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AI for Energy Innovation:

Insights, Examples, and Projections from an Energy Research Lab

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Energy Operations Under Uncertainty: Role of AI

Modern-day energy systems operate under a set of **rapidly evolving uncertainties**, experiencing dramatic shifts due to a multitude of factors.

AI-powered load forecasts

- *Extreme weather*
- *Electrification, Onshoring*
- *AI, Data centers, Large loads*
- *Changing consumer behavior*

Energy Demand

How much energy do we need?

AI-powered energy forecasts

- *Dynamic & extreme weather*
- *Dependencies & Complementarities*
- *Storage, Distribution, Transmission*

AI

AI-powered price forecasts

- *Demand growth*
- *Extreme weather*
- *Economics & Policy*

How much energy do we produce?

How much does energy cost us?

Energy Supply

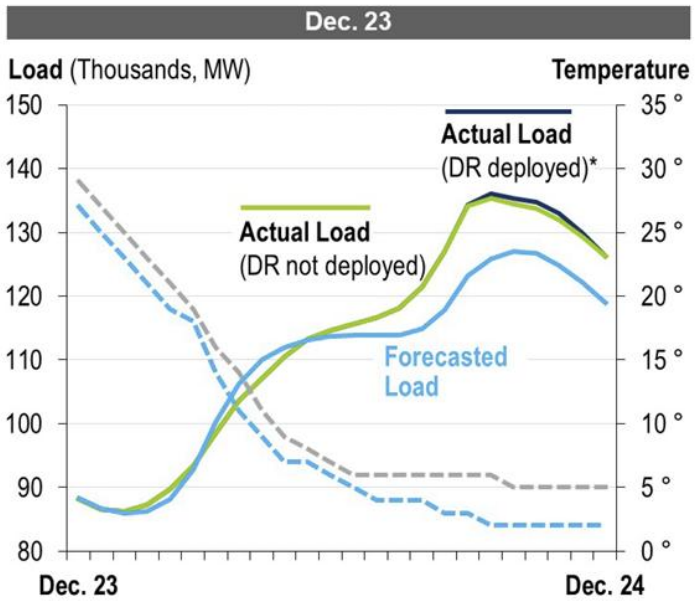
Energy Prices

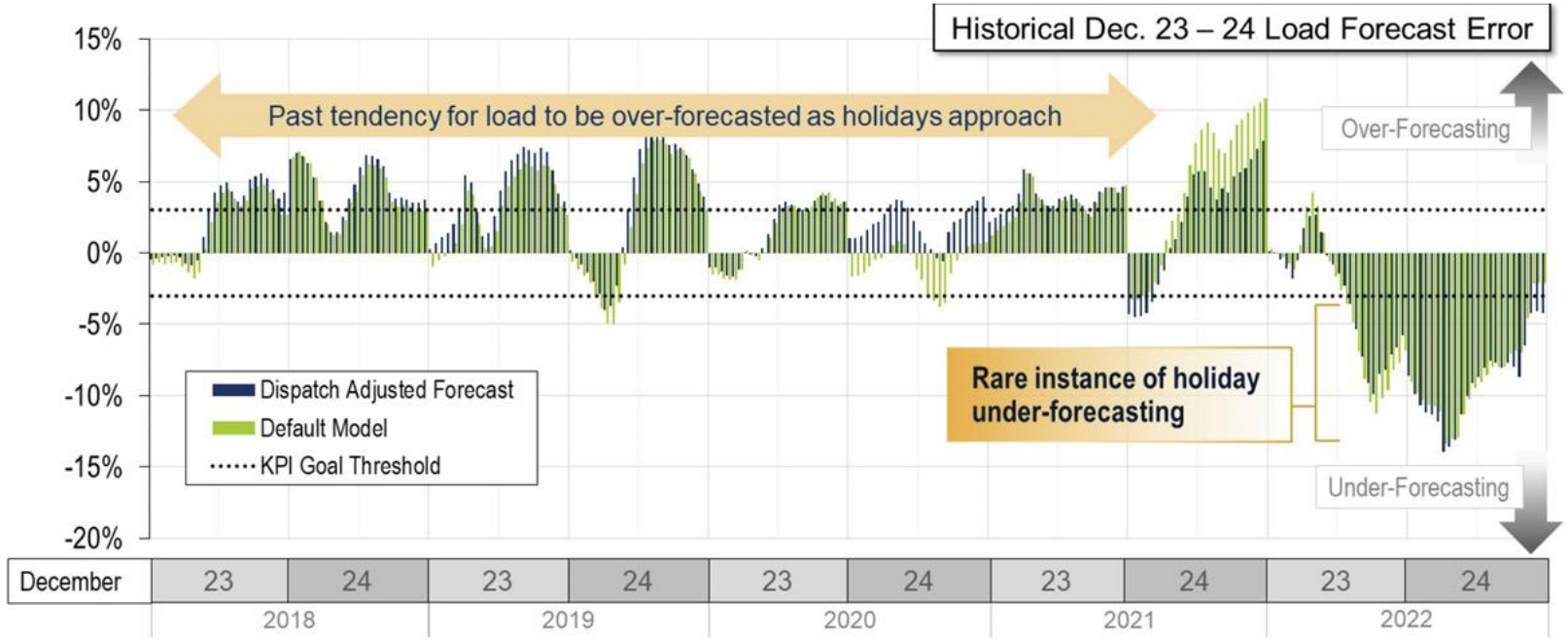
AI can play a critical role in minimizing these uncertainties through **capable forecasting tools** that can better adapt to **dynamic, non-linear, and rare events**.

