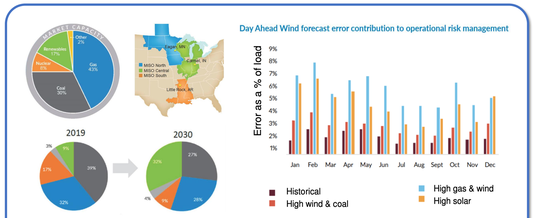
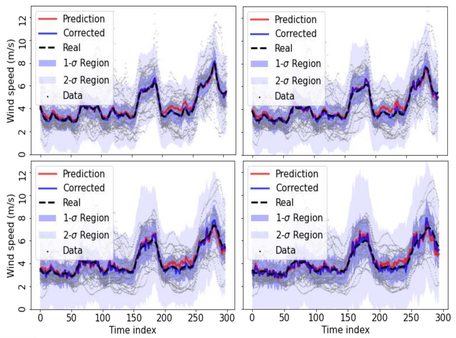
Risk-Aware Market Clearing

Georgia Tech · VANDERBILT UNIVERSITY · RAMC Risk-Aware Market Clearing Project · MISO



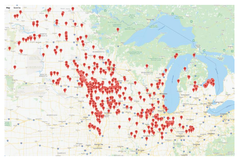
The **increased penetration of renewables and DERs** in MISO will lead to higher operational uncertainty, forecasting errors, and operational risk. (*MISO Futures report* and *Aligning Resource Availability and Need*)



Uncertainty quantification of wind prediction. The overall model consolidates individual regression models for each resolution through the Kriging model and is trained using a variational method for scalability.

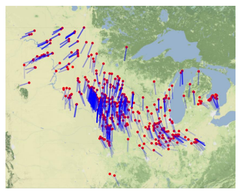
Top-left: 1-hour lead time
Top-right: 2-hour lead time
Bottom-left: 3-hour lead time
Bottom-right: 4-hour lead time

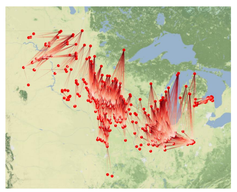
Source: https://arxiv.org/abs/2108.13285



*RAMC develops new **forecasting** and **uncertainty quantification** tools that can capture **spatio-temporal dynamics** to predict future load and renewable production.*

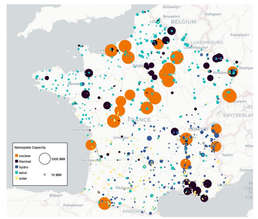
Probabilistic Forecasting





← Wind speed and direction forecast using a Multi-Resolution Spatio-Temporal Kriging model. A dynamic graph leverages the wind direction to capture spatial and temporal correlations. (https://arxiv.org/abs/2108.13285)

Top-left: location of wind turbines in the MISO footprint.
Bottom-left: wind speed and direction at location.
Bottom-right: dynamic graph representation.

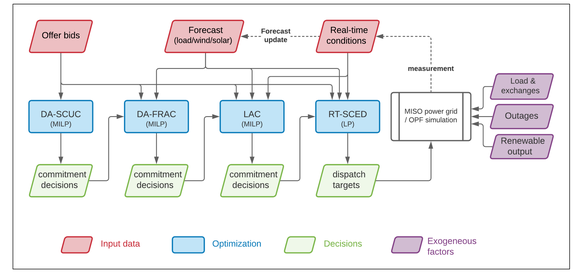


Approximate locations of RTE generators (France) in 2018. Reconstructed data.
Source: rte-france.com/eco2mix

*RAMC has implemented a **digital twin** of MISO's optimization pipeline, and executed it on **two industrial systems**: MISO and RTE.*

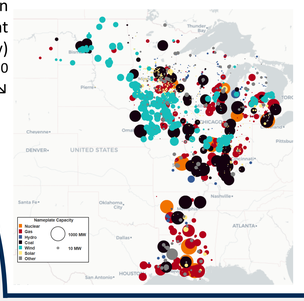
*RAMC has also implemented tools for **stochastic reliability assessment** and **multi-period markets.***

Risk-Aware Optimization



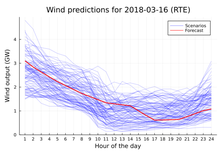
The MISO optimization pipeline, from day-ahead to real-time operations

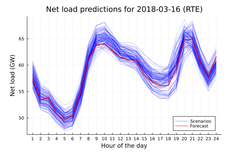
Generation units in MISO footprint (US units only) EIA860 – 2020 ↘



RAMC and MISO are leading the transition **from deterministic to risk-aware** frameworks, where uncertainty is quantified explicitly and incorporated into the market-clearing optimizations.

