New England's Evolving Electricity Landscape:

Highlights from the ISO-NE System Operational Analysis & Renewable Energy integration Study (SOARES)

Team:

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THAYER SCHOOL OF ENGINEERING AT DARTMOUTH | LIINES LABORATORY FOR INTELLIGENT INTEGRATED NETWORKS OF ENGINEERING SYSTEMS EMPOWERING YOUR NETWORK

Presentation Outline

Goal: To highlight results from the ISO New England System Operation Analysis & Renewable Energy Integration Study (SOARES)

- Introduction
- Background: Our electric power system & variable renewable energy (VRE) integration
- The ISO New England (ISO-NE) electric power system
- Study results
- Conclusions and final insights

Motivation

- ❖ Every 7-10 years ISOs conduct a renewable energy integration study
  - ➢ Changes in generation portfolio
  - ➢ Changes in topology of transmission system
  - ➢ Methodologies are continually improving to keep pace with novelty in the literature
- ❖ Role of Independent System Operators
  - ➢ **Grid Operation:** Coordinate and direct the flow of electricity over the region’s high voltage transmission system.
  - ➢ **Market Administration:** Design, run, and oversee the markets where wholesale electricity is bought and sold.
  - ➢ **Power system planning:** Study, analyze, and plan to make sure electricity needs will be met over the next 10 years.

Renewable energy integration studies are at the intersection of energy technology, economics and policy.

New England's Electric Power System Stakeholders

- Utilities
- Transmission Owners
- Distribution Owners
- Regulators
- GenCos
- ESCOs
- Environmental Groups

ISO-NE Stakeholders define much of the study's scope, scenarios, and assumptions.

The Emergence of Variable Renewable Energy (VRE)

Past:

Generation/Supply	Load/Demand
Thermal Units: Few, Well-Controlled, Dispatchable, In Steady-State	Conventional Loads: Slow Moving, Highly Predictable, Always Served

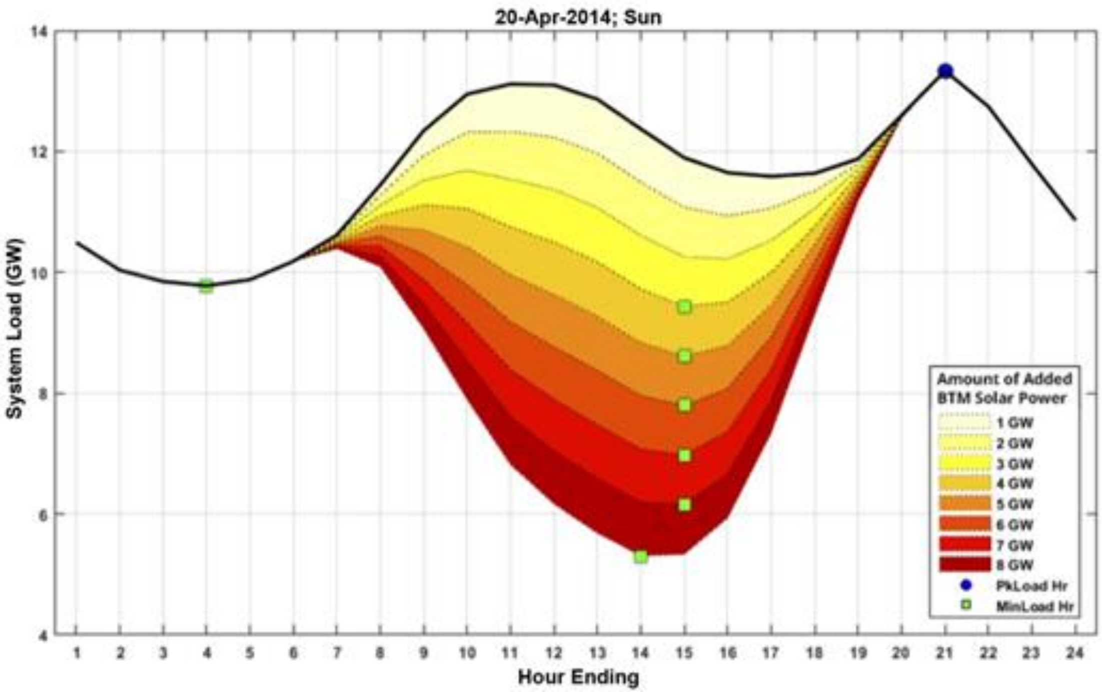
Future:

	Generation/Supply	Load/Demand
Well-Controlled & Dispatchable	Thermal Units: (Potential erosion of capacity factor) ↓	Demand Side Management: (Requires new control & market design) ↑
Stochastic/ Forecasted	Solar & Wind Generation: (Can cause unmanaged grid imbalances) ↑	Conventional Loads: (Growing & Needs Curtailment) ↓

Solar & wind generation erode the dispatchability of generation,

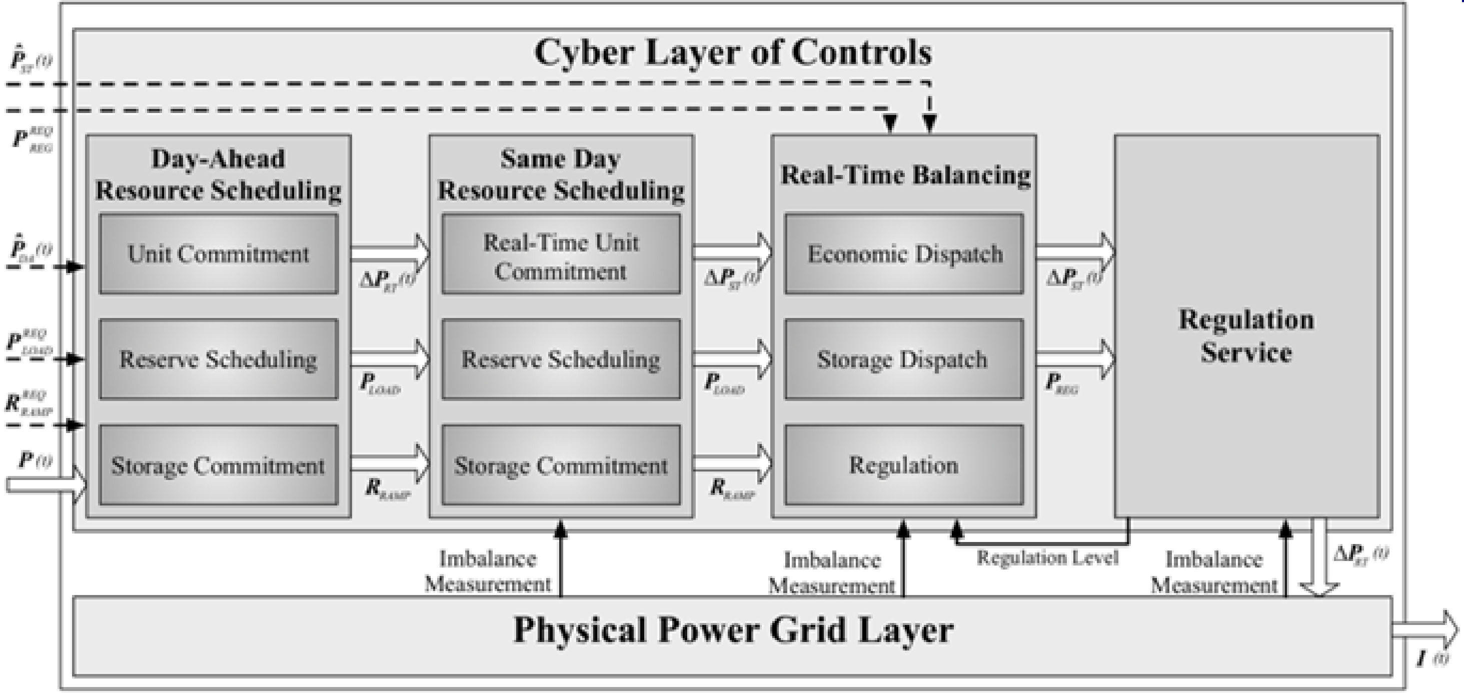
… the demand-side can potentially offer new control levers.

The New England Duck Curve



The integration of solar generation complicates the ability of dispatchable generation to track net load.

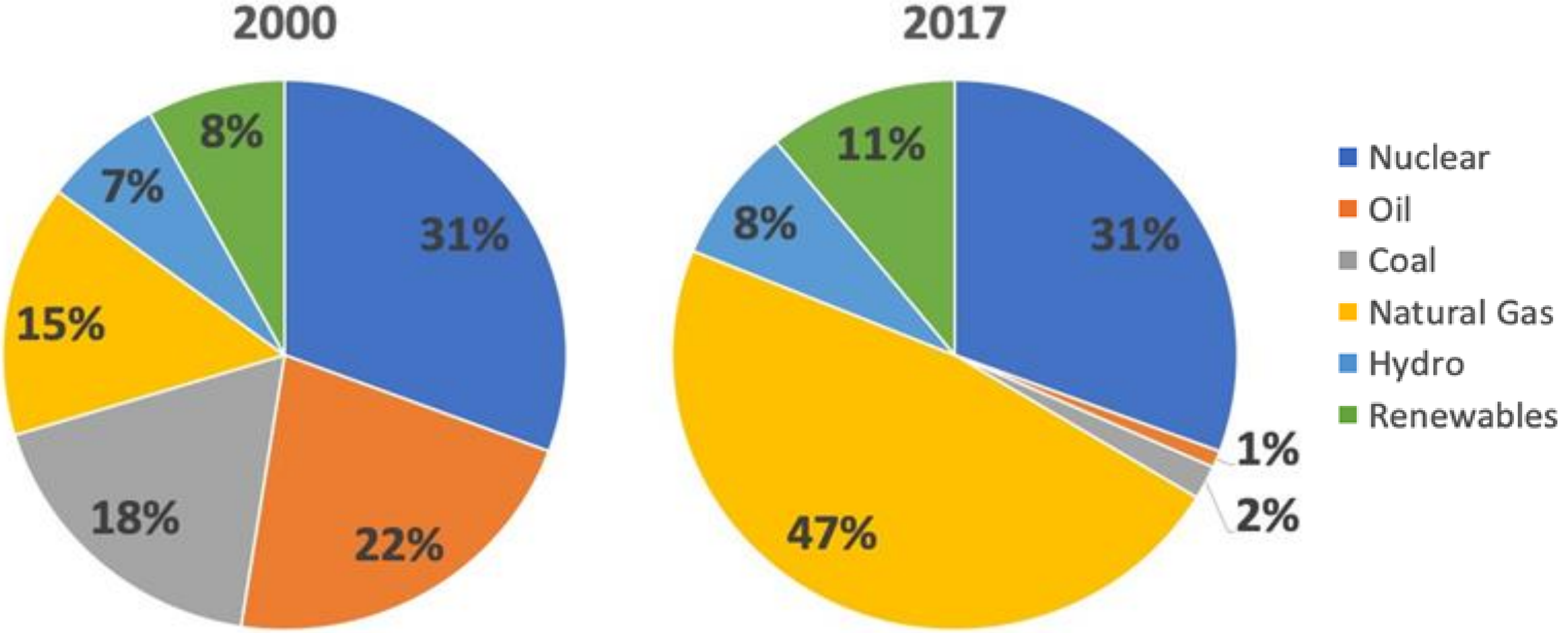
The Enterprise Control Simulation Methodology



The enterprise control methodology mimics ISO-NE market operation and physical power flows.