A real-world example: Pushing the boundaries of forecasting

From PJM report on Storm Elliot (December 2022): *"The load forecast is determined by an algorithm that considers expected weather conditions, day of the week and holidays…. The extreme weather … included bitter cold temperatures that were outside of the data sample used to train the load forecast models…"*

Source: Winter Storm Elliott Event Analysis and Recommendation Report July 17, 2023, PJM.



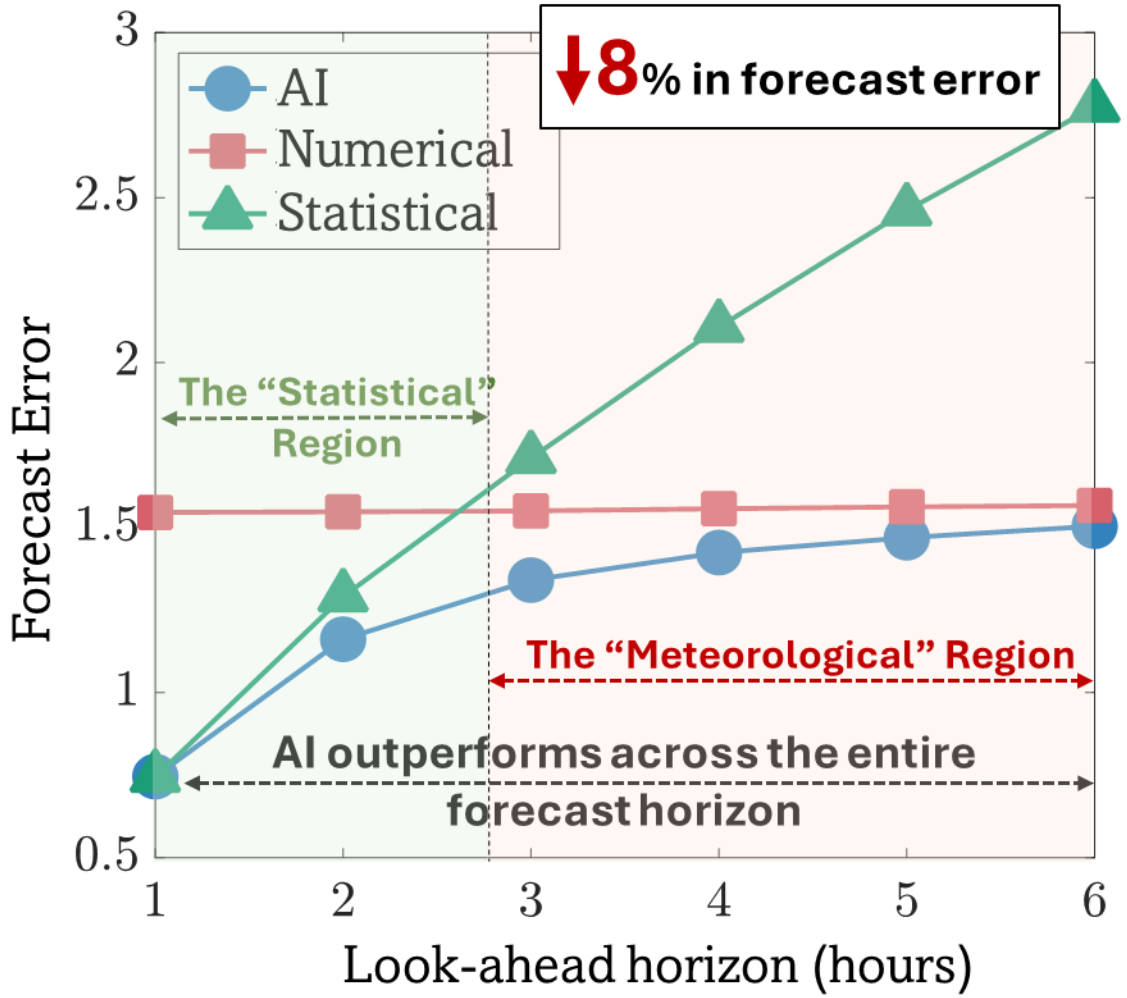


