THE WHITE HOUSE
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AI
ASPIRATIONS

An AI Aspiration for Clean Energy

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IMAGINE IF...

... every American had electricity that was reliable, affordable, and 100% clean. Imagine if electricity were so abundant and resilient that we did not have to worry about growing demand and intensifying weather events. Imagine if we could electrify our homes, our transportation, and even our heavy industries, while fully decarbonizing the sources of that electricity to protect our planet.

Today

America's electric grids have the potential to provide clean, inexpensive, and reliable energy. However, today they face unprecedented challenges: electricity demand is growing, new generation sources are coming on line, and climate change is fueling more frequent extreme conditions that stress reliability. Data centers are expanding rapidly, and they along with electric vehicles and heat pumps will demand more electrical power in the years ahead. We have made an important start in decarbonizing electricity with clean sources like wind and solar, but meeting the climate crisis requires an even faster deployment rate. An increased frequency of extreme weather events, cybersecurity breaches, and an overall increase in grid complexity all challenge our ability to deliver electricity 24/7 safely, at an affordable price.

Achieving the electrical grid of the future requires new approaches for both real-time operations and long-term planning. For planning, a lack of data integration prevents us from siting new generation in ideal locations, and the planning process can be extremely lengthy, driving up utility costs. For grid operations, today's tools are too slow to optimize and manage the grid in real time, which decreases predictability and stability and can lead to unsafe operating conditions. Today's models do not incorporate critical sources of data, ranging from weather to satellite imagery to sensors, limiting operators' ability to anticipate and plan for problems. Smart electronics and control systems yield only incremental improvements to mitigate the intermittency of renewables and maintain resiliency.

AI opens the door

Recent advances in AI have significant potential for application to the grid. In particular, new computing paradigms combine data-driven models with physics-based models to bolster reliability and trustworthiness, which are critical considerations for the unique safety and security constraints imposed on grid management.

Key areas of progress include:

- "Surrogate models" that mimic traditional models (e.g., for simulating power flow or optimizing unit commitment) but run fast enough to execute in real time;
- Algorithms for estimating risk and uncertainty in power markets;
- Increased availability of data, ranging from distributed grid sensors (e.g., for monitoring frequency and voltage) to weather and other geospatial data;
- Federated learning and synthetic data, which allow models to be trained without compromising privacy or security;

- Large AI models that can integrate diverse, messy data types and impute missing information;
- Increased availability of cloud computing, democratizing access to AI without investment in hardware infrastructure; and
- New algorithms to estimate uncertainty and guarantee that solutions meet physics constraints and safety requirements

The work ahead

Navigating the transition to clean electricity will require a paradigm shift in how we plan and operate the grid. To create such a capability will require the following steps:

Define data structures and grid ontology

Modeling the grid requires integrating many different types of data and algorithms across spatial and temporal scales, including network topology, device characteristics, power flow data, grid sensors, and weather data. Most of this data exists but has yet to be operationalized and integrated. For the grid, it is challenging to define data representations that are rich enough to be descriptive, but abstract enough to translate between domains. For example, the grid is usually represented as a network (nodes and connections), but weather is spatiotemporal and siting/permitting constraints are embedded in text. A modeling environment requires data representations that can be flexibly merged and overlaid. AI can speed this process by imputing missing data and linking messy datasets.

Establish design constraints and standards

Diverse stakeholders including utilities, software developers, AI researchers, and privacy advocates will need to converge on a set of design constraints to ensure that grid models meet stringent requirements. AI-powered grid models will need to meet challenging performance constraints in terms of speed, computational cost, and optimality. They will need to achieve a high level of reproducibility and explainability to be trusted by grid operators and utilities. They will need algorithms to guarantee that solutions fall within safe operating conditions. Finally, model development and use must meet high privacy standards. Moreover, developing a scalable solution will require substantial coordination between government, industry players, utilities, Independent System Operators (ISOs), and academia/national labs. We will need open standards for data, algorithms, and testing. This could be accomplished by a coordinating body empowered to establish standards and identify problems facing the whole industry that no individual actor can address on its own.

Build prototypes

The software architecture would include layers for:

1) Data sources and models;
2) Modules to integrate data sources for specific tasks like power flow optimization, demand forecasting, and weather forecasting; and
3) Applications that combine modules to carry out real-time grid management and capacity planning.

The data layer must be able to flexibly integrate diverse data types, algorithms, and trained model weights and make them available for consumption by independent modules. Modules may be proprietary and some data private, but the software environment and associated standards should be open and transparent. The environment should be hardware-agnostic to ensure compatibility and scalability with local or distributed computing resources.

Demos and verification

Widespread adoption will require AI models that can meet the stringent safety, performance, and security requirements of grid applications. AI models have the potential to outperform existing models on all fronts, but they cannot be deployed until their performance is rigorously quantified and characterized for specific use-cases. This requires an infrastructure for testing and independent evaluation, potentially by a body that can issue trusted certifications. The testing process should include training on real data and deploying in realistic scenarios, with quantitative performance metrics. If done correctly, such a process has the co-benefit of training future users. The testing infrastructure must be designed with privacy and security in mind, which could be achieved with federated learning or synthetic data. Another option is to develop simulators that correctly represents the statistical patterns of real data without revealing sensitive information.

Rollout and replicate
Achieving widespread adoption will require utilities and software vendors to arrive at mutually acceptable business models that can fund rapid private scaling while meeting the utilities' responsibility to keep rates low for customers.

Major hurdles and societal risks

Key hurdles include data access, validation of AI models, and adopting new approaches in a historically conservative industry. Because safety and reliability are so important in the power sector, it is challenging to rapidly deploy new technologies. We will have to earn the trust of utilities and grid operators to implement new solutions for critical tasks and potentially contribute to/draw from shared assets like synthetic datasets or model weights. Moreover, utilities have a responsibility to maintain affordability for their ratepayers, so any solutions have to demonstrate clear value relative to their cost.

The societal risks include safety, security, and privacy. Effective real-time grid modeling will likely require granular information about household energy usage. As such, it will be essential to establish safeguards which allow people to maintain control over their personal information. Technological solutions such as federated learning can help mitigate this risk, but technology cannot substitute for an emphasis on ethical practices and informed consent.

A transformative national capability

We rely upon electricity to meet our daily needs, whether these are receiving a life-saving medical procedure or simply having a video call with loved ones. Harnessing AI to build the grid of the future would help us preserve reliability in the face of extreme weather and an ever-more-complicated power sector, allowing planners to optimize resiliency using climate and demand forecasts, while enabling grid operators to respond to events in real-time (or even ahead of time) with more rapid responses to contingencies. Enhanced grid modeling capability would also allow us to upgrade generation and transmission as efficiently as possible, help us achieve our goals at a cost that keeps electricity affordable and accessible to all Americans. Finally, an advanced grid will help us accelerate decarbonization and mitigate the consequences of climate change. If we achieve this AI Aspiration, we can provide clean electricity for all, allowing every American to achieve their personal aspirations while protecting the planet.

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