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SEE ENERGY BRIEF

Monthly Analysis

The Vital Role of AI in Electricity Grids

Introduction

In energy circles, few topics dominate conversations quite like artificial intelligence (AI), whether the focus is on unprecedented demand for electricity or the tools that could revolutionize the generation, management, and distribution of power. AI will be a critical piece of the clean energy economy, according to a new report **(1)** by the US Department of Energy and its six national laboratories. Last year, President Joe Biden issued an executive order calling for the agency to produce a public report "describing the potential for AI to improve planning, permitting, investment, and operations for electric grid infrastructure and to enable the provision of clean, affordable, reliable, resilient, and secure electric power to all Americans." **(2)**

The rise of AI data centres, with their insatiable hunger for electricity, is asking an awful lot of the world's utilities and grid operators. On the bright side, AI can also give a fair bit back, by helping transform ancient, overloaded and dumb electricity networks into something fit for the digital and decarbonised age. America's Department of Energy reckons that AI and other improvements to the country's existing grid could liberate as much as 100 GW in transmission and distribution capacity over the next 3-5 years without the need to build new lines. That is about 13% of current peak demand of around 740 GW. **(3)**

This Monthly Analysis will attempt to shed light on the emerging topic of AI in conjunction with the operation of electricity grids and how AI can transform them in the energy demanding future.

How AI is Powering Today's Energy Technologies

Like oxygen, the power grid is essential to modern life but is not always top of mind – until problems occur. Today, in several countries, aging grid infrastructure is taking a beating from severe weather events around the world, resulting in power outages that threaten health, safety, and economic activity. At the same time, a number of other factors are also putting pressure on century-old grids. The way that energy is produced is rapidly changing – more wind and solar, less coal and fossil fuel. This shift requires new processes and ways of managing. The "who" is also shifting, with energy now produced not only by the major energy companies, but also by a plethora of new competitors and prosumers (consumers who produce energy).

And not only is the natural world changing fast, but the technological world is advancing at a gallop as well. Cloud-connected AI technologies like machine learning, data analytics, and the Internet of Things (IoT) are driving the advancement of smart grids capable of managing far more complex power generation and distribution. These technologies herald significant opportunity for those in the complex energy ecosystem that are able to harness them.

1. What is the difference between the traditional grid and a smart grid?

The main difference between traditional systems and smart grids lies in the ability to exchange information in both directions across the network, from utility companies to consumers and vice versa. Some of the top features that differentiate smart grids include **(4)**:

- **Technology:** AI, cloud, and digital technologies allow all the devices and assets within the grid to communicate, supporting better control and self-regulation.
- **Distribution:** Energy generated by prosumers and other renewable energy sources – such as solar or wind – can be intermittent and uneven. Smart grid technologies help to coordinate, store, and distribute power from such sources into a steady and reliable stream.
- **Generation:** Predictive analytics in smart systems means that high-demand strains can be forecasted and distributed to multiple plants and substations.
- **Sensors:** IoT sensors across the network can help detect risk early on, redistributing power to decrease outages and help balance loads without direct intervention by operators.
- **Self-repair and predictive maintenance:** Sensors can also be used to detect mechanical problems and do simple troubleshooting and repairs, notifying technicians only when necessary – before anything actually breaks down.
- **Customer choice:** More energy suppliers, cooperatives, and micro-generators can join the grid, allowing consumers to have more choice in how they receive energy.

2. Applications of AI in smart energy solutions: The utilities sector perspective

AI is the driving "intelligent agent" behind smart grids – evaluating the environment and taking actions to maximize a given goal. AI is fundamental to the integration of renewable energy, the stabilization of energy networks, and the reduction of financial risks associated with instability in the infrastructure.

For instance, the self-learning, adaptability, and calculation capabilities of AI have significant potential to address the intermittent nature of renewable energy. An imbalance in peaks of production and consumption are often represented through "the duck curve" and can make these sources of energy difficult to control. The use of AI in smart grids will help address this challenge by rebalancing inequity between production and consumption loads.

Smart grid technologies help to make utilities sector activities more transparent and competitive. Some of the applications of AI and machine learning in smart grids include:

- **Agility and resilience:** When renewable energy is generated by new partners like cooperatives and prosumers, it is often intermittent and variable. Sensors and automation can be used to identify parts of the grid that are vulnerable and respond with automated rerouting – storing surplus energy during peak generation times and rerouting it during gaps in the flow.

- **More precise forecasting:** The utilities sector faces widespread price variability due to changes in consumption. Predictive analytics models can be used to more reliably predict power loads and renewable energy generation. By combining data from advanced metering infrastructure (AMI) with AI, predictions are more accurate than traditional approaches.

- **More sophisticated outage alerts:** The network of sensors, meters, and actuators in a smart grid can give a "last gasp" short signal transmission, including time and date, to indicate a loss in power due to partial or complete outages. In addition, the predictive capabilities of AI and the real-time data of smart meters can notify operators of outages right before they happen. These systems can even differentiate between individual, street, and zonal outages.

