The Value of Modeling DA/RT Uncertainty in Market Simulations

PRESENTED BY

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PRESENTED FOR

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Brattle

System Planning Should Model Operational Uncertainty

Managing operational uncertainty can add millions in operating costs

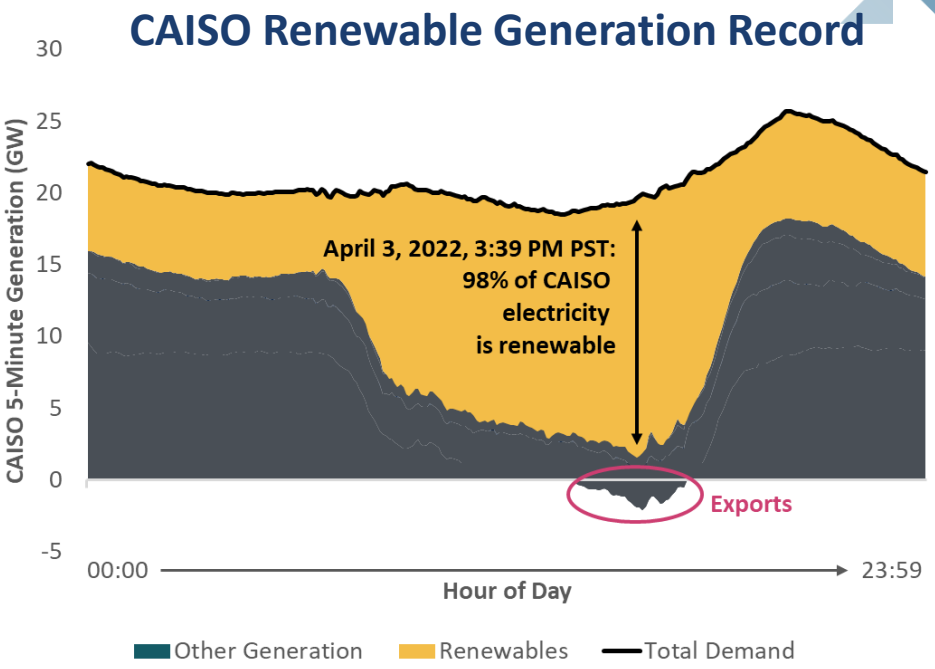
- Renewables need firm backup capacity as systems approach 100% renewable generation (example on slide 6)
- Transmission outages/congestion can cause expensive redispatch
- Heat waves can increase air conditioning demand suddenly, necessitating expensive generation

System flexibility (ability to adjust supply and demand to maintain system frequency) reduces the cost of uncertainty (slide 2)

- Storage can provide reliability and balancing at less cost than peakers if charged from renewable energy (slide 3)
- Markets coordinate participants' flexibility resources (slide 4)
- Transmission increases flexibility by enabling markets (slide 5)

Including uncertainty in planning models can reveal additional flexibility value not captured by perfect foresight models and lead to greater investment in expanding system flexibility

- Slides 3-5 give examples of this flexibility value



Source: Fox Weather

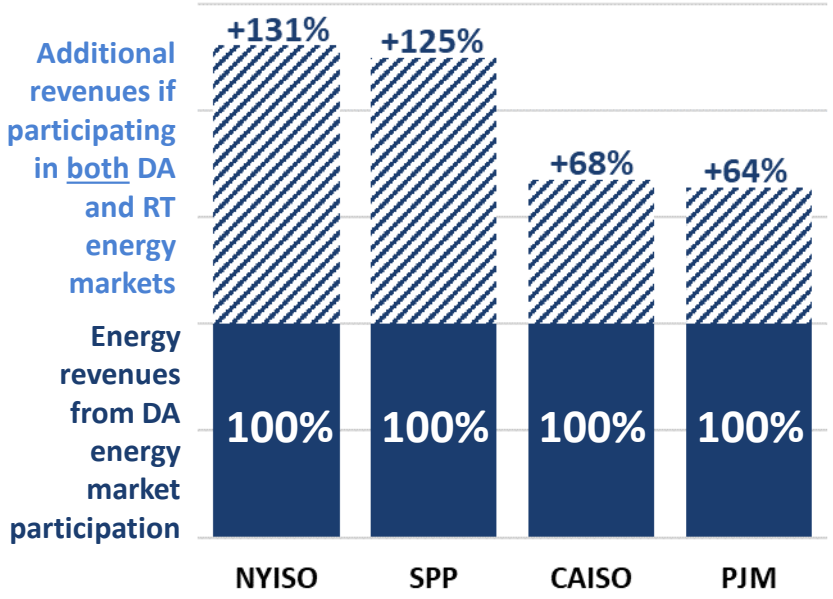
Modeling Uncertainty Reveals The Value of Flexibility

System planning uses modeling to evaluate the economic and non-economic benefits of different sources of flexibility

- Traditional planning modeling simulations use perfect foresight (no DA-RT uncertainty included)