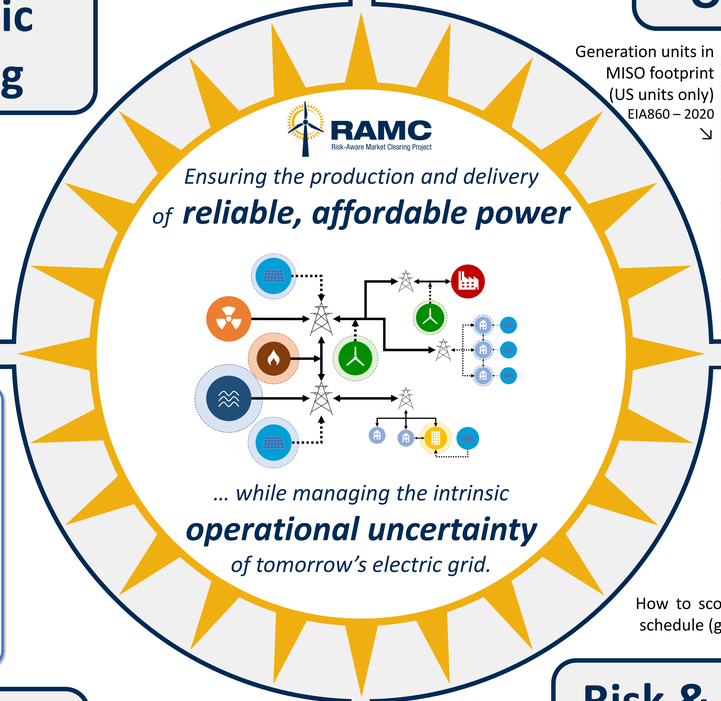
This **change of paradigm** simplifies the structure of energy markets and enables the **endogenous pricing of risk** in day-to-day operations.





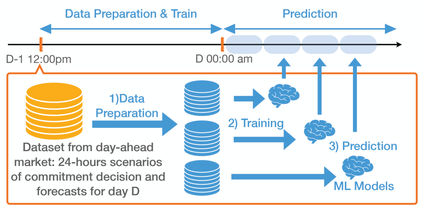
← Net Load scenarios ↑ Wind scenarios

Stochastic algorithms take as input multiple scenarios rather than a single, deterministic point-forecast. The resulting solutions hedge better against uncertainty.



The seasonality of net load, combined with the **combinatorial explosion** of topology changes and commitment decisions, results in **distribution shifts**, which degrades the performance of learning models.

The RAMC **just-in-time learning pipeline** leverages most-recent market decisions, predictive models for future load and renewable output, and **fast, distributed training procedures**.



Source: https://arxiv.org/abs/2112.13469

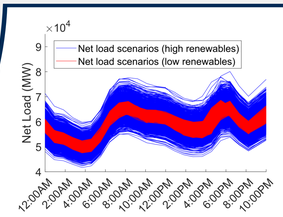
Mean Absolute Error (MAE) of dispatch predictions for RTE units, for each hour of Feb. 12 (top-left), Apr. 5 (top-right), Aug. 26 (bottom-left) and Oct. 23 (bottom-right) 2018.
Source: https://arxiv.org/pdf/2112.13469.pdf

Next-Generation Machine Learning

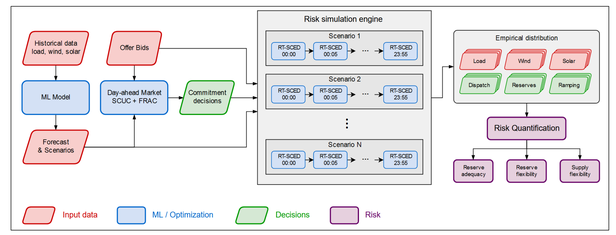
*RAMC has developed **next-generation learning tools** that combine ML and optimization techniques to address computational challenges.*

*RAMC has introduced **physic-informed architectures** that exploit domain knowledge, a novel **just-in-time learning** framework, and **fast predict-then-repair procedures** to compute close-to-optimal solutions in real time.*

SCAN ME



How to score the risk underlying a generator schedule (grid operator's decision)?

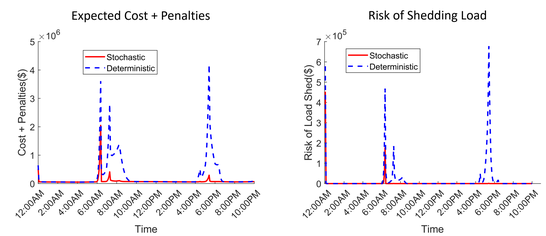


The RAMC risk quantification engine for day-ahead operations

Risk & Reliability Assessment

*RAMC has proposed **risk and reliability metrics** for bulk power systems, which enable grid operators to evaluate **risk-versus-cost tradeoffs** for **proactive risk management**.*

*The **risk quantification engine** allows to score the risk and reliability associated with a given unit-commitment portfolio or operational decision. It can be executed in **day-ahead and real-time operations**.*



Cost vs risk tradeoff of different unit-commitment portfolios.

The risk engine allows to compare the solutions of deterministic and stochastic unit-commitment algorithms. The **stochastic** approach **marginally increases the cost** but **significantly reduces the risk** when compared to the currently-practiced deterministic approach.