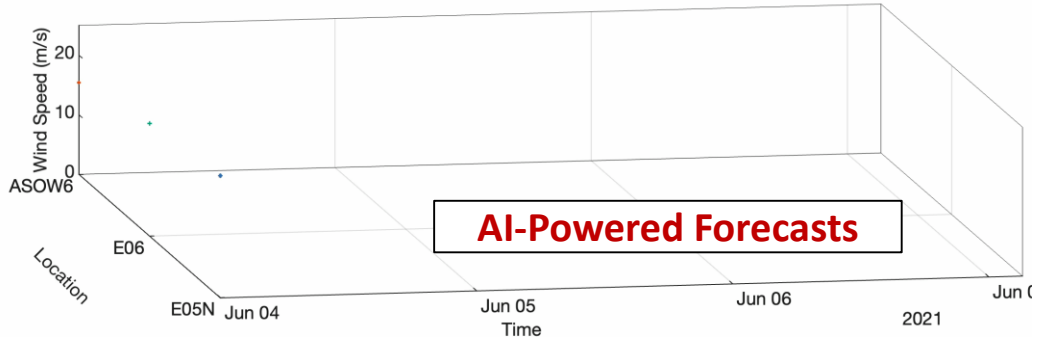
Why can AI be the answer? It's not only about data volume… AI can unlock:

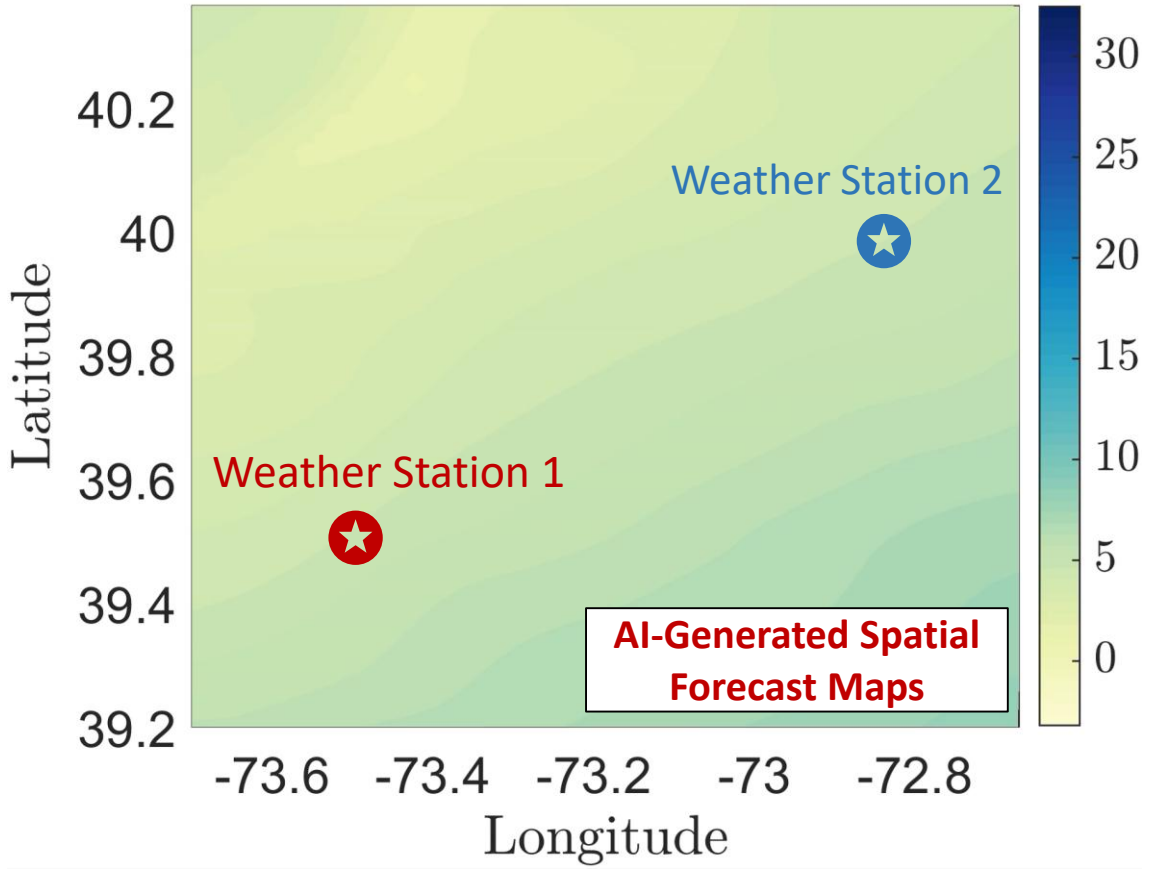
- Multiple **data modalities** (e.g., image, text, time series, event data)
- Multiple **data sources** (e.g., satellites, numerical products, smart meters, weather stations, social signals)
- **Generative capabilities** for improved generalization.
- Ability to rapidly adapt to **dynamic**, **complex**, and **rare events**, based on multi-modal and multi-source data.