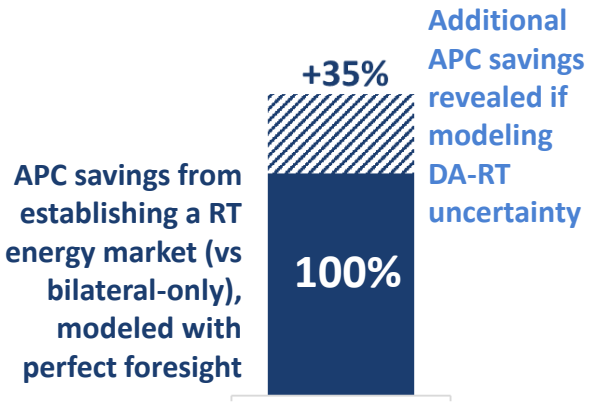
Planning studies that model DA-RT uncertainty tend to reveal more system benefits than perfect foresight modeling

Providing Flexibility in RT Markets Reveals Additional Storage Revenues



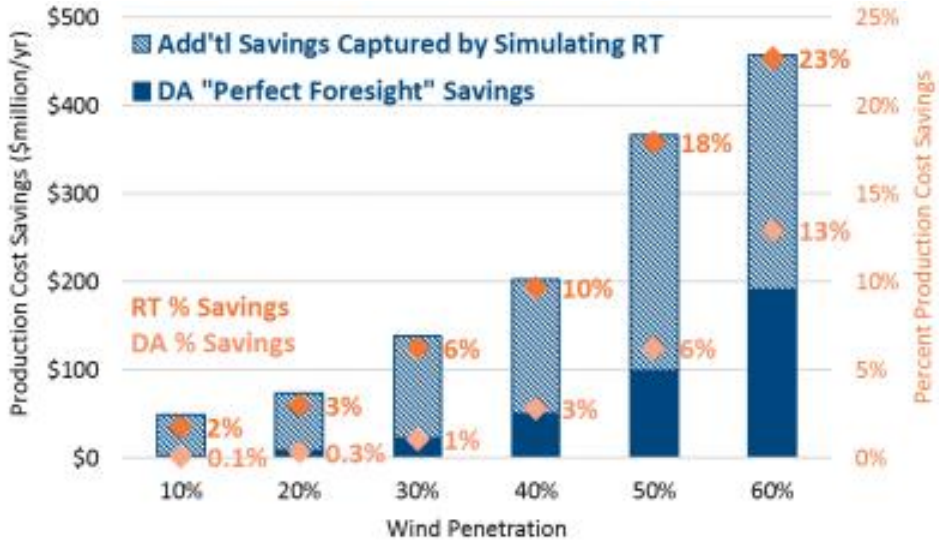
Note: Average of 2019 and 2020 simulations of a 4-hour battery with 85% efficiency and 365 annual cycles. Results do not include ancillary service market revenues.

APC Savings From RT Market Integration Increasing System Flexibility



Note: RT market benefits defined as APC savings. Figure does not include other benefits like congestion and transfer revenues.

APC Savings Due to Increased Transmission Capacity With Varying Penetrations of Wind



K. Van Horn, J. Pfeifenberger and P. Ruiz, The Value of Diversifying Uncertain Renewable Generation through the Transmission System, Boston University Institute for Sustainable Energy, September 2020.