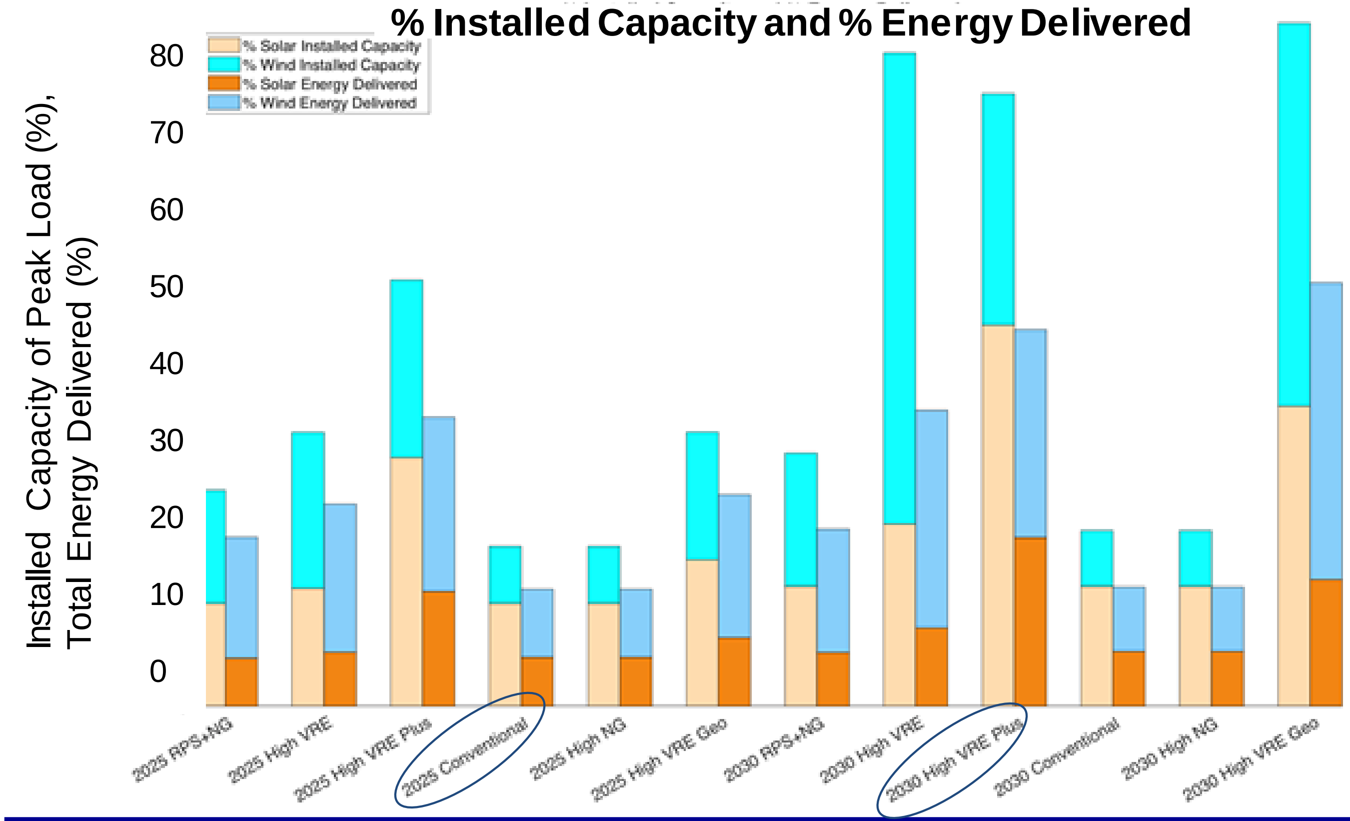
New England's Evolving Electricity Mix

Percent of **Total Energy** Contribution by Fuel Type



The electric energy mix is evolving toward natural gas and renewables.

The ISO New England Renewable Energy Study Scenarios

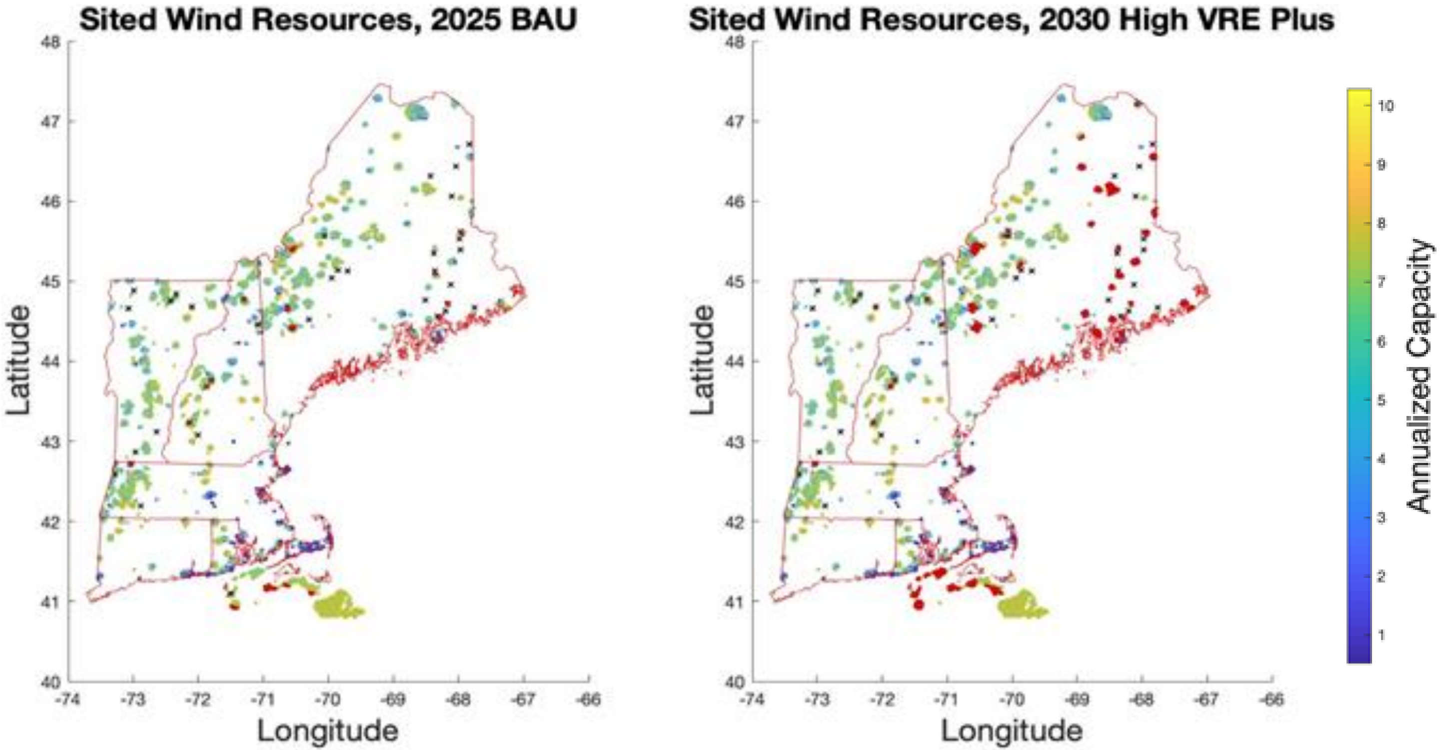


The stakeholders agreed on 12 study scenarios.

The ISO New England Renewable Energy Study Scenarios

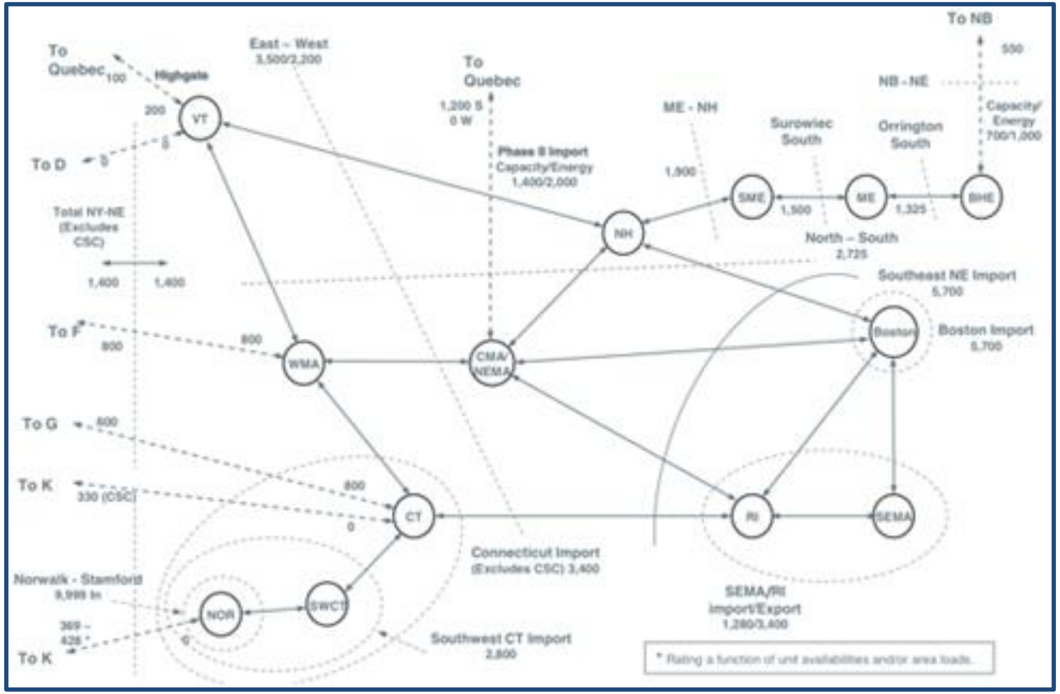
Disclaimer from our Sponsor: These scenarios are neither predictions of the future nor do they indicate ISO-NE's future plans. Rather, they represent 12 consensus scenarios that ISO-NE stakeholders have collectively agreed warrant deep investigation.