Better forecasts = Better operations
(cost, reliability, environmental footprint)

Example 1: AI-Powered Short-term Weather Forecasting for Energy System Operation







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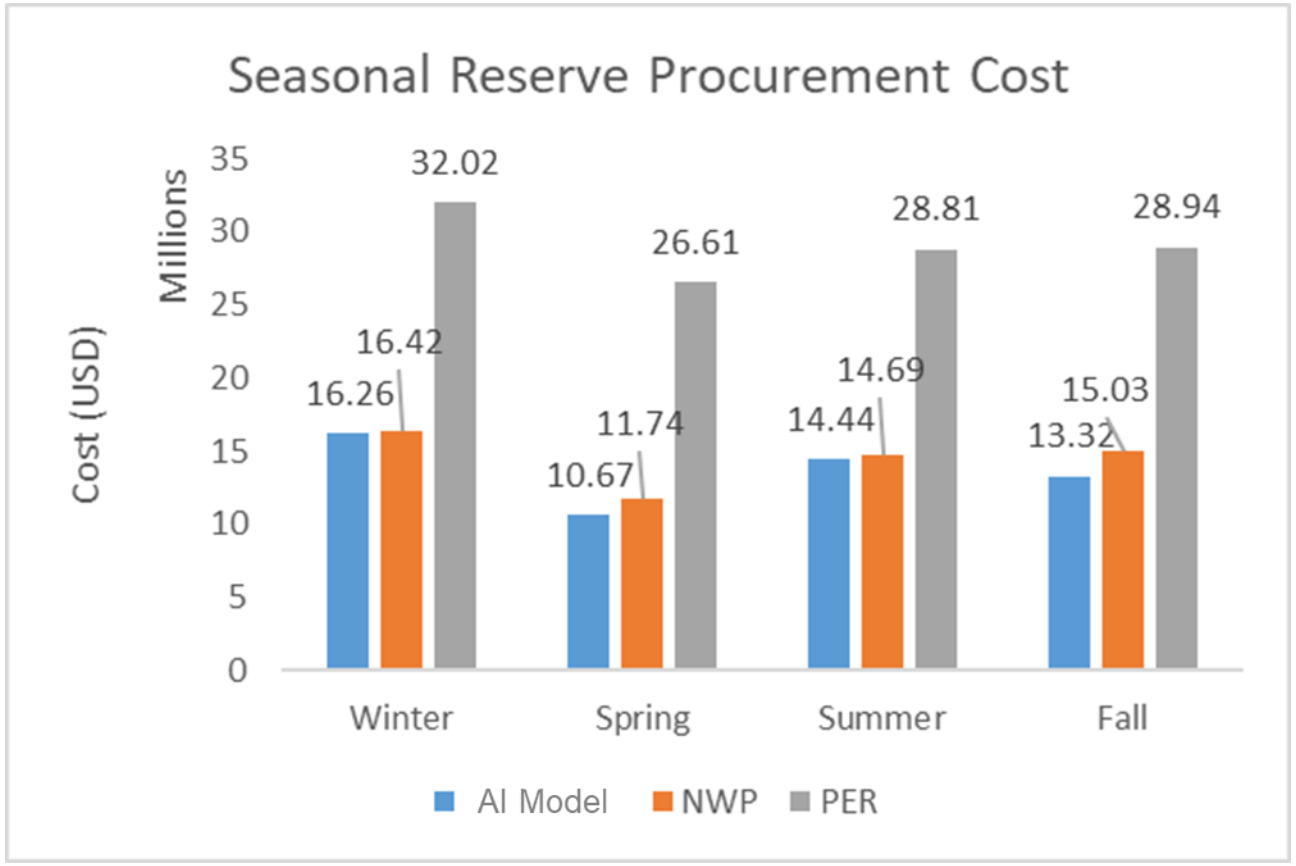