Flexible Resources Like Storage Balance The System

System operators use forecasting to commit the system for RT operations

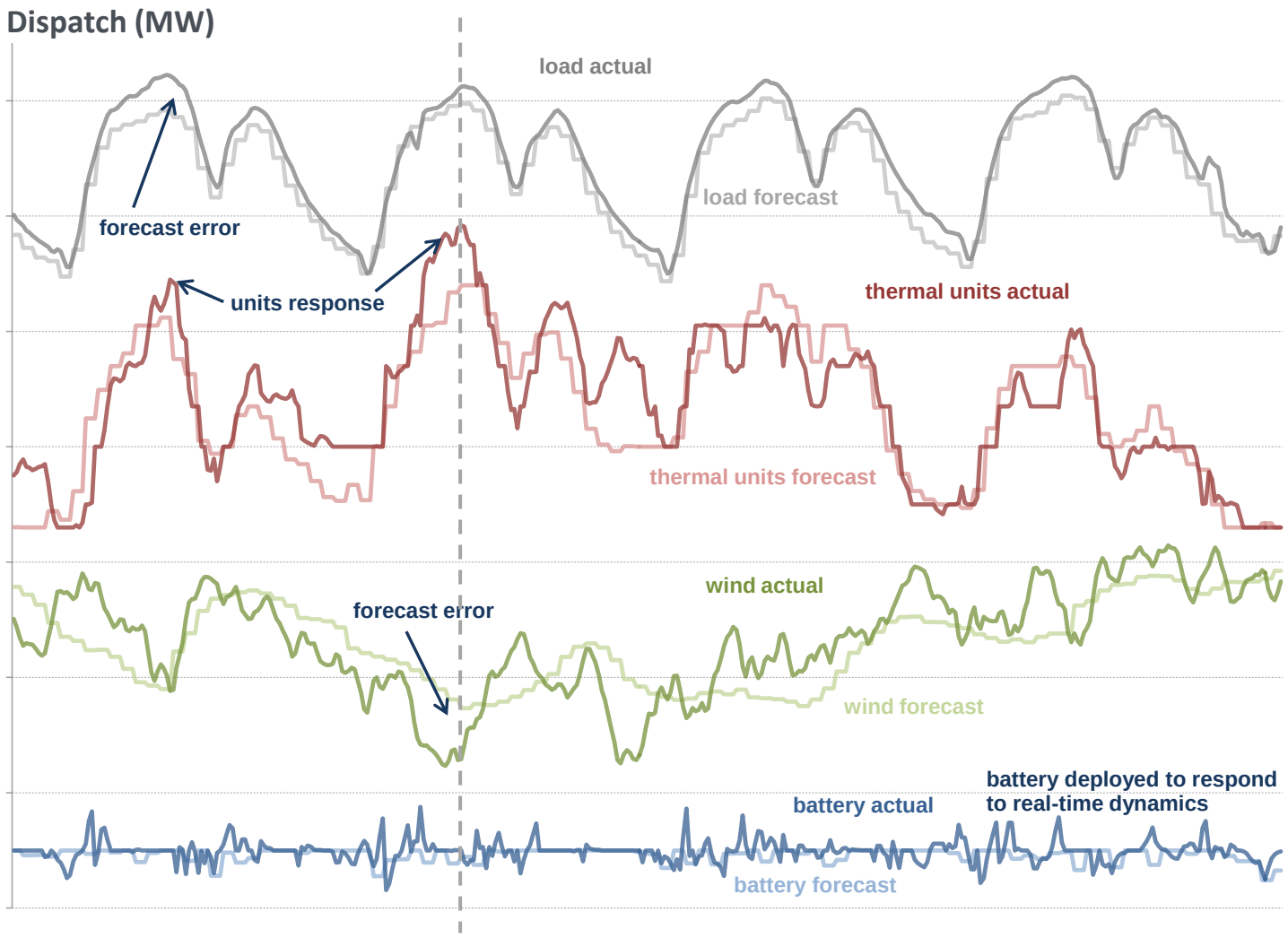
- Forecasts are seldom right

Storage, demand response, and fast-ramping thermal resources adjust their dispatch to compensate for forecast error and maintain system frequency

Discharging storage that was charged from excess renewable energy that would otherwise have been curtailed can provide flexibility less expensively than peakers

- Can save tens to hundreds of thousands of dollars in peaker operating costs per cycle
- Modeling this value can help make a business case for storage

Illustrative 4-Day Operations Simulation Summary



Dark lines: real-time "actual" outcomes

Light lines: day-ahead scheduling outcomes, based on forecasted conditions

Markets Centrally Coordinate Flexible Resources

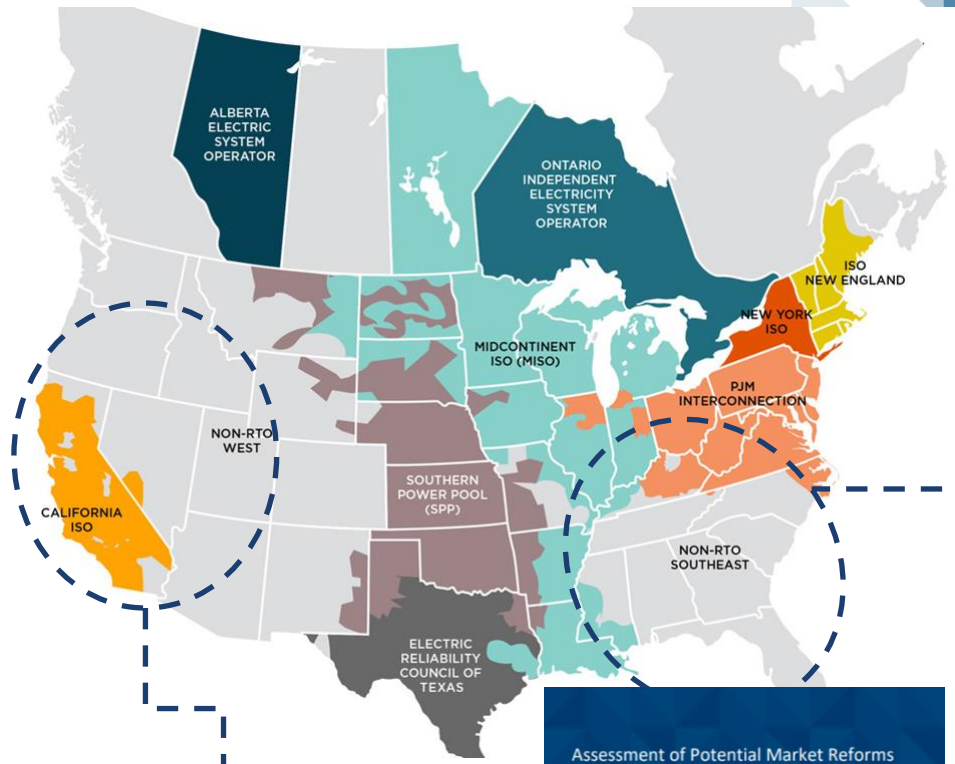
Markets improve flexibility by coordinating members' storage, demand response, and other sources of flexibility