Wind Integration



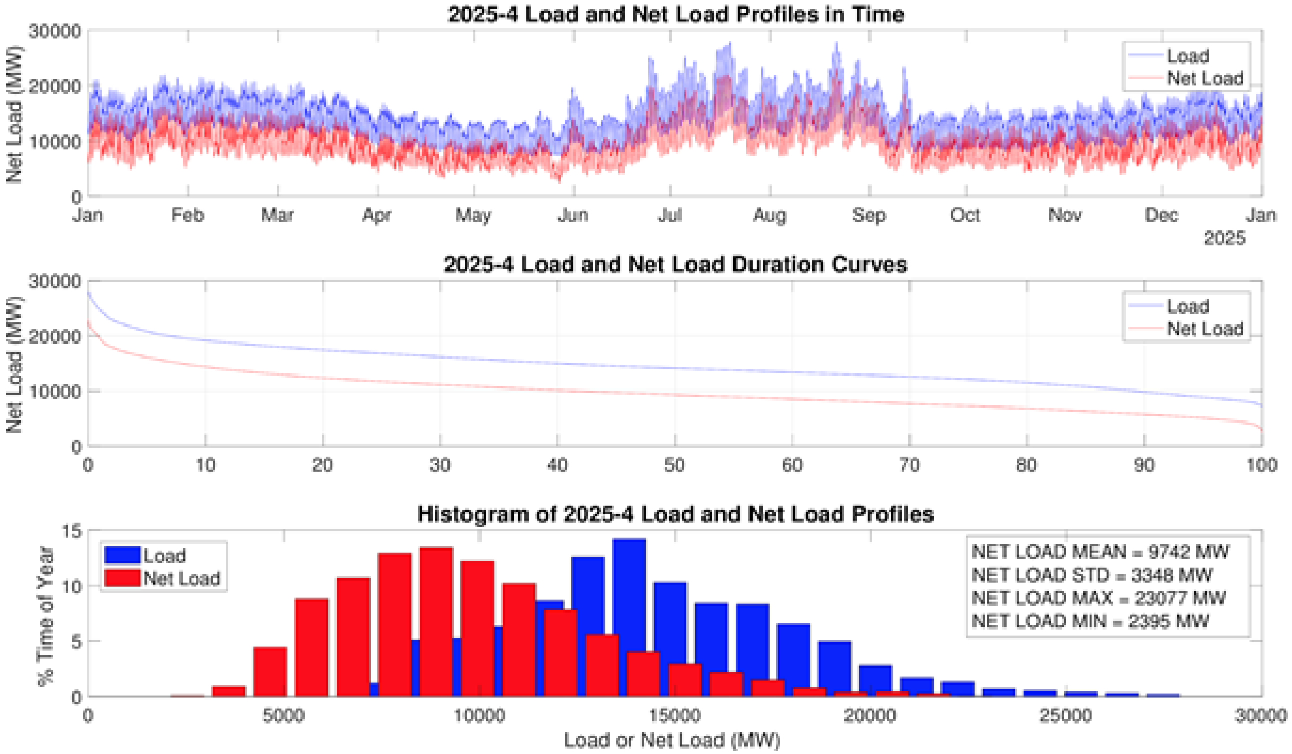
Renewable resources were sited according to highest geographic potential.

The ISO New England Pipe and Bubble Model



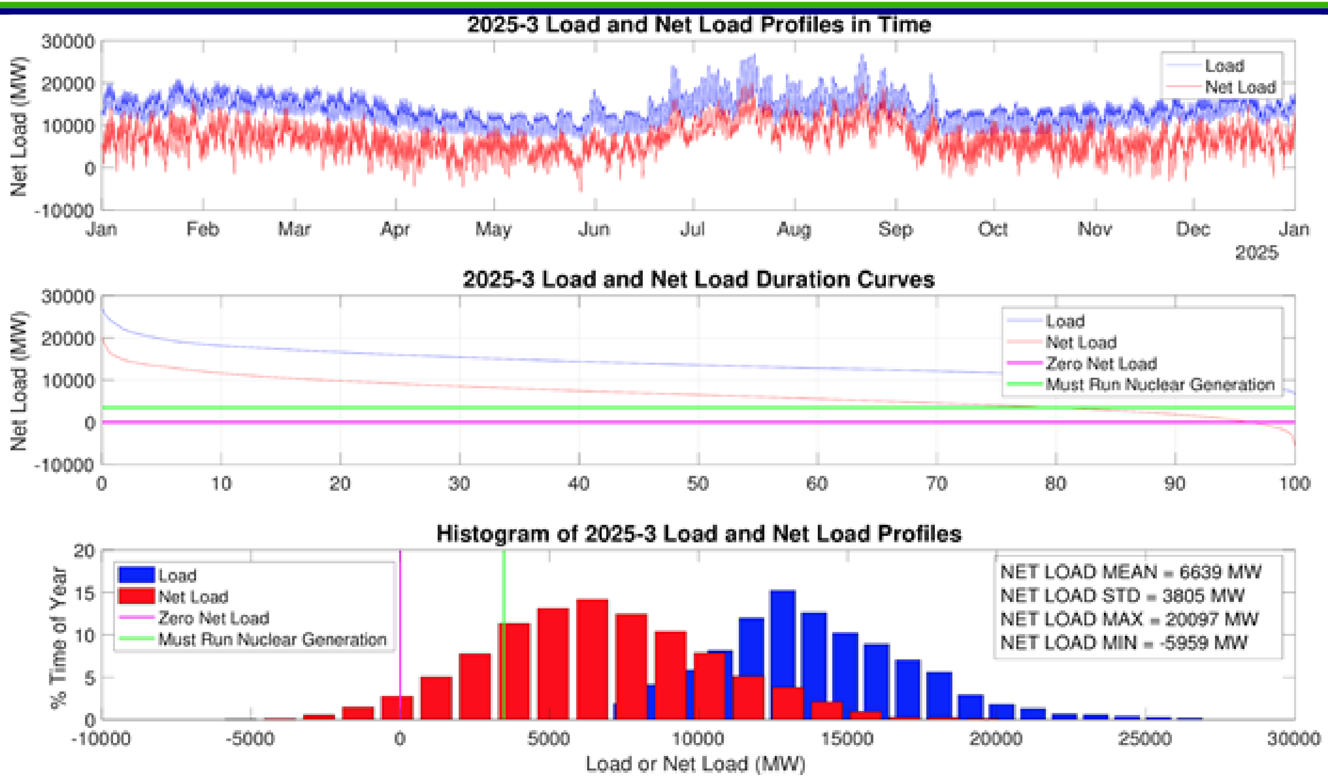
The stakeholders agreed on a pipe and bubble model for the study.

Load and Net Load Profiles: 2025 Business as Usual Case



The addition of renewables shifts the net load profile down.

Load and Net Load Profiles: 2030 High Variable Renewables Case



Large quantities of renewables cause negative loads and excess generation.

Background | ISO-NE | Results | Conclusion

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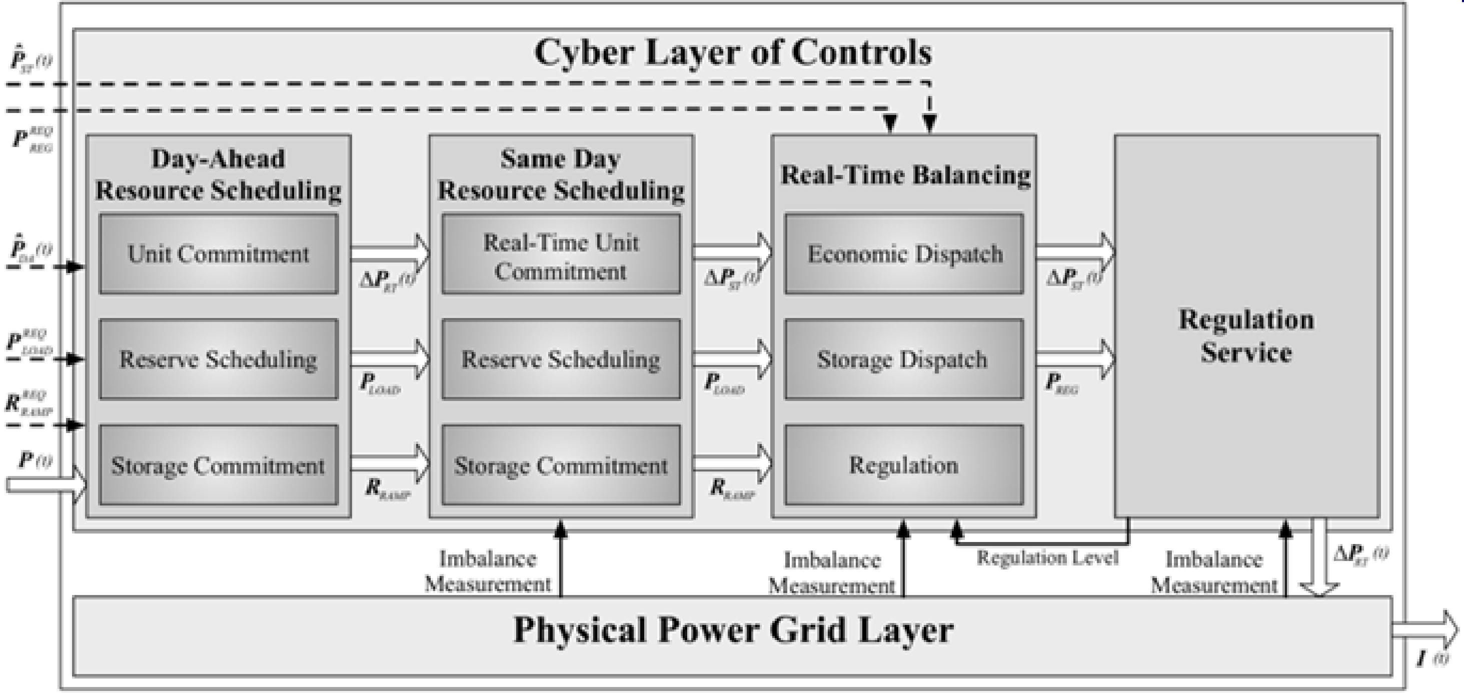
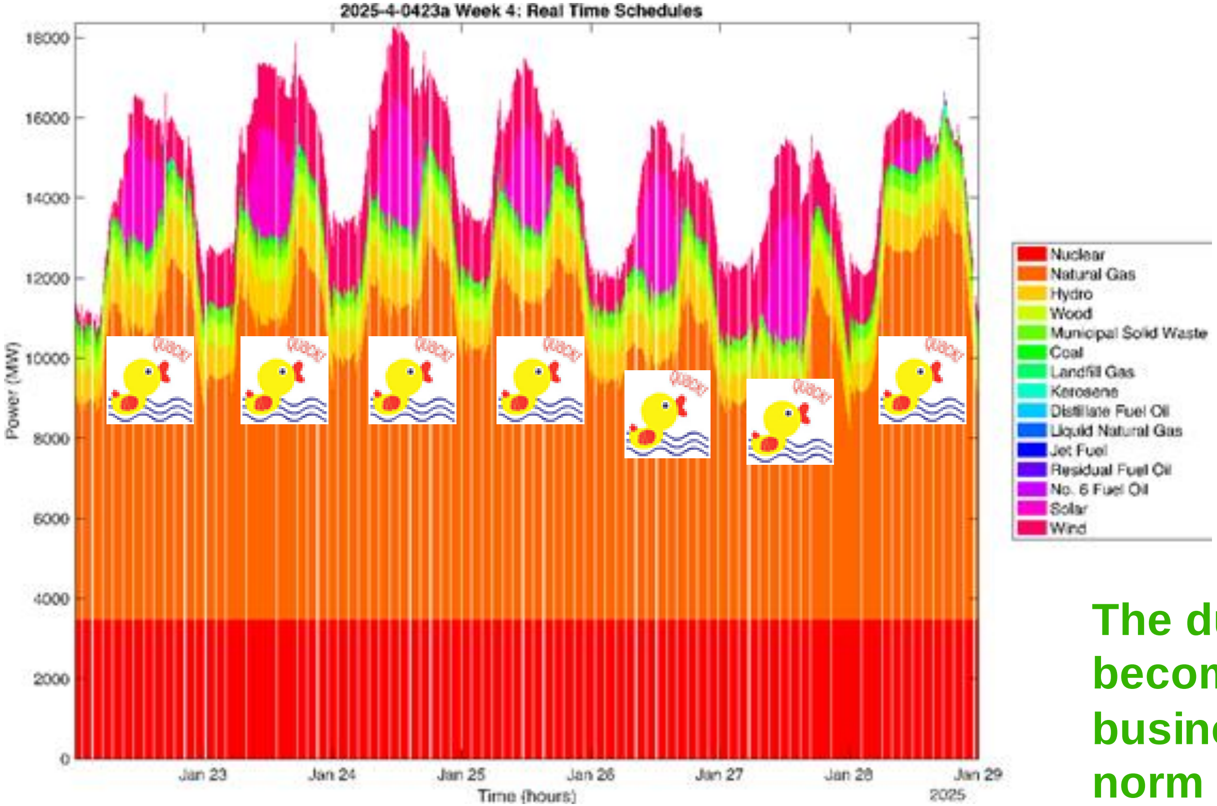
The Enterprise Control Simulation Methodology



