI-related risks, by directing key agencies like the U.S. Department of Homeland Security and the U.S. Department of Energy to evaluate potential standards for critical infrastructure sectors.

This top-down approach means that regulators with substantial interactions with the energy industry will place increasing importance on ensuring that AI is implemented safely and effectively.

The executive order is likely to result in more stringent oversight and the development of comprehensive standards and frameworks to govern the use of AI in critical energy infrastructure, driving a coordinated effort to mitigate risks and ensure robust cybersecurity and operational efficiency.

Conclusion

From enhancing grid resilience and optimizing energy procurement to addressing cybersecurity threats and regulatory complexities, the rapid integration of AI into the energy sector brings both opportunities for innovation and challenges that require careful navigation.

As AI technologies continue to develop, stakeholders must collaborate to ensure sustainable and secure energy solutions that can support the growing demands of this transformative technology. The future of AI and energy lies in balancing technological advancement with regulatory oversight, environmental responsibility and infrastructure development.

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