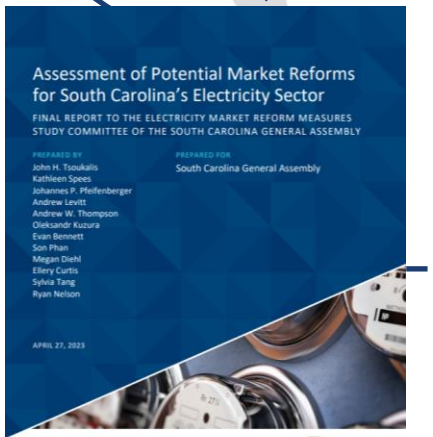
- DA markets can help position the system to manage uncertainty by centralizing forecasting, commitment, and procurement of ancillary services (spinning reserves, regulation, ramping)
- RT (balancing) markets deal with DA-RT uncertainty by optimizing resource dispatch across their footprint

Several non-RTO regions are considering joining or creating DA and/or RT markets, which typically involves quantifying the benefits of market participation

Market integration can produce hundreds of millions of dollars in benefits due to increased system flexibility, optimized dispatch and transmission usage, and reduced curtailments

- Modeling these benefits can inform formation/participation decisions





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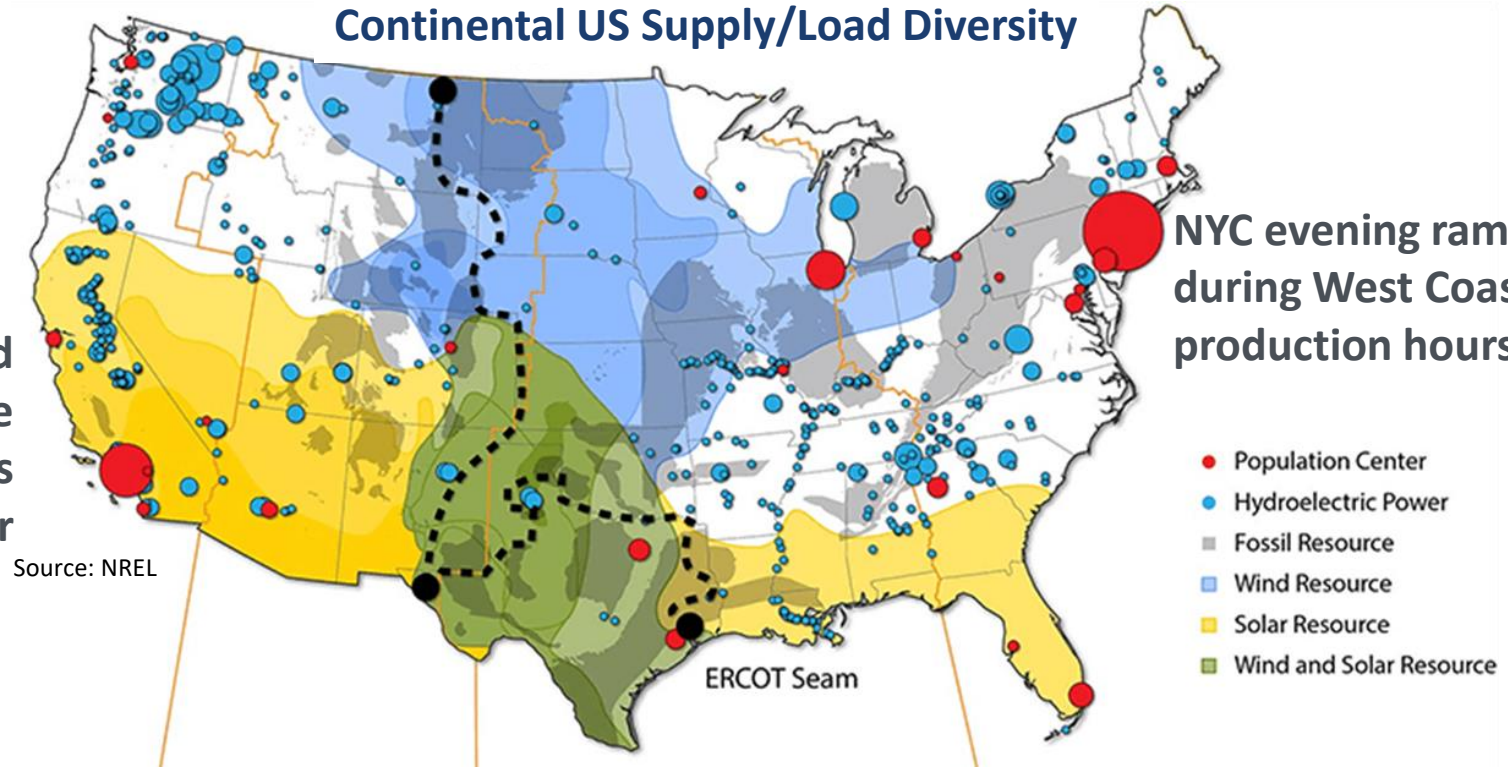
Transmission Enables Market Coordination of Resources

Transmission provides additional system flexibility from exploiting regional diversity in weather, customer types, time zones, and other factors impacting supply availability and load characteristics

- Different regions' uncertainty profiles "balance out" when connected

Modeling DA-RT uncertainty when evaluating proposed new transmission projects can reveal additional value and help projects clear B-C thresholds to enter the approval and permitting process