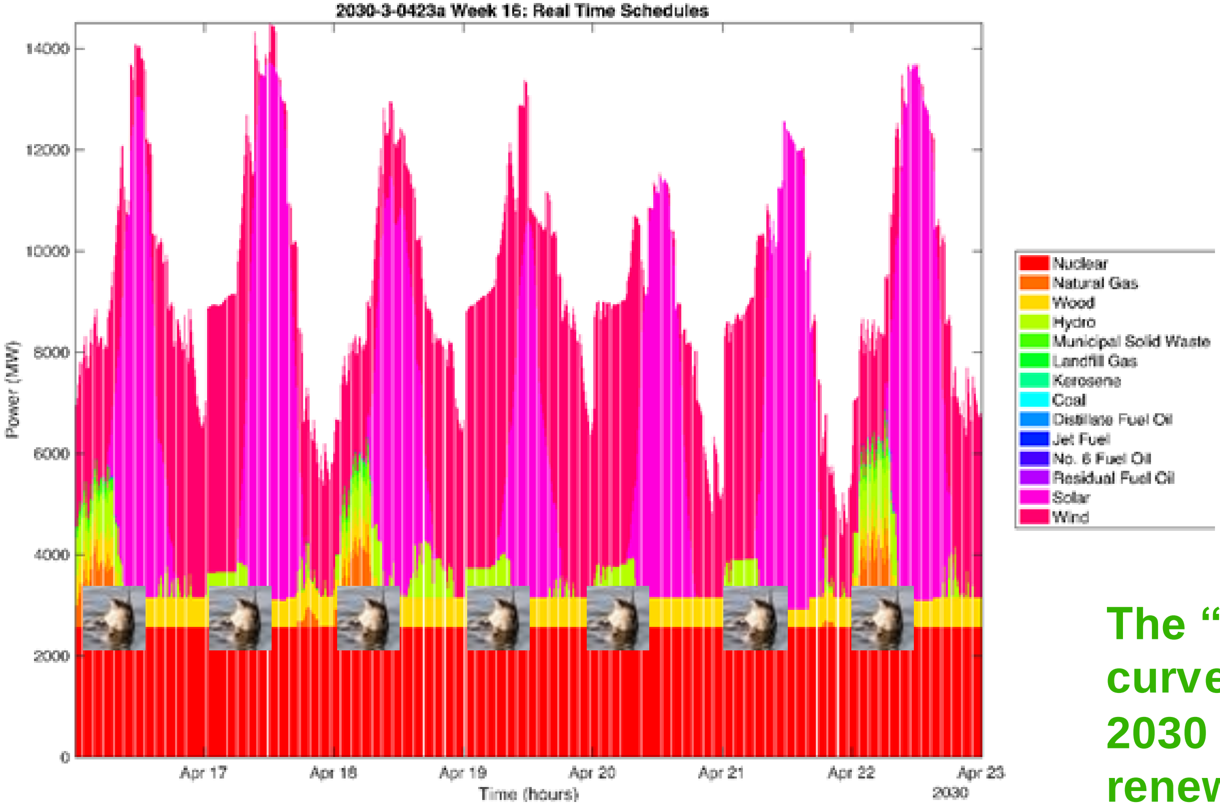
The enterprise control methodology mimics ISO-NE market operation and physical power flows.

Real-Time Energy Market Dispatch: 2025 Business as Usual Case



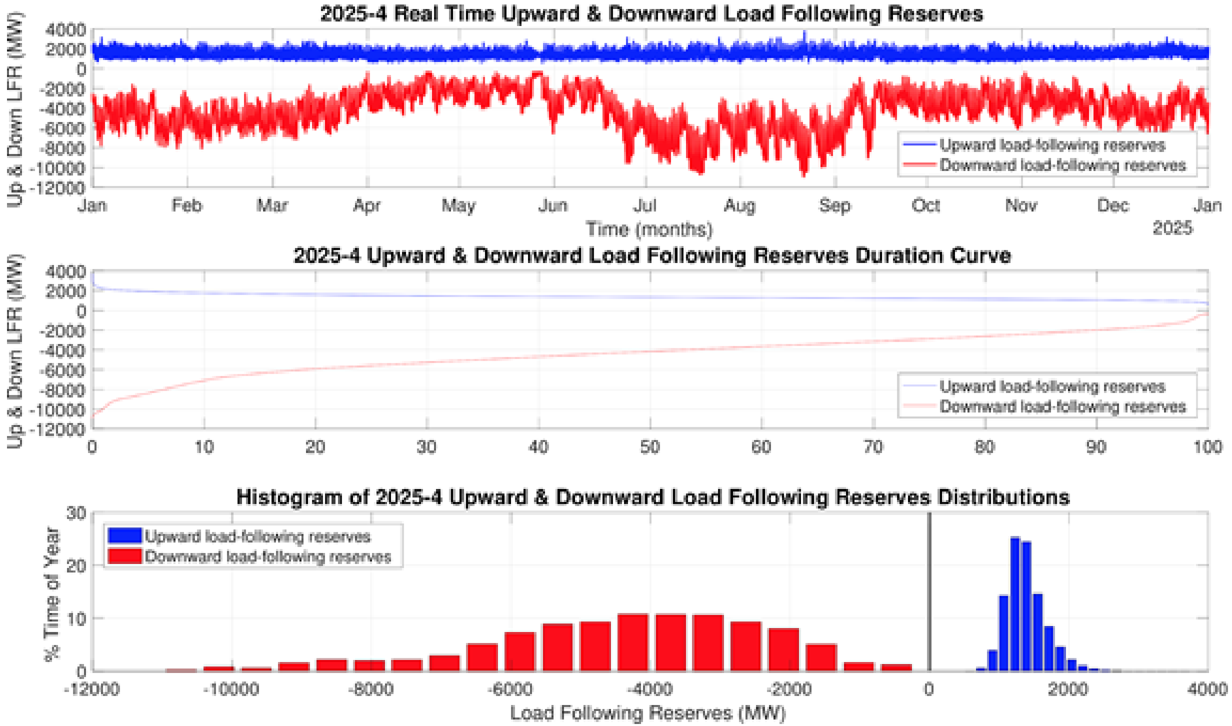
The duck curve becomes the new business-as-usual norm in 2025.

Real-Time Energy Market Dispatch: 2030 High Variable Renewables Case



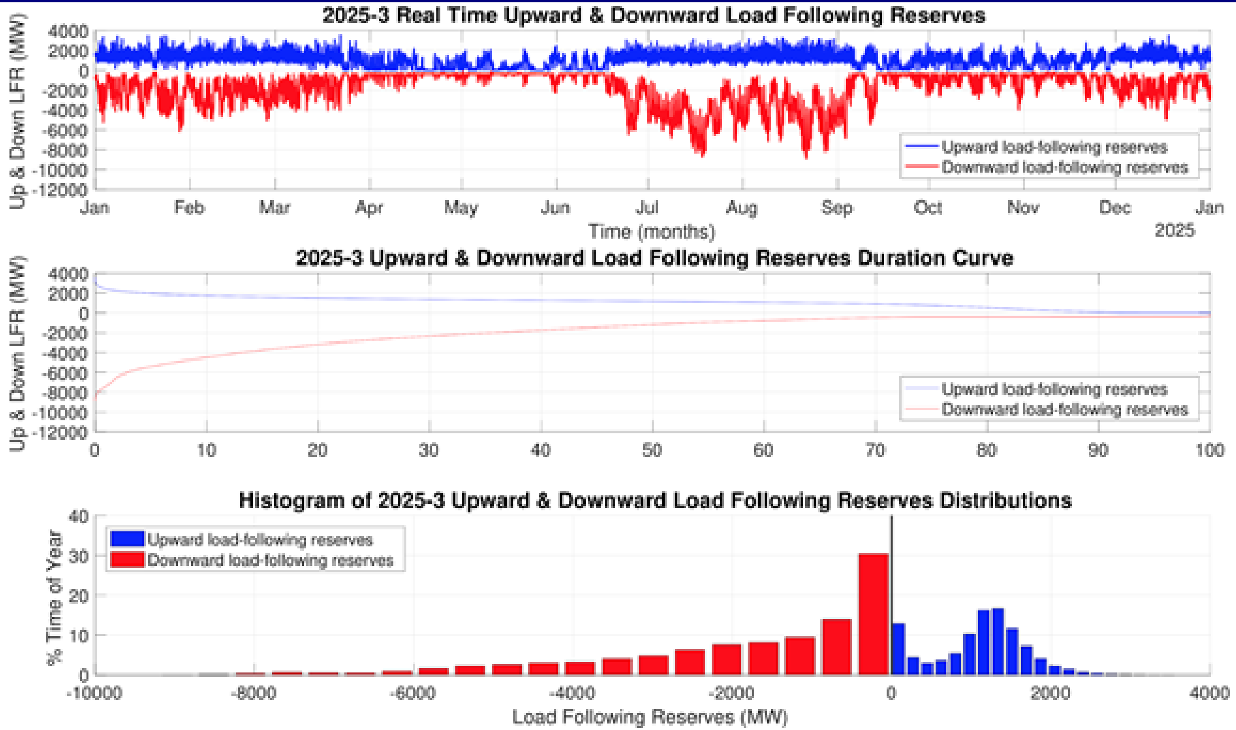
The "duck-dive" curve appears in the 2030 high variable renewables case.