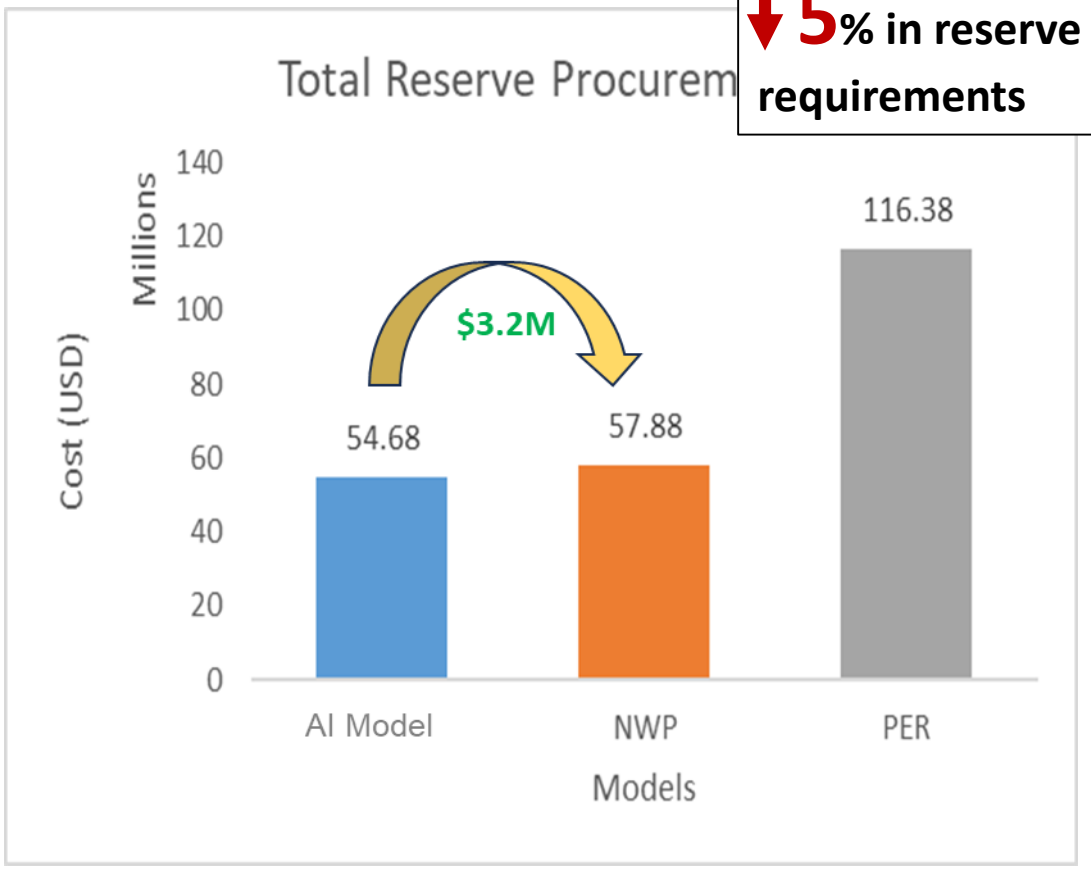
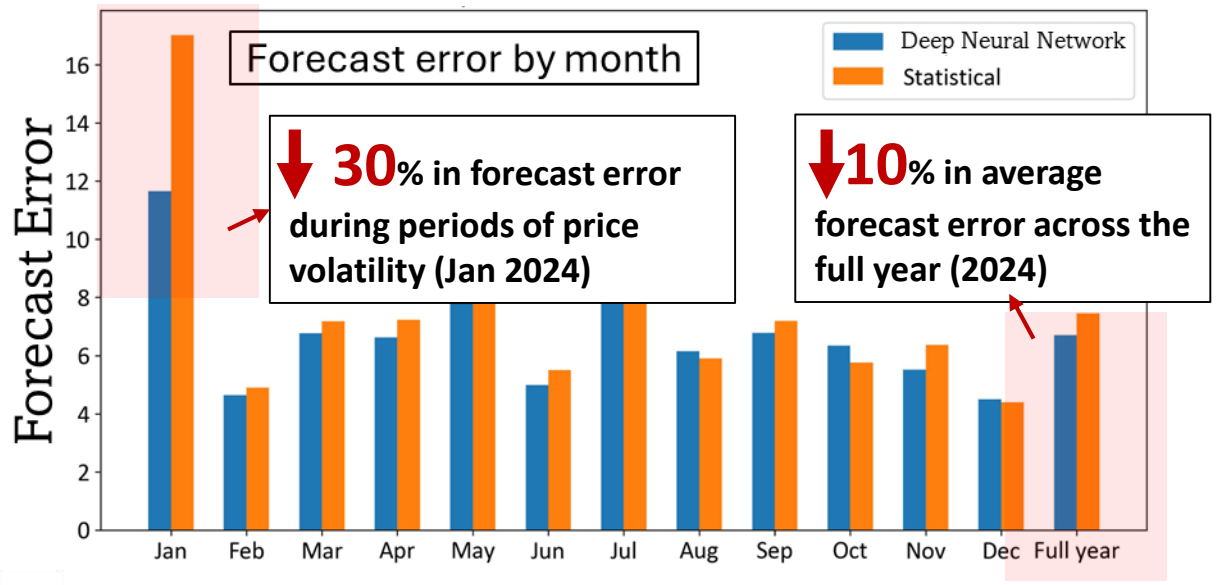
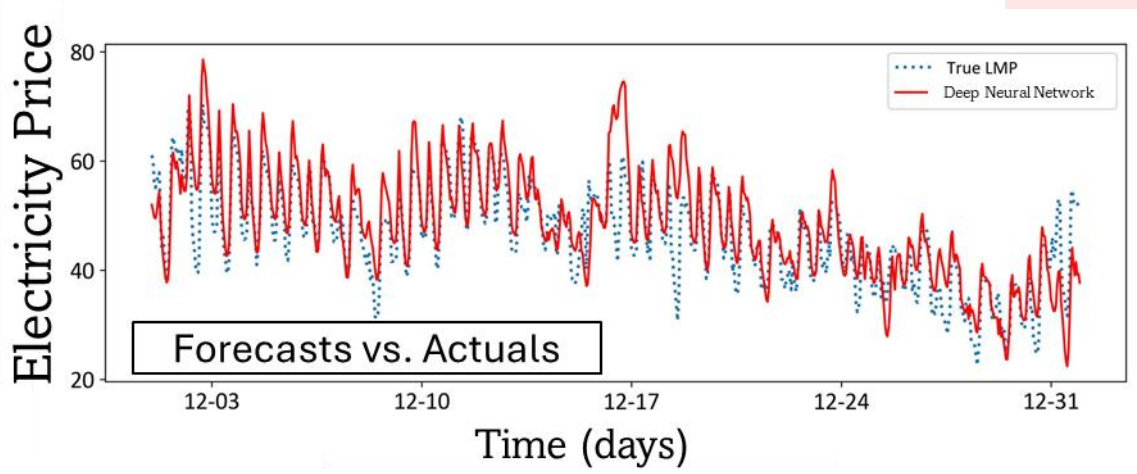