Continental US Supply/Load Diversity



Wyoming wind production profile complements Southwest solar

NYC evening ramp occurs during West Coast solar production hours

Source: NREL

Chilean Supply Distribution

Solar in the north

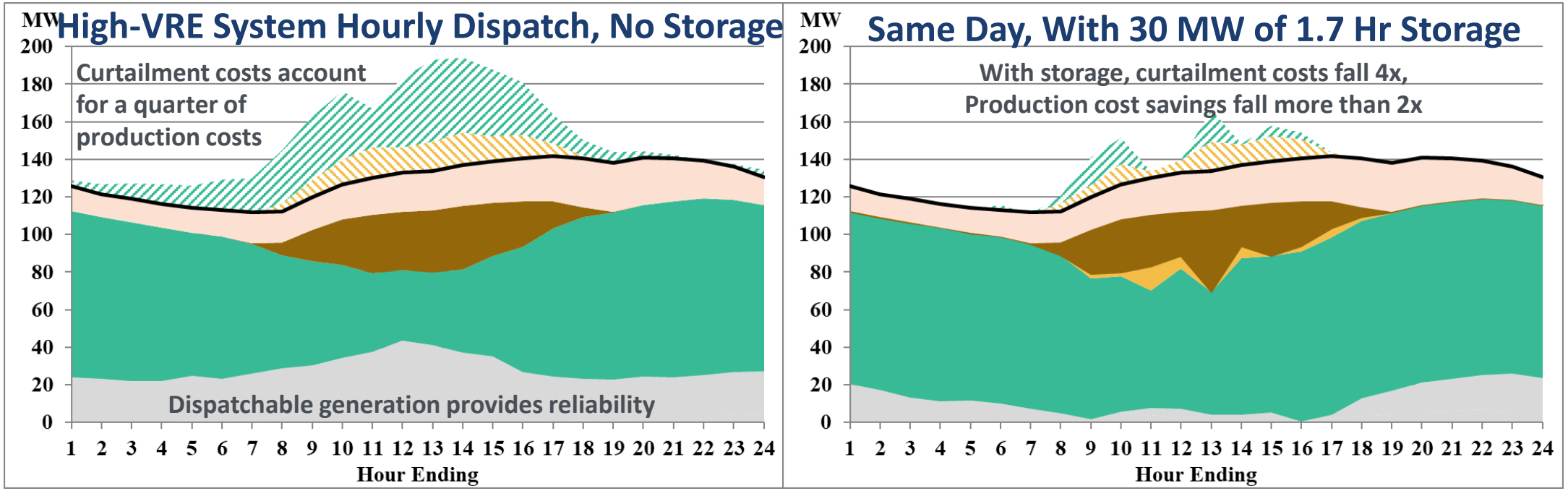
Hydro in the south

Planning For Uncertainty Can Save Millions in Operating Costs

Keeping thermal generation online to provide minute-to-minute balancing of renewable generation fluctuations in a high-VRE system can cost millions in fuel expenditures and curtailment costs due to displaced renewable generation

Using storage, charged from renewable energy that would otherwise be curtailed, to provide system flexibility can save millions in fuel and curtailment costs

- Tens of millions of dollars in annual operational savings in the example below are 10x the annual storage payments



Note: Simulations model a present-day system (150 MW peak demand) with increased wind and solar capacity (80% clean generation) and no additional storage.

There Are Many Forms of Uncertainty Beyond DA-RT

Planned-for demand can grow or shrink faster than expected

- Rate structures that over-incentivize BTM solar can lead to sudden and unexpected demand growth as customers use extra incentive income to buy second air conditioners
- Crypto mining can necessitate T&D upgrades and/or new generation procurement – then disappear

Supply availability can likewise change

- Extreme weather and drought can undermine assumptions on transmission and hydro availability
- Not weather-proofing fuel supplies/pipelines can cause generation shortages
- Supply chain issues can delay resource procurements
- Geopolitical factors can limit access to fuels and critical minerals

Proper planning and risk analysis can protect against expensive emergency measures to address uncertainty

Brattle Can Help You Evaluate and Plan For Uncertainty

Modeling uncertainty can enhance asset valuation and planning in a range of contexts, and is only becoming more important as operational uncertainty increases with the accelerating renewables buildout

- This feature has become standard practice for much of our modeling

In addition to modeling DA-RT uncertainty, we are continually growing our modeling capabilities to meet the needs of an evolving energy system, including:

- Modeling **extreme weeks/weather patterns**, to reflect the increasing frequency of these high impact events
- **Unit-specific GHG accounting** to capture the dynamics of GHG pricing covering only part of a regional market (such as the Western EIM)
- Dynamically modeling system **dispatch crossing the eastern and western interconnections**, such as for the SPP RTO West
- Detailed modeling of bilateral markets, including **block trading**, **transmission reservation impacts**, **multi-timeframe trade dynamics**
- **Rolling-horizon dynamic ELCC calculation** for capacity expansion modeling

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Mr. Kuzura helps clients gain clarity on operational, economic, and regulatory issues in the rapidly changing electric power industry.

He leverages his optimization-based modeling expertise to help ensure a just transition to a decarbonized, efficient, and reliable power system. With a background in engineering, Mr. Kuzura has experience spanning the production, storage, transmission, and consumption of electricity, as well as the market structures that make it all possible.