Load Following Reserves: 2025 Business as Usual Case



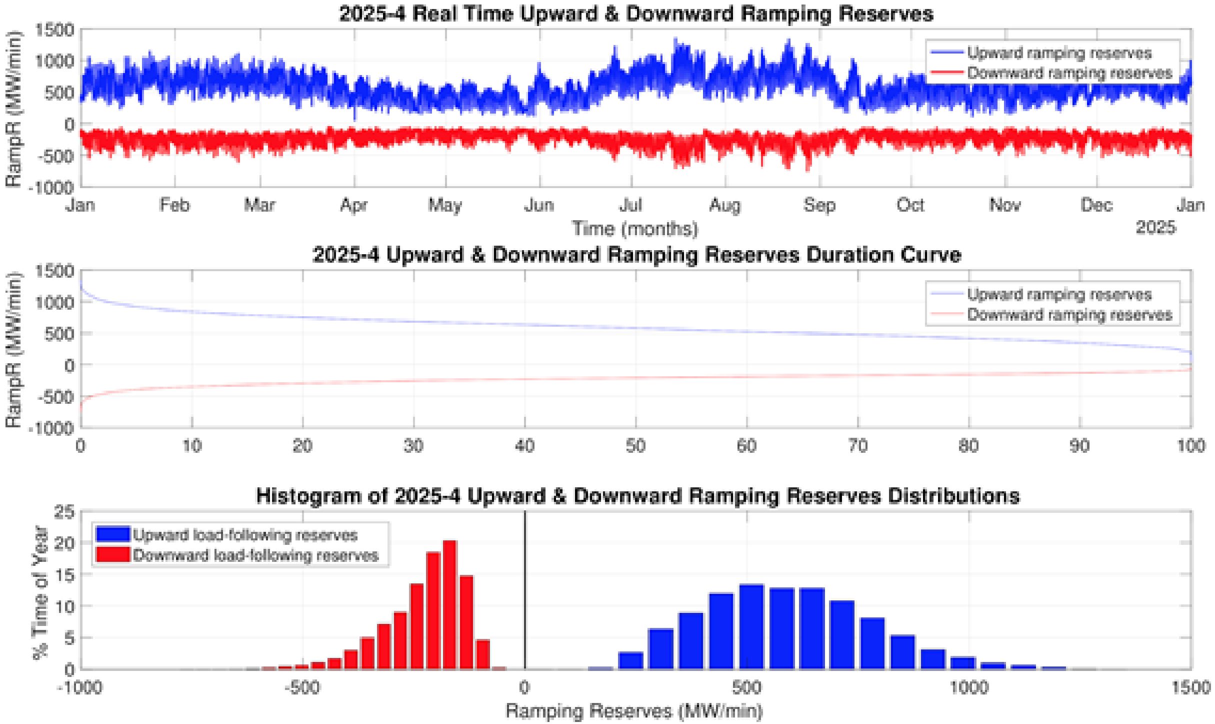
The load following reserves currently procured at ISO-NE are sufficient for "business as usual" development of the system.

Load Following Reserves: 2030 High Variable Renewables Case



In Spring & Autumn, the ability to track net load conditions is highly constrained.

Ramping Reserves: 2025 Business as Usual Case



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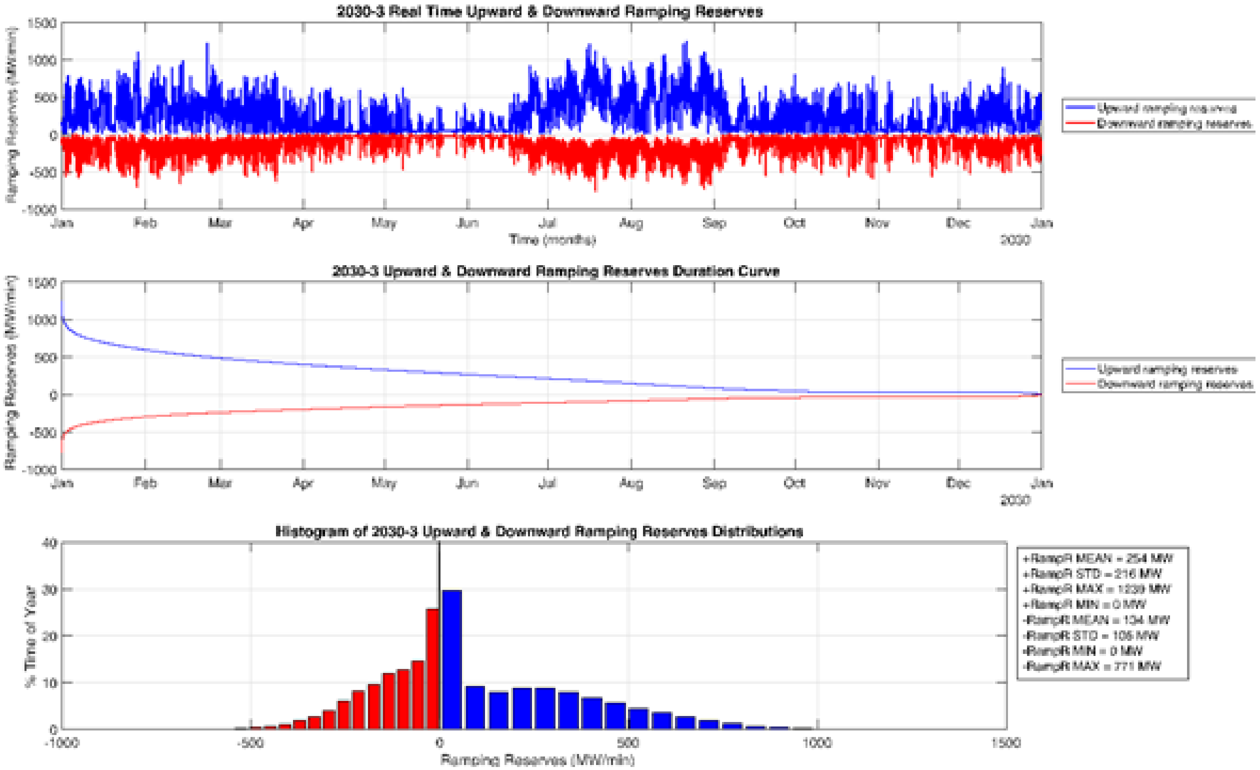
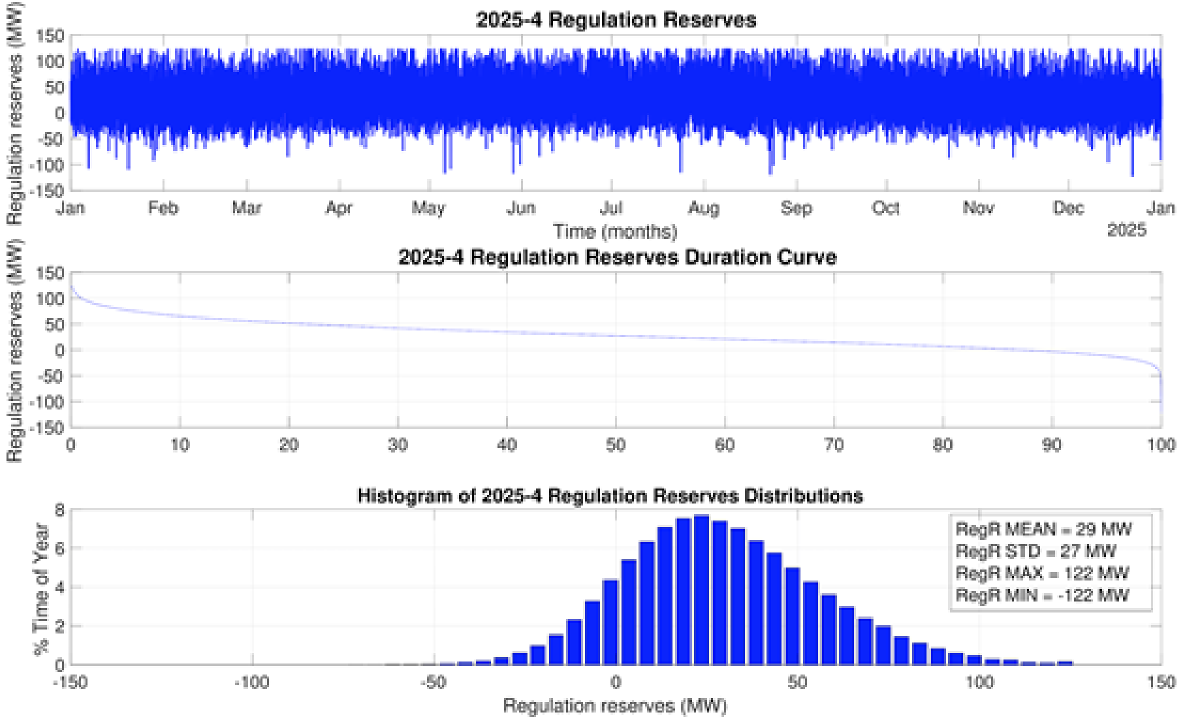
Ramping Reserves: 2030 High Variable Renewables Case



In Spring & Autumn, the ability to track net load conditions is highly constrained.

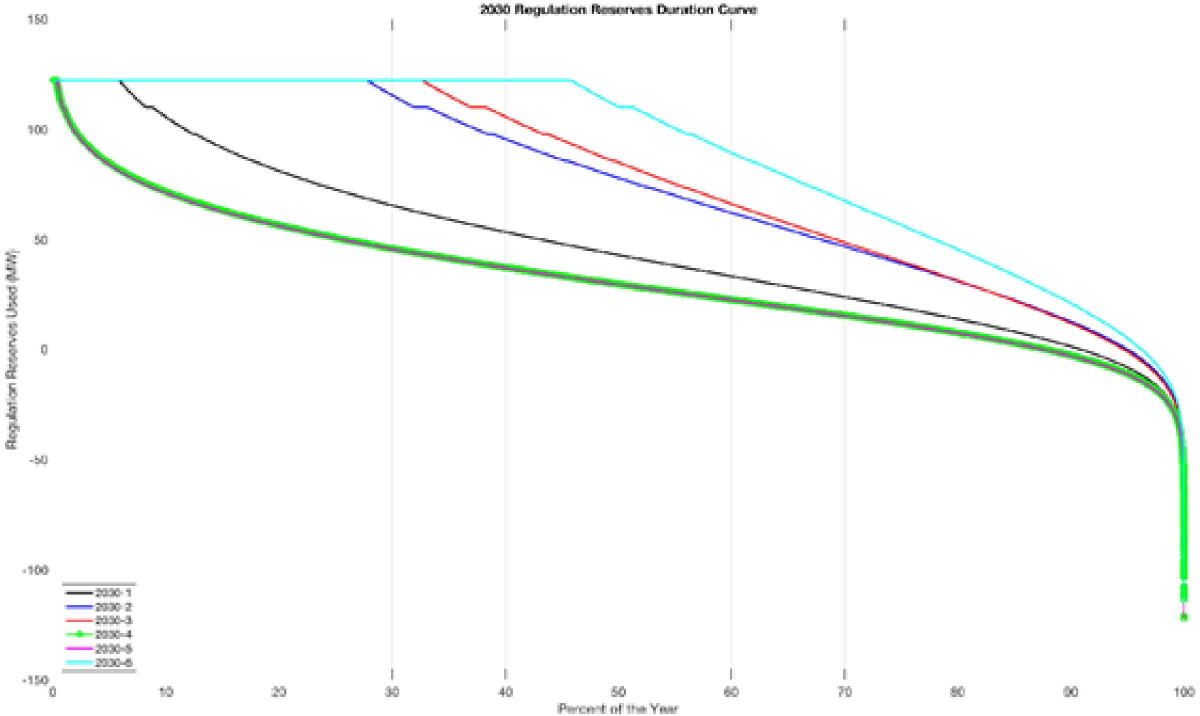
Regulation Reserves: 2025 Business as Usual Case



The regulation reserves currently procured at ISO-NE are sufficient for "business as usual" development of the system.