- **Optimized power yield:** The use of AI-powered sensor networks in generation stages can also be used to optimize power output. In a similar way, solar energy also benefits from AI tools to increase productivity by predicting solar radiation.

- **Improved automated switching:** The ability of AI tools to predict grid imbalances and to differentiate between a brief power interruption and a full-on outage will soon allow switching protocols to be automated. This will allow utility companies to reroute energy or isolate affected areas before severe damages occur or the outage expands to other areas. These tools are a line of defense that ensures the safety of the essential equipment used to isolate and repair faults.

- **More flexible demand-side management (DSM):** Peaks in energy demand put utility companies under great strain. Using AI and smart meters in homes and offices can help with scheduling, planning, executing, and monitoring changes in energy demand to ensure that providers can meet them. Doing this can have a major impact on power usage, as shown by the US Federal Energy Regulatory Commission, which found that peak loads can be reduced by up to 150 GW through demand management. Similarly, the Electric Power Research Institute (EPRI) has estimated these smart tools could lead to a 175 GW reduction in summer energy peaks by 2030.

- **Improved security:** Cybersecurity is a key concern for all business sectors. And the increasing number and complexity of cyberattack strategies presents a risk to both existing and new electrical grids. AI tools can help reduce this risk by detecting network attack features, malware, and intrusion and by providing network security protection for power systems. In addition, other technologies, like blockchain, can provide transparent, tamper-proof, and secure systems that enable novel business solutions, especially when combined with smart contracts.

3. Applications of AI in smart energy solutions: The consumer perspective

Recent surveys from the UK and US show less-than-great customer attitudes toward utility companies. With the rise in energy suppliers and prosumers, utilities companies will need to leverage smart solutions to help nurture better customer engagement and satisfaction. Below are some of the ways smart grid technologies can help to improve customer satisfaction:

- **Lower costs:** AI-powered smart grid management and smart metering allow customers to get hourly assessments of their power usage – helping them to see not only when and where they use the most energy but offering personalized tips and suggestions for optimizing their typical daily routines to lower usage during peak times. It also helps prosumers manage energy production which can be sold back to the grid to reduce costs even further.
- **Improved sustainability and transparency:** Smart grid data can help customers become more aware of where their energy is coming from, increasing their engagement and helping to democratize the grid. This can help to give them new perspectives on energy provision and the ability to choose more sustainable options.
- **Fewer outages:** As mentioned, AI tools can help reduce the number of outages and mitigate their impact both for residential and commercial customers. This means an increase in security and confidence for consumers – especially as weather events and record temperatures bring fears of brownouts and other disruptions.

4. Big Data in energy: Why it matters

From the point of view of both customers and utilities companies alike, it's not simply the ability of these technologies to gather and manage large and disparate amounts of Big Data that matters – it's the ability to leverage and understand all that data and use it to optimize power usage and inform operations. Big Data is key to helping:

- Better integrate renewable and alternative power in utilities companies by learning to predict and manage intermittence, and balance a myriad of small inputs from prosumer players.
- Protect consumers by anticipating outages and redirecting resources in a fraction of a second – rather than after everything has gone down.

- Save money for companies and consumers alike by digitally learning from past activities and using that intel to better manage and automate day-to-day activities.
- Provide fast, actionable insights that let utilities companies make confident and quick decisions in an increasingly competitive environment.

5. How today's utilities industry is preparing for the smart grid of the future

Most analysts agree that the future of energy is moving toward more decentralized, flexible, and sustainable power provision. But we are talking about a global industry that is over a century old – and often must rely upon infrastructures from nearly that long ago to serve billions of people and their rapidly changing demands.

Other challenges include complex regulatory changes, the rise of prosumers, and new startups emerging in deregulated regions. Like any journey of business and digital transformation, the move to smarter grid management starts with a few cautious steps before breaking into a run. Utilities sector technologies are undoubtedly powering and enabling the evolution of this sector. However, for meaningful change to occur, utilities companies will need establish strong communication, customer engagement, and change management plans including:

- Communicating a vision of the smart grid and aligning teams and stakeholders around it
- Strengthening consumer education about the changes and opportunities to come
- Providing win/win motivation for consumers, prosumers, and potential distribution partners
- Developing metrics to monitor progress in the implementation and effectiveness of smart grids
- Keeping the customer experience and customer retention in mind, given the additional competition and decentralization of a smart energy market

The Future of AI and Electricity Grids

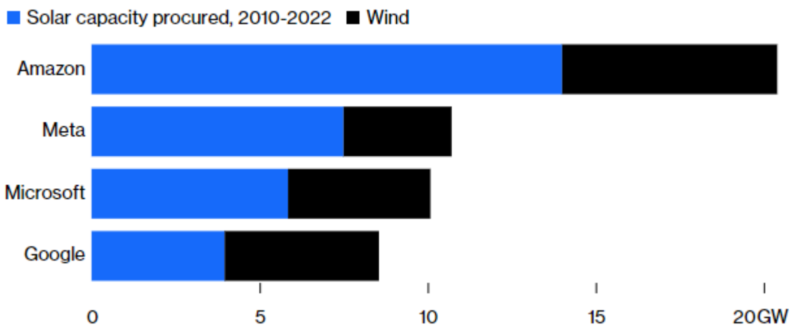
By 2026, booming AI adoption is expected to help drive a near-doubling of data centers' global energy use, to more than 800 TWh — the annual carbon-emission equivalent of about 80 million gasoline-powered cars. Will this voracious energy appetite undermine efforts to combat climate change? To the contrary, it can and should be harnessed to speed the green transition. **(5)**