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Appendix: Brattle's Modeling Capabilities

ENELYTIX®
powered by PSO

Platform for Power Market Modeling

ENELYTIX® is the advanced power market modeling platform for forecasting, asset valuation, system planning, operational analysis, policymaking, and market design

- Expansion planning, optimal commitment and dispatch, and resource adequacy model of power markets
- Purpose-built to model power market dynamics on a path to decarbonized future while modeling energy, ancillary, capacity, REC, and carbon markets. More accurate and sophisticated than any other commercially available platform
- Flexibility to configure models and data set-ups across a wide range of alternative market structures, policies, and business use cases and desired spatial/temporal granularity ranging from minutes to decades
- Cutting edge cloud-based architecture can scale up/down to match business needs. The automated workflow, parallelization and scalability enable high peak usage at record performance/run time)

For more details, see:
http://www.enelytix.com/

Multi-Functional Simulation of WECC

Markets/RTO Functions & Configurations

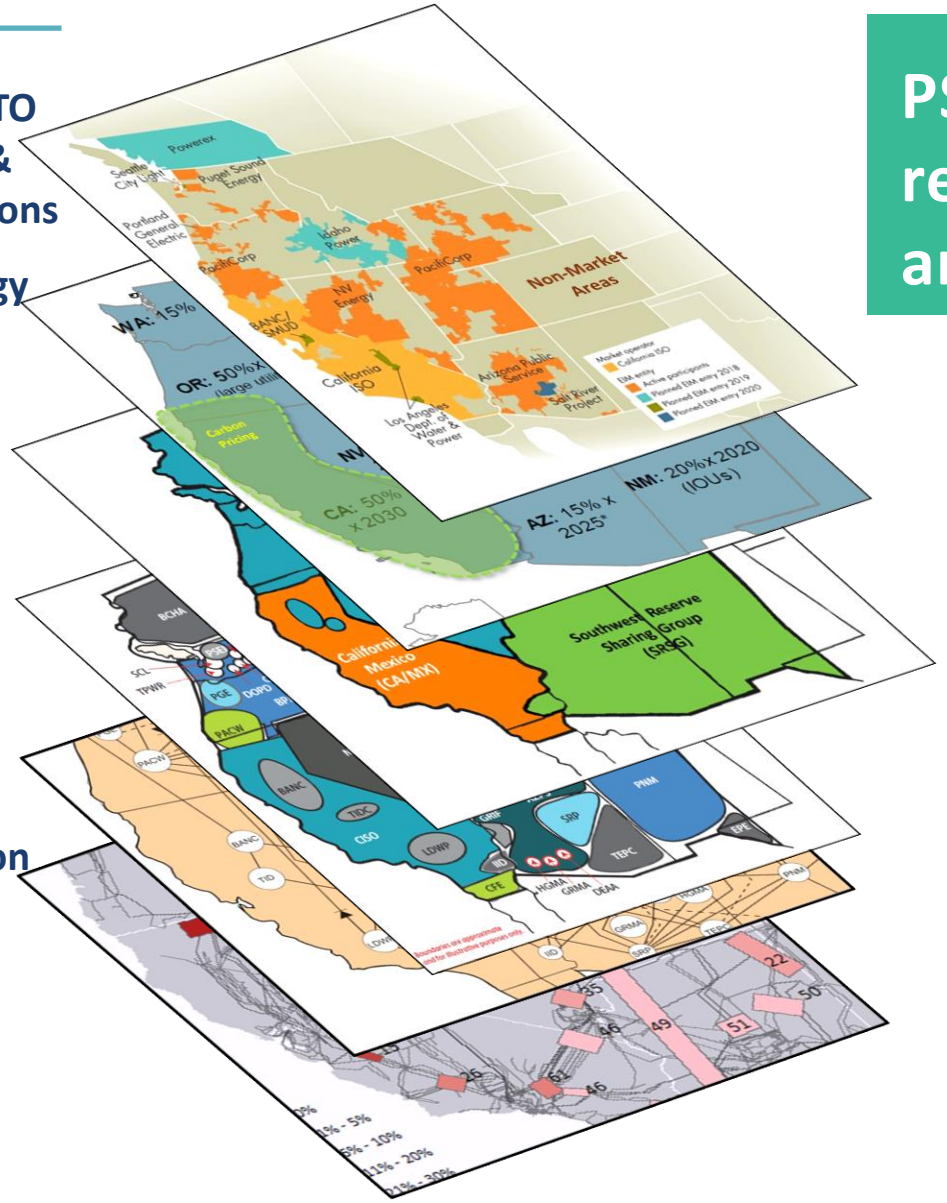
Clean Energy Policies

Reserve Sharing

BAA Functions

Bilateral Contract Paths and Transmission Rights

Physical Flows and Constraints

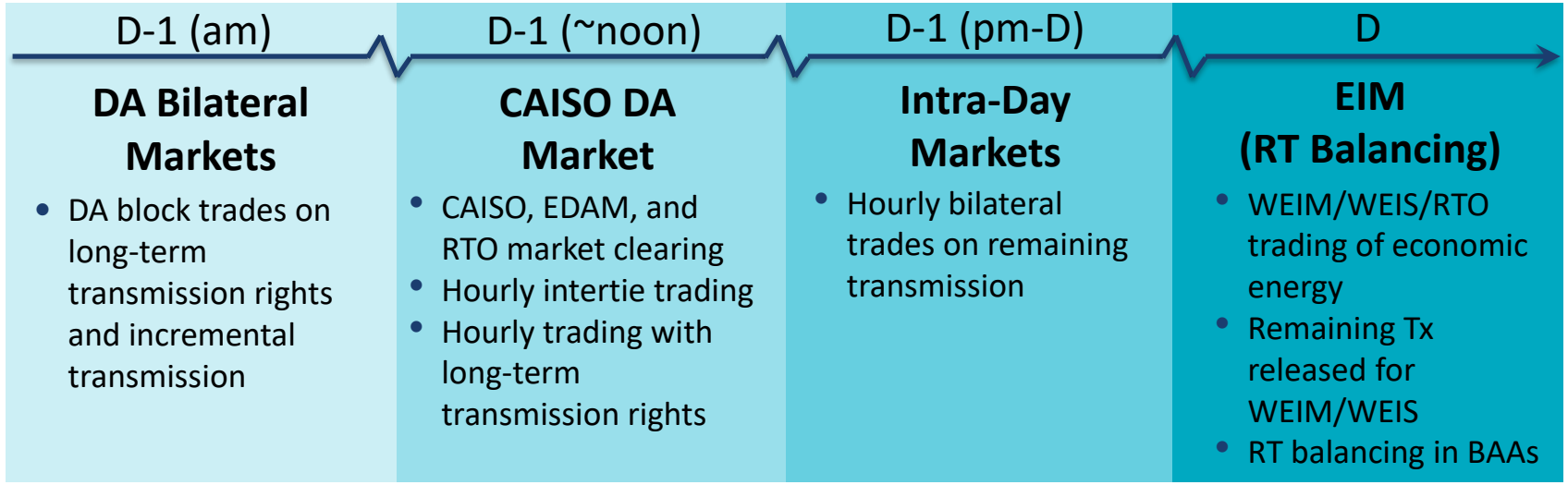


PSO employs multi-layer simulations to represent the various physical, policy, and operational facets of the WECC

- Physical grid with ~20k buses, ~25k lines and ~5k generators
- 38 balancing areas (BAAs)
- The WECC reserve sharing groups
- Diverse state clean energy policies
- Major trading hubs (e.g., Mid-C, Malin, PV)
- Bilateral transmission rights
- Renewable diversity, day-ahead forecast uncertainty, real-time operations
- CAISO, WEIM and WEIS market footprint(s), and future Western RTO(s)