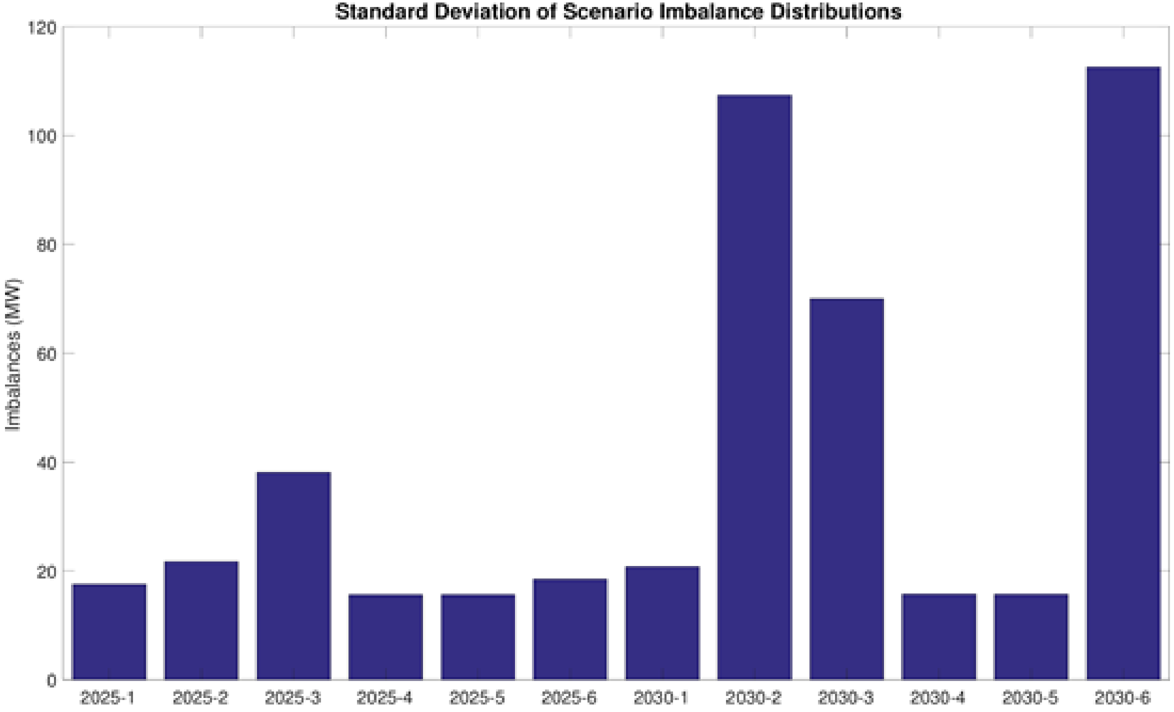
Background | ISO-NE | Results | Conclusion

Regulation Reserves: 2030 Scenarios



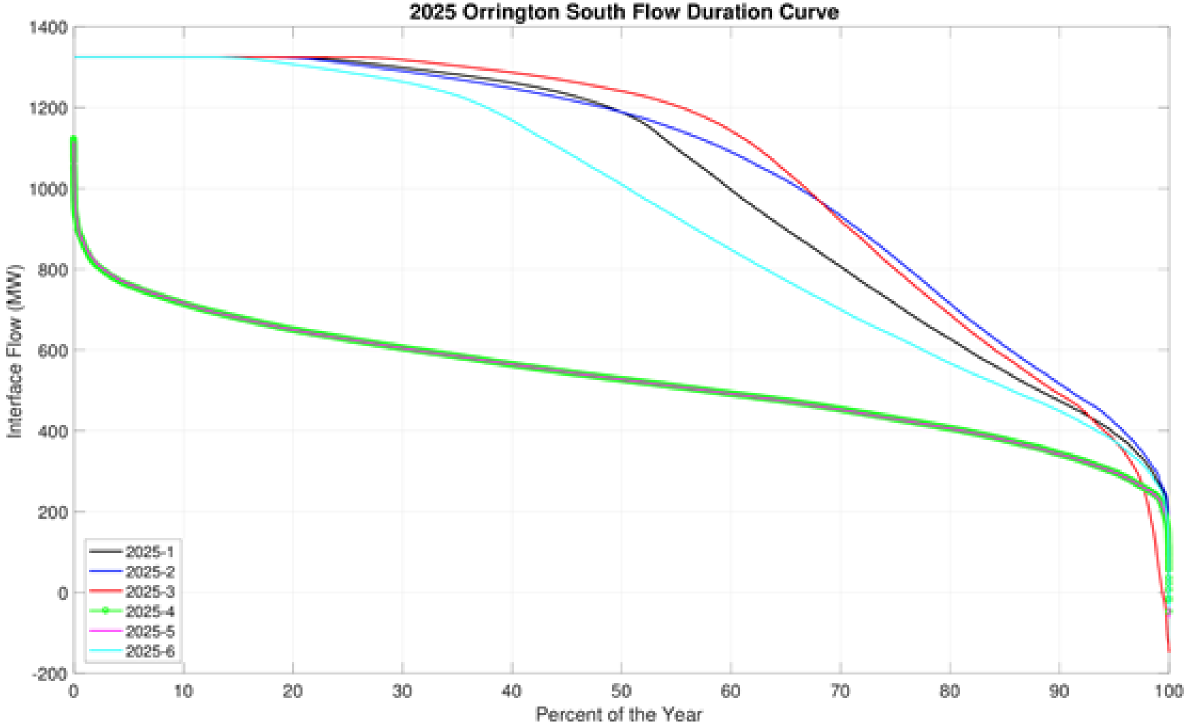
Relative to the business as usual scenarios, high variable renewables saturate regulation reserves.

Electric Power System Imbalances



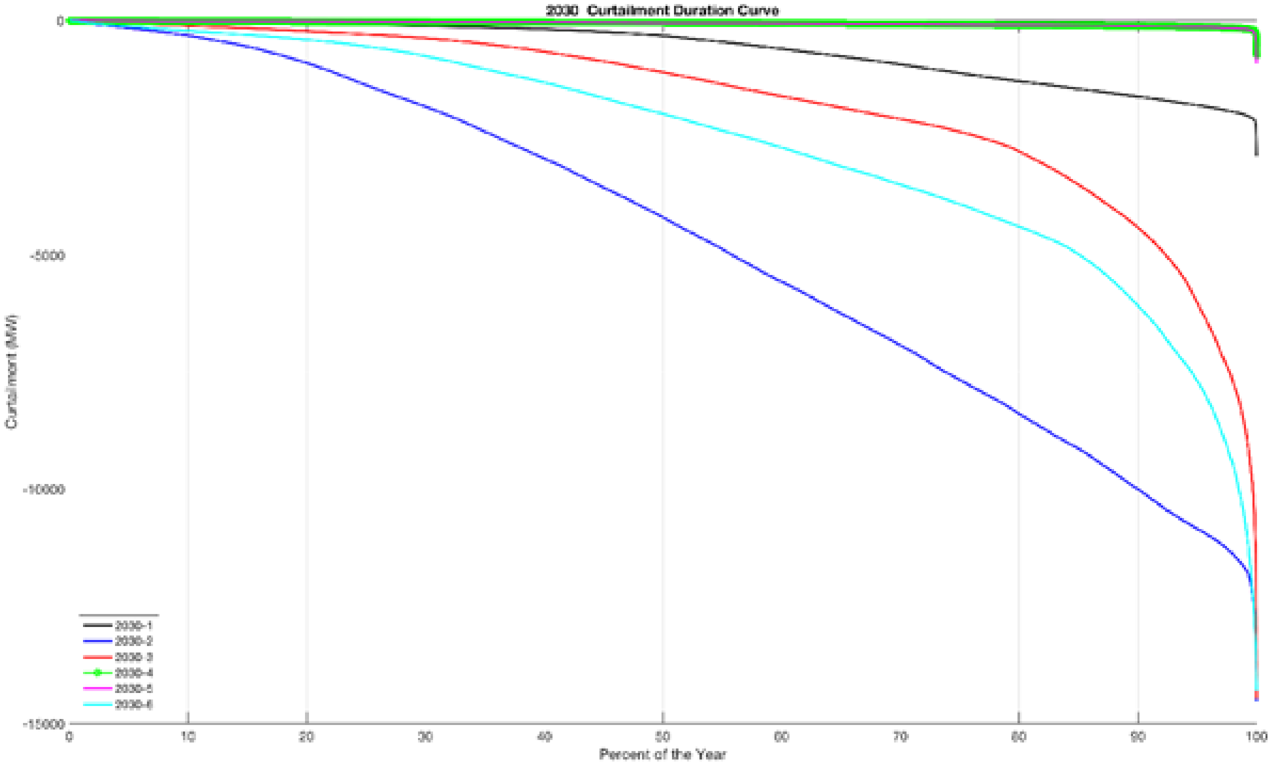
The three 2030 high variable renewable energy scenarios significantly increase the degree of imbalance variability relative to other scenarios.

Power Flow Congestion from Maine



For high renewable scenarios, the transmission system is a bottleneck and limits power delivery from Maine.

Curtailment of Variable Renewable Energy: 2030 Scenarios



Relative to the conventional scenarios, high VREs require significant curtailment.

ISO-NE VRE Integration Study: Key Findings

- **Commitment Decisions**: The commitment of dispatchable resources and their associated quantities of committed load following and ramping reserves has a complex, difficult to predict, non-linear dependence on the amount of VREs and the load profile statistics.
- **Load Following Reserves**: For the scenarios with a significant penetration of VREs, the system may require additional amounts of upward and downward load following reserves to effectively mitigate imbalances and maintain reliable operations.
- **Ramping Reserves**: For the scenarios with a significant penetration of VREs, the system entirely exhausts upward and downward ramping capability.

ISO-NE VRE Integration Study: Key Findings

- **Curtailment**: The curtailment of VREs becomes an integral part of balancing performance; in part to complement operating reserves and in part to mitigate the topological limitations of the system. (Up to 14.5GW and 41% of TWh).
- **Congestion**: The integration of significant amounts of VREs increases the potential on several key interfaces from remote Maine (e.g. Orrington-South).
- **Regulation Reserves**: For the scenarios with a significant penetration of VREs, the system experiences heavy saturation of regulation reserves. More are needed.
- **Balancing Performance**: The scenarios with significant penetration of VREs have significantly degraded balancing performance.

Business-as-usual power system operations and control will do ….

… but market and policy innovations can lead to vastly improved outcomes.