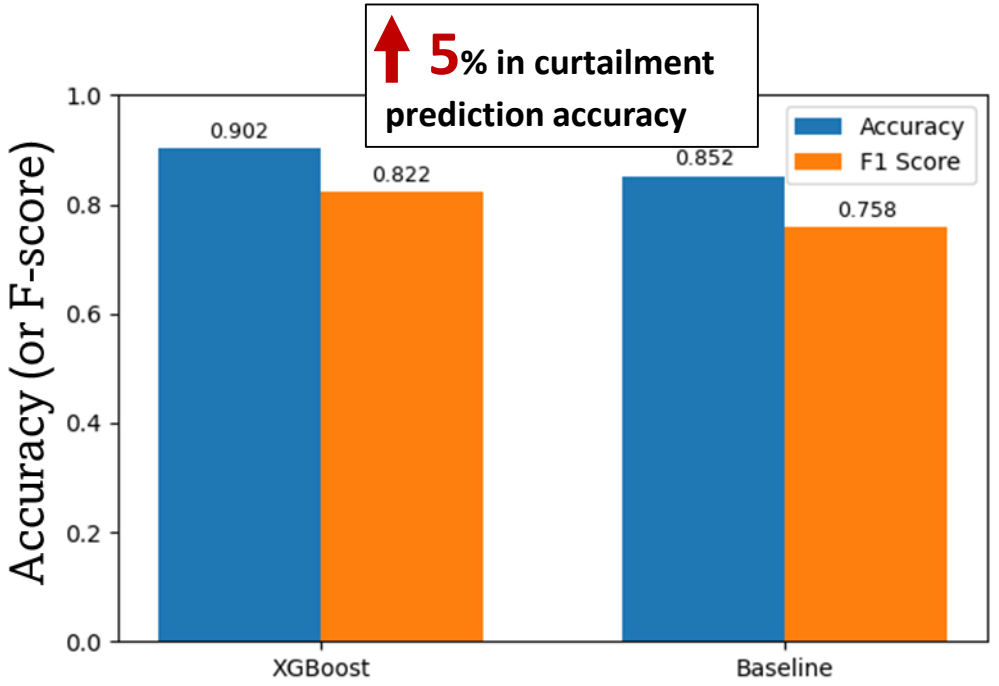


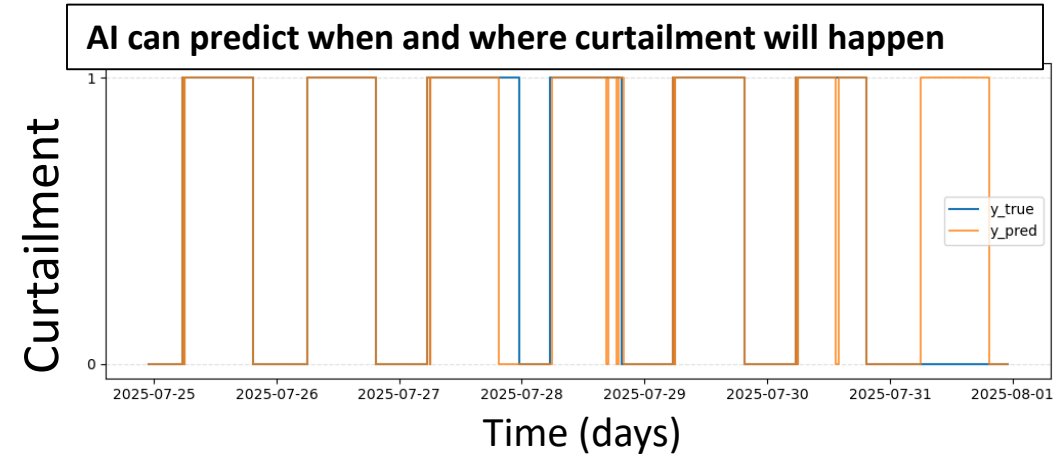
↓5% in reserve requirements

Example 2: AI-Powered Short-term Electricity Price and Curtailment Forecasting









Thoughts and Takeaways:

- **AI unlocks the Big Data Era:** By integrating diverse data modalities and sources, and by leveraging generative capabilities, AI allows us to extract more from information, learning what traditional models cannot.
- **AI reduces uncertainty in energy operations:** Better forecasting of demand, supply, and prices can make energy systems more efficient, more reliable, and more sustainable.
- **Many examples to highlight:** AI for predictive maintenance, for load forecasting, and for co-existence of energy systems with environmental habitats.
- **The benefits of AI can potentially outweigh its costs, but efficiency matters:** If developed responsibly, AI can be a net generator of value, delivering system efficiency, reliability, and environmental gain, but we must invest in Frugal AI — models that achieve high performance without excessive computational or energy costs.
- **Collaboration is key:** Crowdsourcing AI (data, models, computational resources) to scientists, researchers, and students, can accelerate innovation and broaden impact of AI.
- **Prepare the next generation:** Training AI-literate engineers and scientists is essential to fully harness the opportunities and promise of AI.