Independent Simulation of Multiple Time Horizons

PSO simulates multiple independent decision cycles to capture day-ahead vs. real-time unit commitment and dispatch



Independent real-time decision cycle used to simulation EIM functions

Decision cycles capture bilateral trading, market clearing, and BAA functions in DA and RT

Independent real-time decision cycle used to simulate DA vs. RT, including forecast error for wind and solar

gridSIM: System Planning, Price Forecasting, Market Design

INPUTS

Supply

- Existing resources
- Fuel prices
- Investment/fixed costs
- Variable costs

Demand

- Representative day hourly demand
- Capacity needs

Transmission

- Zonal limits
- Intertie limits

Regulations, Policies, Market Design

- Capacity market
- Carbon pricing
- State energy policies and procurement mandates

gridSIM OPTIMIZATION ENGINE

Objective Function

- Minimize NPV of Investment & Operational Costs

Constraints

- Planning Reserve Margin
- Hourly Energy Balance
- Operational Reserve Requirement
- Regulatory & Policy Constraints
- Resource Operational Constraints
- Transmission Constraints

OUTPUTS

- Annual Investments and Retirements
- Hourly Operations
- Marginal Costs of Capacity, Energy, and Reserves
- System and Customer Costs
- Emissions and Clean Energy Additions
- Supplier Revenues

Link to Brattle's gridSIM website

Brattle Capabilities for Assessing Market Reform Options

Market reforms will impact *investment* and *operational* decisions
Brattle has models to analyze both impacts in detail

Optimal investment in generation and transmission under market reforms

- Generation divesture
- Regional transmission planning
- Clean energy mandates
- Multi-decade investment time horizon

OPTIMAL RESOURCE MIX & EXPANSION PLAN MODELING

- Long-term investment & retirement simulation model
- Determines least-cost resource mix to meet reliability & policy needs