ISO-NE VRE Integration Study: Final Insights

- Expand transmission from remote renewable energy to load centers
- Treat curtailment as a type of operating reserve
- Procure more regulation reserves from a diversity of energy resources
- Coordinate the scheduled maintenance of nuclear power generation
- Expand the role of energy storage and demand side resources

… to the demand side…

Thank You

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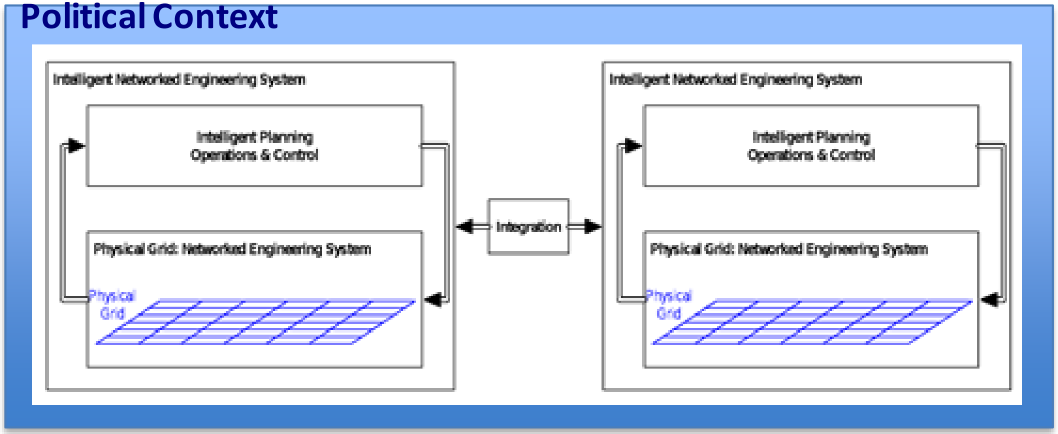
For further reading:
http://arxiv.org/abs/1812.04787

LIINES Research




Smart Power Grids


Energy-Water Nexus

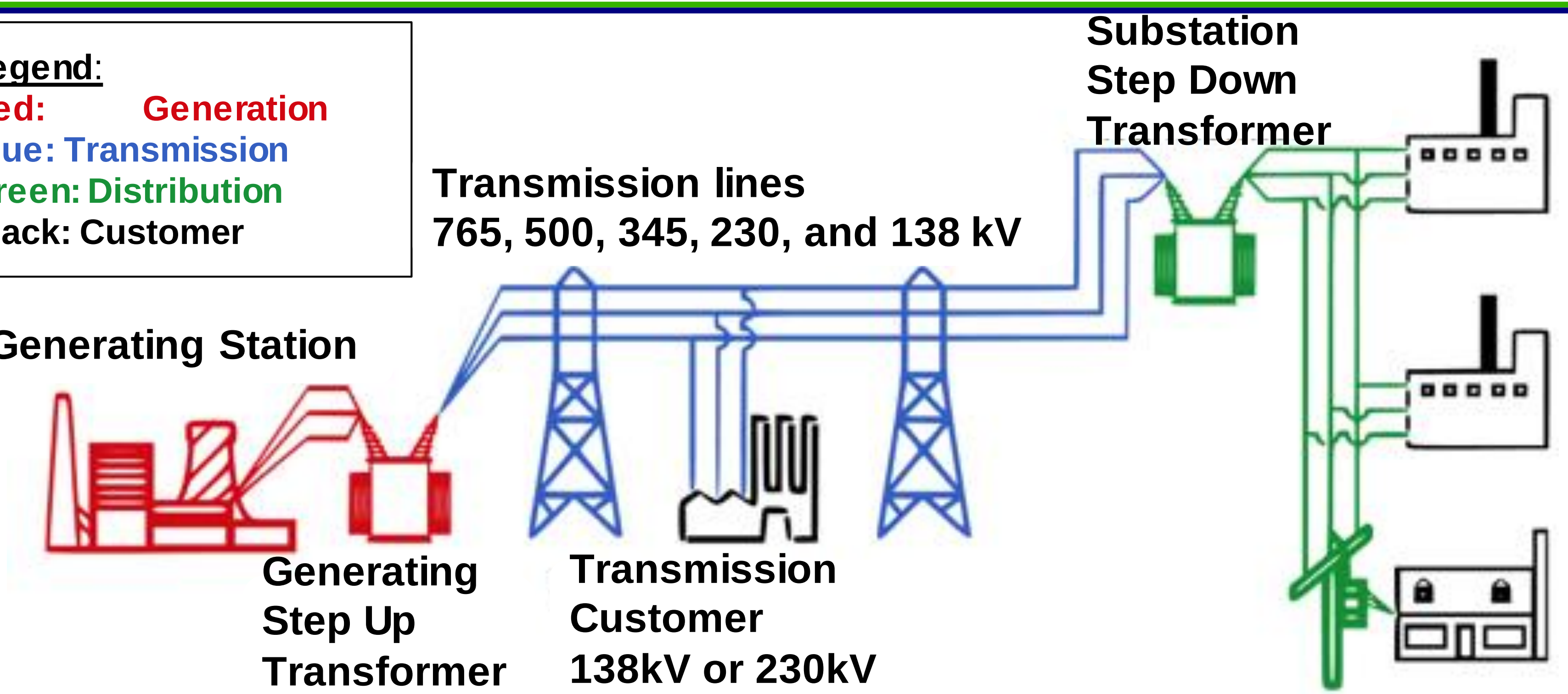

Electrified Transportation Systems


Industrial Energy Management


Integrated Smart City Infrastructures

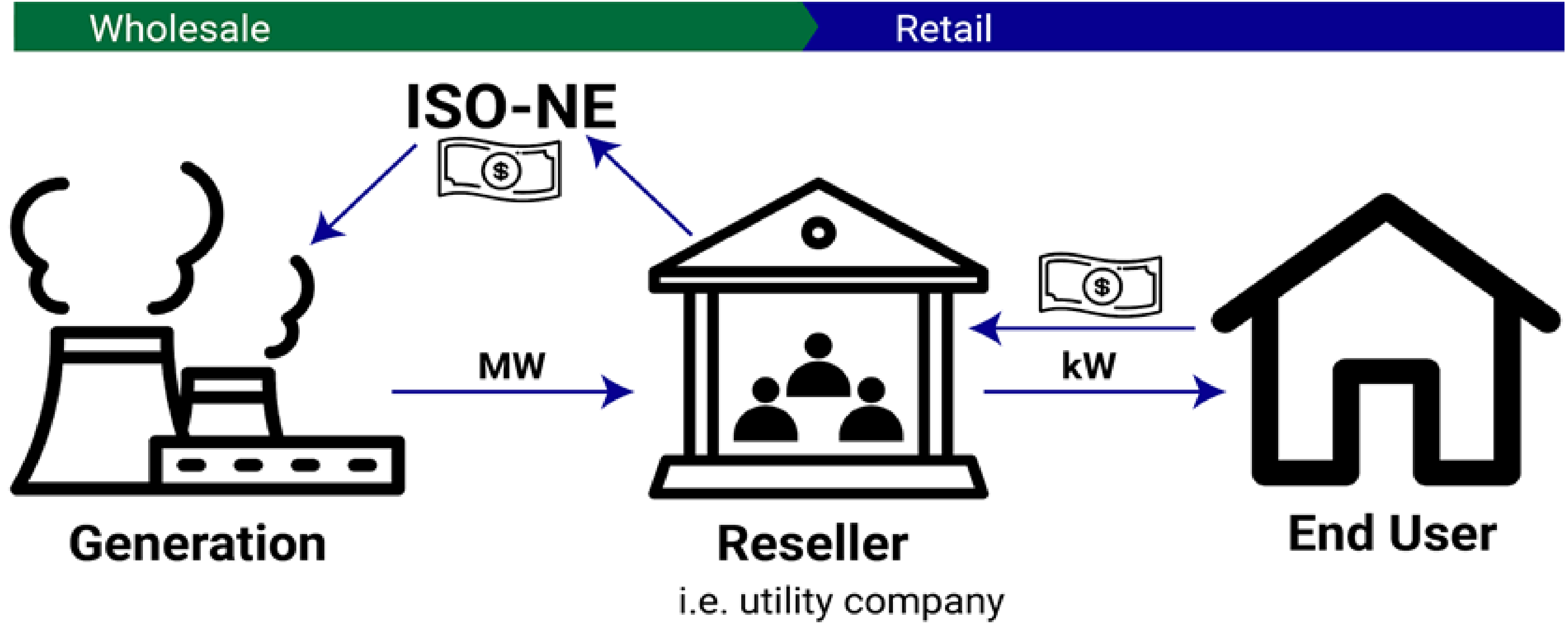
Power Grid Value Chain

Legend:
Red: Generation
Blue: Transmission
Green: Distribution
Black: Customer



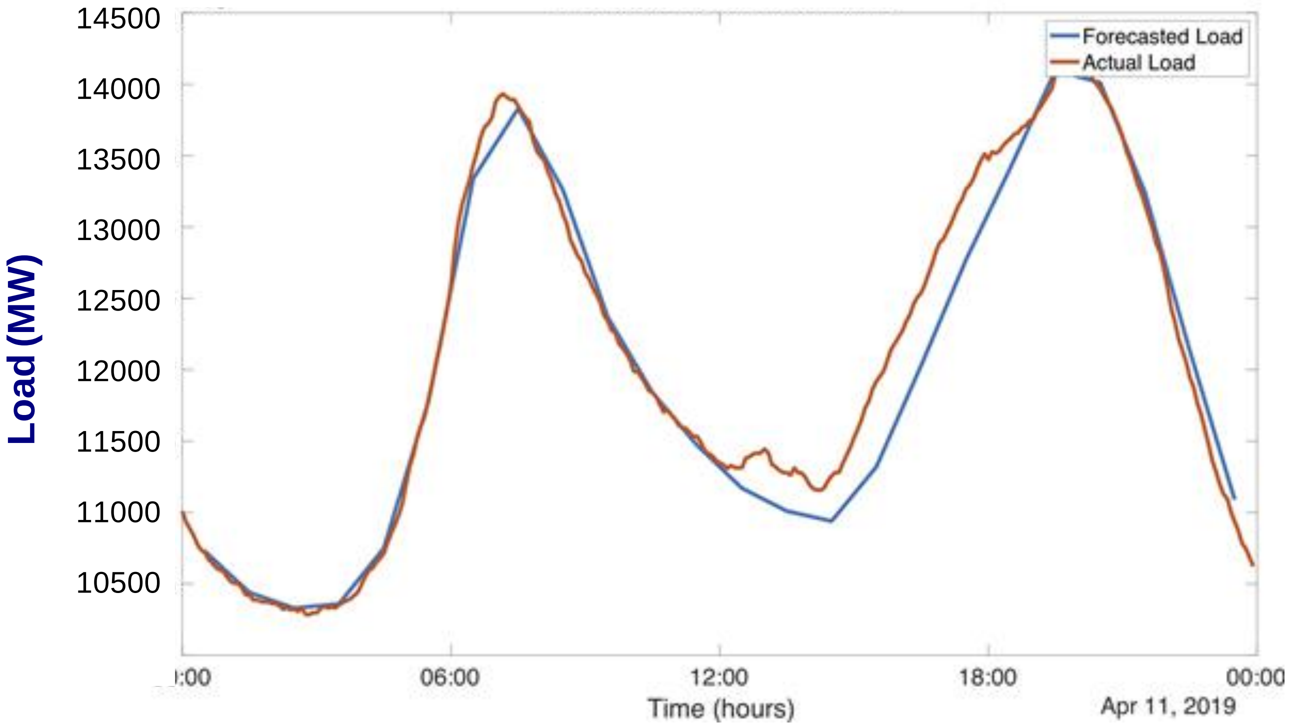
This study focuses on the bulk power system of transmission and generation.