It's easy to envision how things could go wrong. In the US, power-hungry AI applications are already adding to strains on electricity grids and pushing utilities to burn more fossil fuels. In Ireland, a global computing hub, data centers are expected to consume nearly a third of all electricity by 2032. Cue a vignette of people unwittingly boiling the oceans in pursuit of the perfect dog portrait.

There's also a more positive scenario. The users and owners of these data centers — including Alphabet Inc., Amazon.com Inc., Meta Platforms Inc. and Microsoft Corp. — are among the world's largest companies, with ample cash, long strategic horizons and public commitment to the environment. **(6)**

To an encouraging extent, it's already happening. Tech companies have long been top buyers of renewable energy, and have lately breathed life into technologies such as hydrogen storage and small modular nuclear reactors — ideal for providing the stable power that data centers require. The more they invest, the more they'll help such innovations reach economies of scale, lowering the cost of clean energy for everyone.

Figure 1: Tech Companies Dominate RES PPAs



Sources: IEA, Bloomberg

They might also help solve one of the biggest challenges of renewables: Wind and sun are highly variable, requiring a lot of fossil-fuel capacity to fill sometimes extreme gaps between supply and demand. With the aid of AI, data centers can help a grid meet peak demand by dialing back nonessential operations or shifting work elsewhere — a technique that Google has pioneered. In doing so, they can reduce emissions and increase the whole system's resilience.

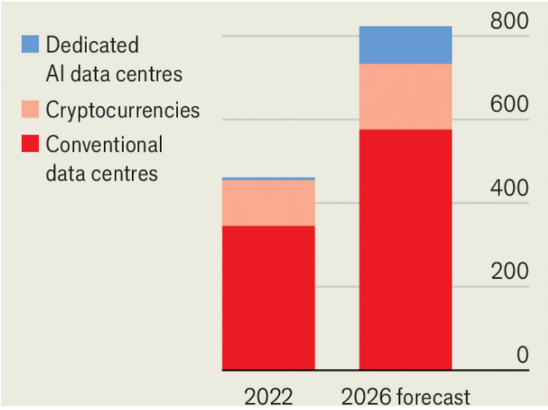
What, then, can policymakers do? The best approach by far would be for them to support a tax on carbon emissions. This would encourage investment in clean energy, help displace fossil-fuel generation and induce more innovation. Officials should also remove bureaucratic obstacles to building much-needed capacity, especially nuclear.

Beyond that, the authorities who approve new data centers should be more selective. They should require, for instance, that owners pay for transmission infrastructure (instead of shifting the cost to other consumers) and invest in added clean-energy capacity that can supply the grid when needed. Some of these conditions already apply in places like Ireland and Singapore. They should be standard everywhere, particularly for the data centers that governments use.

Finally, the public needs better information. Although many companies have pledged to achieve net-zero emissions, disclosure standards are lacking. Exactly how much energy data centers consume is hard to say. If they all reported their true energy mix, power efficiency and capacity to support the grid, they would illuminate best practices, enable better planning and ensure accountability.

To be sure, data processing isn't necessarily the biggest challenge of the green transition. By one estimate, it accounted for less than 2% of global electricity demand as of 2022. Growth forecasts often prove wrong. Technological breakthroughs can change the picture. Yet the need for cleaner energy could hardly be clearer. Even if AI proves to be a bubble, we have to ensure that some benefits will ultimately come out of it.

Figure 2: Global Estimated Electricity Demand (TWh)



Sources: IEA, Economist

Discussion

Data center energy use is spiking around the world. As AI workloads soar, the International Energy Agency says that demand could double in the next two years. Many utilities in the US are scrambling to procure more power to meet growing load from new manufacturing plants, electrification, and data centers – often by proposing new gas plants.

This trend is worrying environmentalists and clean power advocates, who say AI could make decarbonization harder on an already-constrained grid. But many experts see it as an opportunity to get creative about expanding grid capacity and designing data centers – and that the benefits of AI in the power sector will far outweigh the increase in power demand.

Several experts point out that the laboratories should establish a leadership computing ecosystem to train and host data and foundation models at ever-increasing scales. Fine-tuned models need to be developed for each domain that are coupled, where possible, with ground-truth, first-principles physics. Although the laboratories have hundreds of petabytes' worth of data, only small amounts of these data are cataloged, warehoused, and ready for AI model ingestion. Curation of one-of-a-kind, ground-truth data coupled with energy industry data will be essential to building models at these scales **(7)**. Most important, partnerships across laboratories, government, industry, and academia are essential to realizing the transformational benefits which AI can bring to energy.

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