gridSIM

GRANULAR OPERATIONS & DISPATCH MODELING

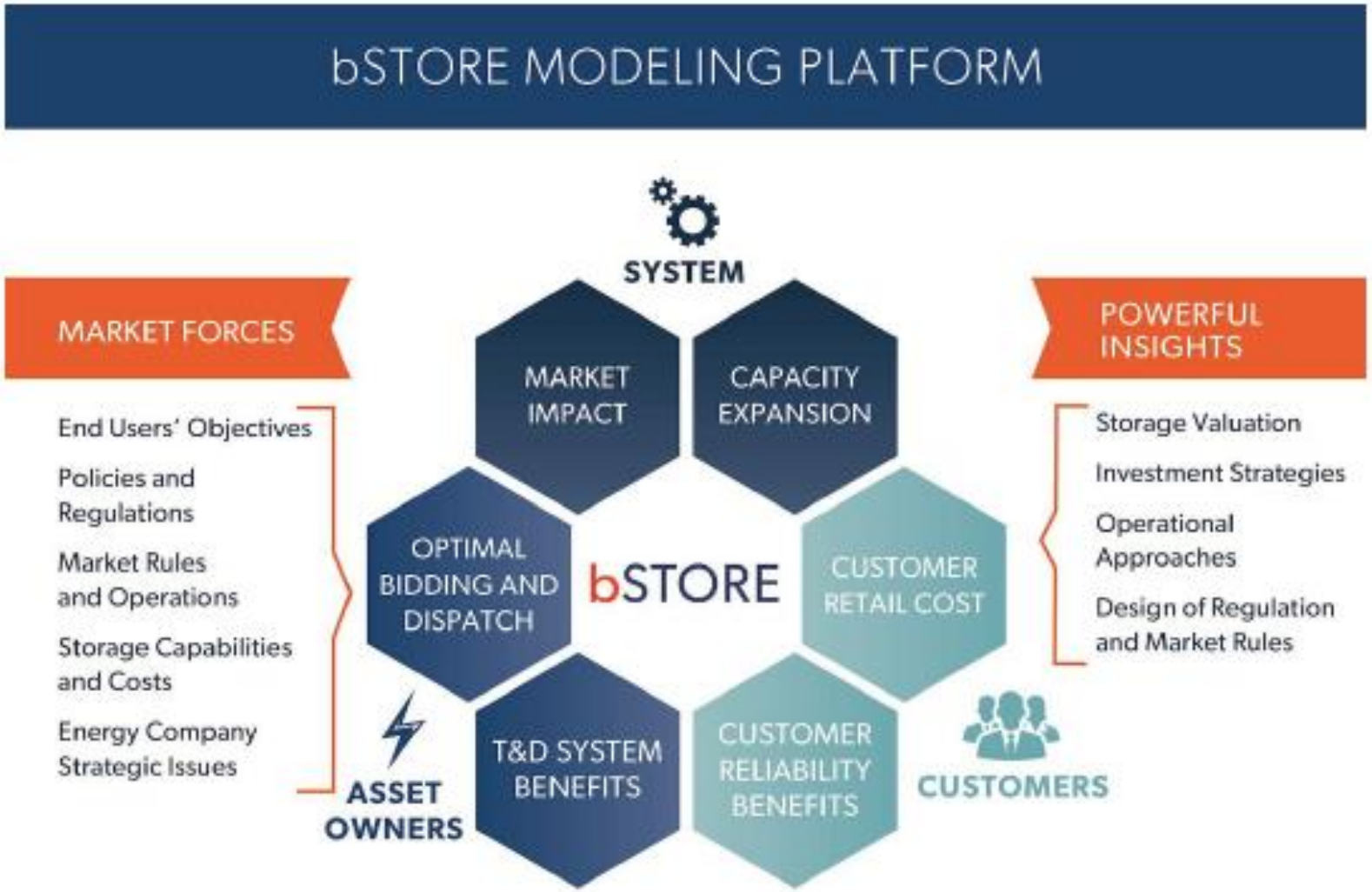
- Nodal unit commitment and economic dispatch model
- Hourly (or sub-hourly) nodal dispatch simulates detailed operational decisions

Power System Optimizer (PSO)

Detailed system operation in different market structures

- Hourly results for all generation and load in the region
- Simulation of RTO and energy imbalance markets
- Joint transmission tariff

bStore: Storage Valuation, Operations, and More



Link to Brattle's bSTORE website

Selected Past Capacity Expansion Engagements

Analysis of the Role of Zero Carbon Fuels in New York. For New York Independent System Operator (NYISO), Brattle used gridSIM to simulate the New York grid's transition to zero emissions by 2040, consistent with state mandates. The study considered the role of clean fuels, specifically renewable natural gas, to help balance the grid and meet reliability requirements. S

Rhode Island 100% Renewable Study. For the Rhode Island Office of Energy Resources, Brattle analyzed the renewable resources necessary to achieve the state's nation-leading goal of 100% renewable generation by 2030, and the implications for ratepayer costs, economic impacts, etc.

North Carolina Clean Energy Legislation. For Cypress Creek Renewables, Brattle analyzed alternative resource mixes for the Duke Energy Carolinas and Progress service territories that accelerate coal plant retirements and rely more heavily on renewable energy resources and battery storage compared to the 2020 IRP to inform debate on North Carolina clean energy legislation.

US Department of Energy Grid Interactive Buildings. For the US Department of Energy, Brattle is used the National gridSIM model to evaluate the future value of grid interactive and energy efficient buildings to reduce system costs, integrate renewables, and reduce emissions.

Incorporating EE and Other DERs into Resource Planning. For Electric Power Research Institute (EPRI), Brattle conducted a study to explore methods for incorporating DERs into integrated resource planning, including modeling DERs on the supply and demand side, synergies with EV and rooftop solar adoption, and impacts on renewables integration, and impacts of considering "non-traditional" DER benefits in planning simulations.

Life Extension for Diablo Canyon. For an environmental organization in CA in 2022, Brattle evaluated the net benefits of extending the operating life of the Diablo Canyon Nuclear Power Plant. We calibrated the base case in Brattle's gridSIM capacity expansion model to existing studies sponsored by CA state agencies, and estimated the impacts of retaining Diablo Canyon in terms of emissions, fixed and variable costs, and ability to meet both reliability objectives and clean energy goals.