Electricity Market Structure



ISO-NE facilitates generation companies (GenCos) and utilities as wholesale market participants.

Forecasted vs. Actual Load



Dispatchable generation must track the forecasted net load.

A Classification of Operating Reserves

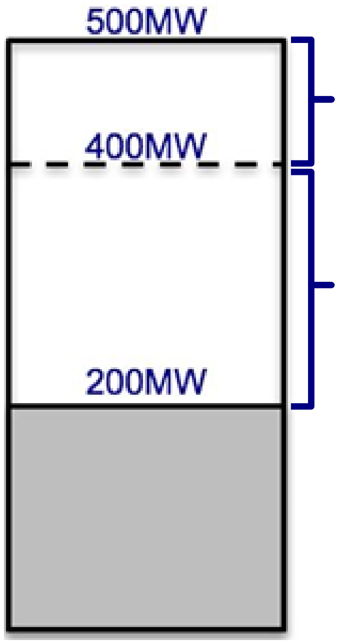
- Load Following Reserves
- Ramping Reserves
- Regulation
- Curtailment of Variable Renewable Energy

Load Following Reserves

Max Capacity Limit

Dispatch Setpoint

Min Capacity Limit



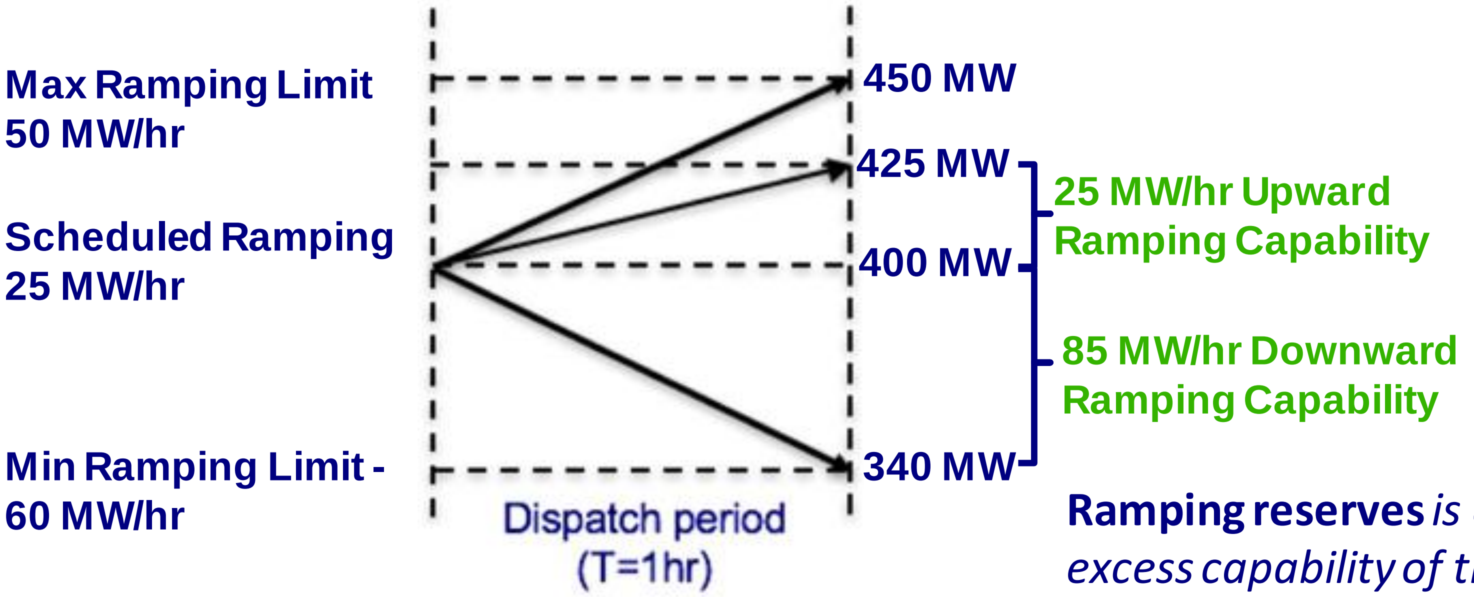
100 MW Upward Load-Following Reserves

200 MW Downward Load-Following Reserves

Load-following reserves: *are equal to the ability of available generation fleet to move up or down (i.e. economic surplus)*

Load-following reserves, as a physical quantity, assist in responding to net load variability and uncertainty.

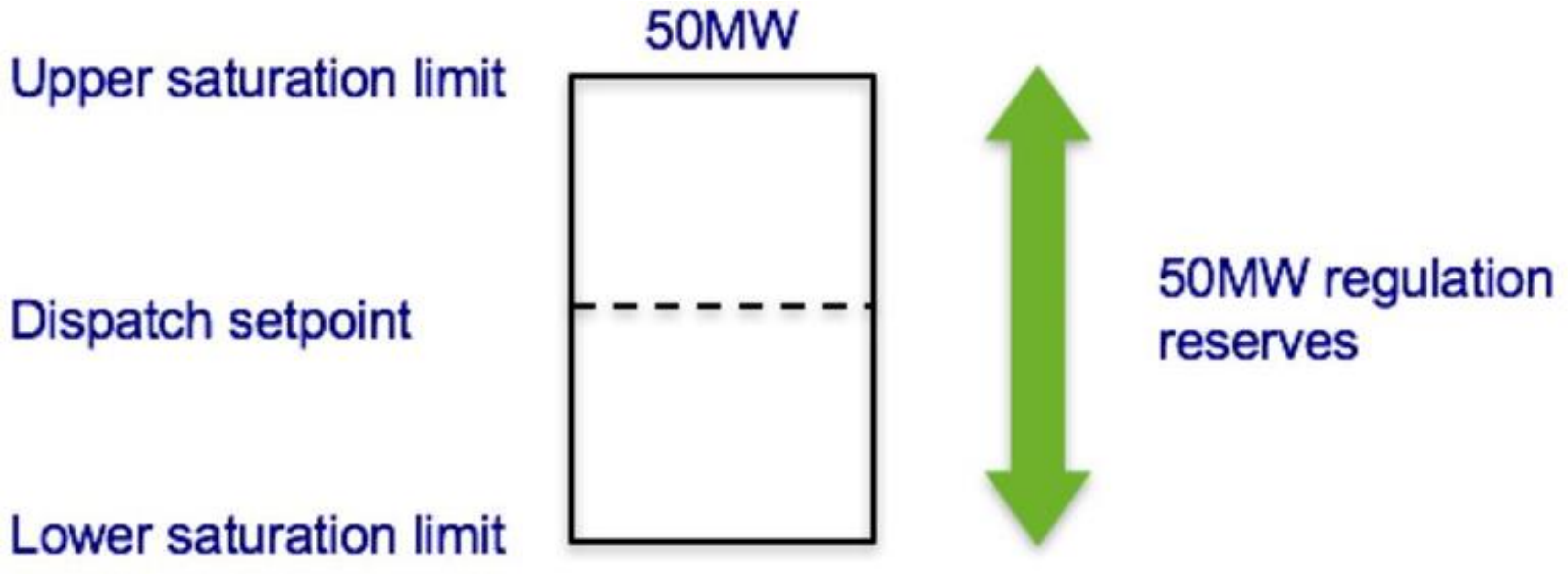
Ramping Reserves



Ramping reserves *is equal to the excess capability of the available generation fleet to move up or down per time.*

Ramping reserves, as a physical quantity, assists in responding to net load variability and uncertainty.

Regulation Reserves



Regulation Reserves: Power capacity available during normal conditions to assist in active power balance and to correct any imbalances that requires a fast, real-time, automatic response.

The ISO New England Transmission System

Computational Burden

1,500
Simulation Years

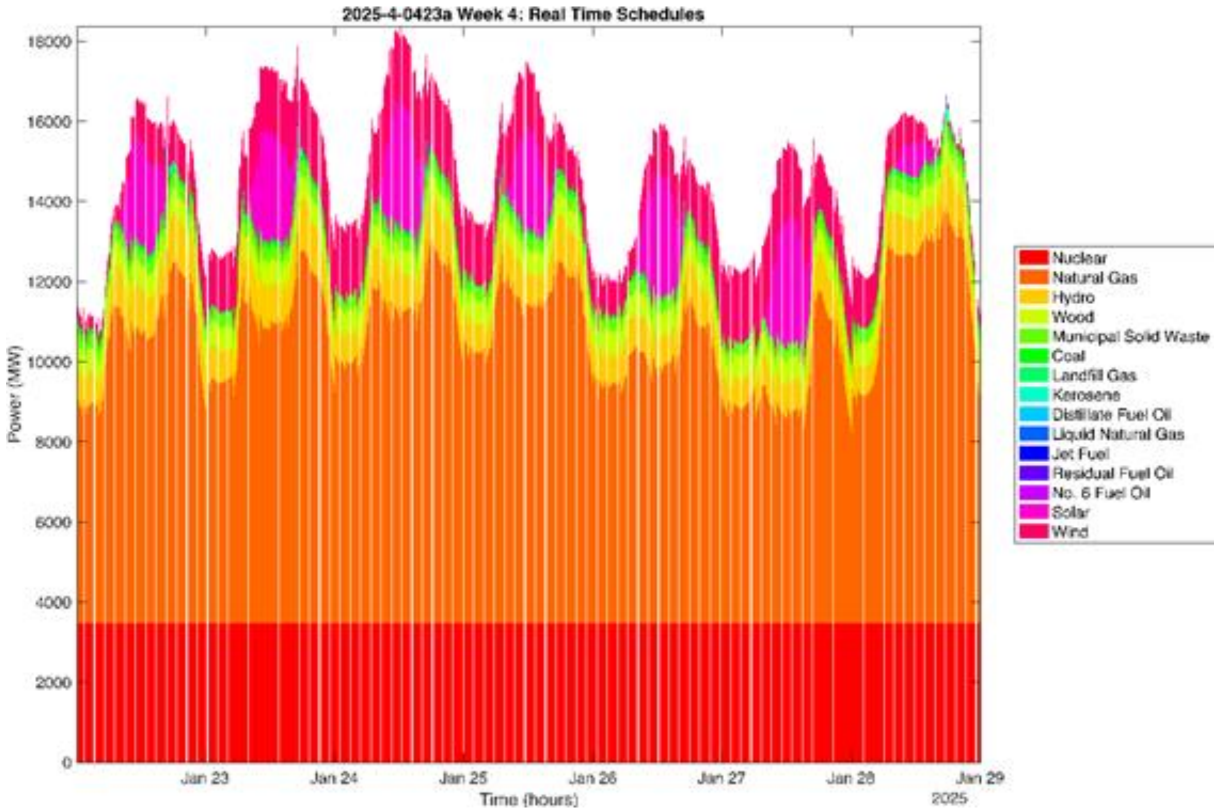
1 min.
Time Resolution

2 Days
per Simulation

500MB
Raw Output per Simulation

Very computationally heavy; days to run one simulation; output files require large amounts of storage.

Real-Time Energy Market Dispatch: 2025 Business as Usual Case



Real-Time Energy Market Dispatch: 2030 High Variable Renewables Case