The Transformation of the Power Sector to Clean Energy

ECONOMIC AND RELIABILITY CHALLENGES

PRESENTED TO

Power Engineers
4th Annual Power Symposium

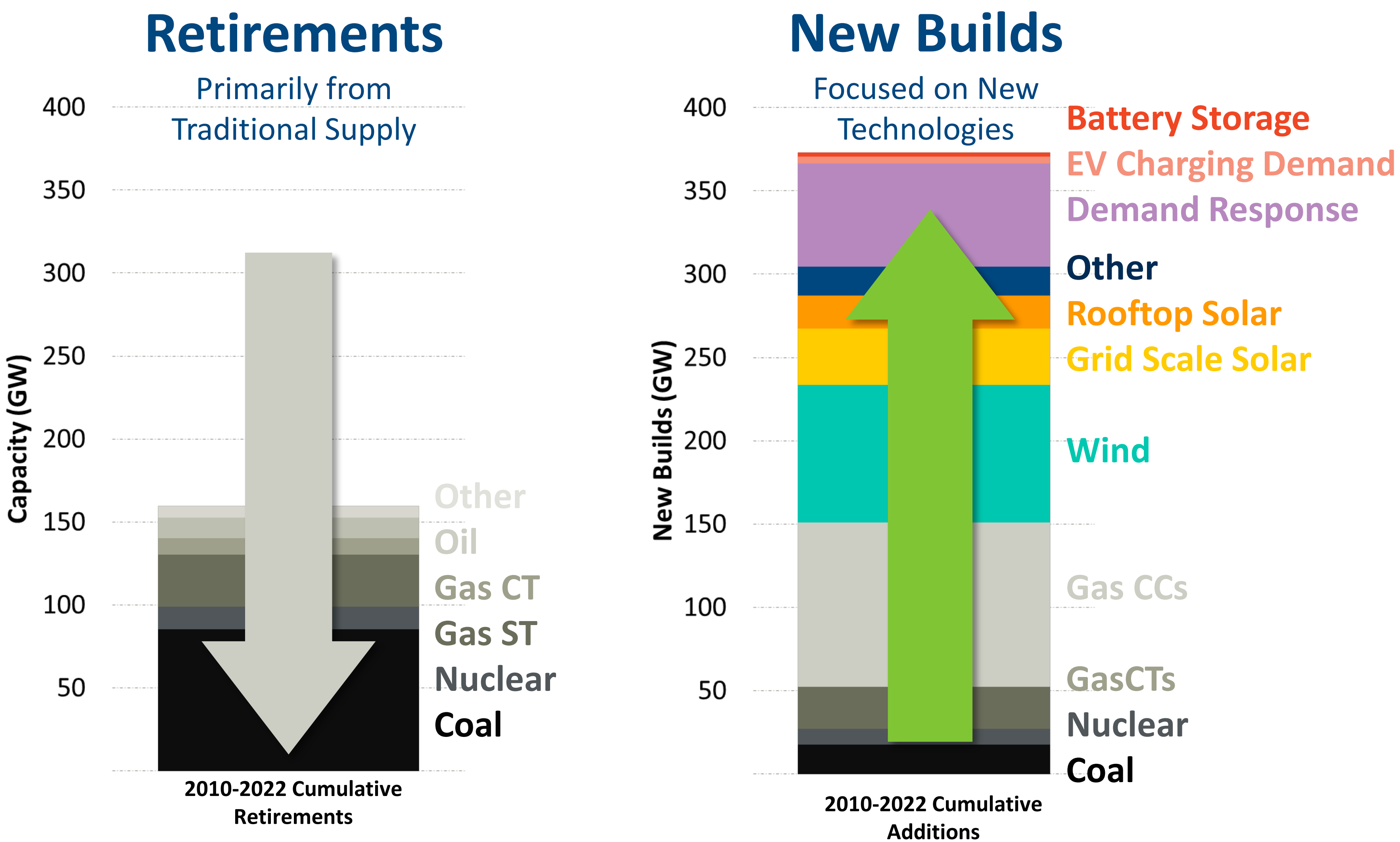
PRESENTED BY

Sam Newell

April 4, 2019

THE Brattle GROUP

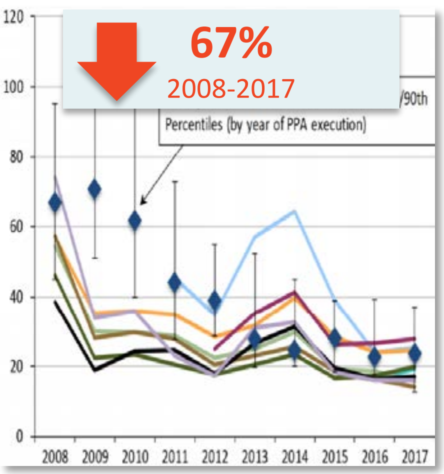
New Technologies & Engaged Customers Are Rapidly Overtaking Traditional Supply



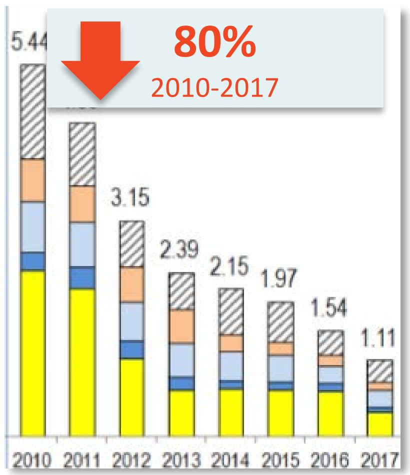
Sources: Energy Velocity Suite (US and Canadian generation) and Brattle research (US-only distributed resource and storage).

Technology Drivers: Declining Costs

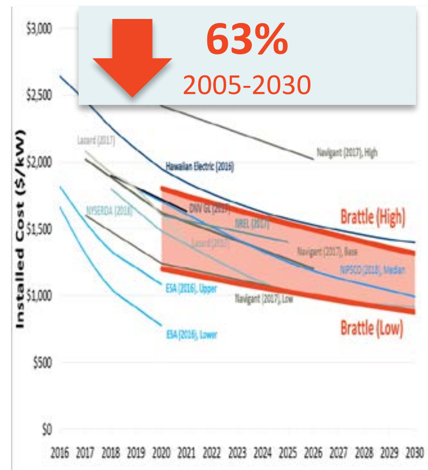
Wind



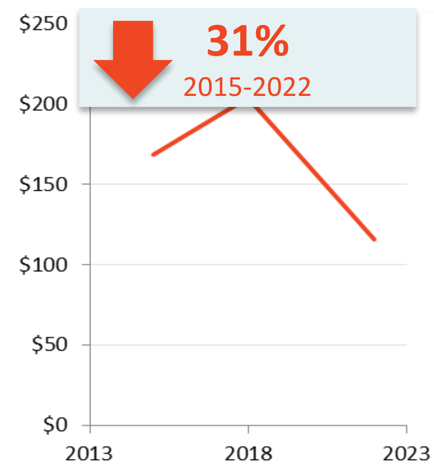
Solar



Batteries



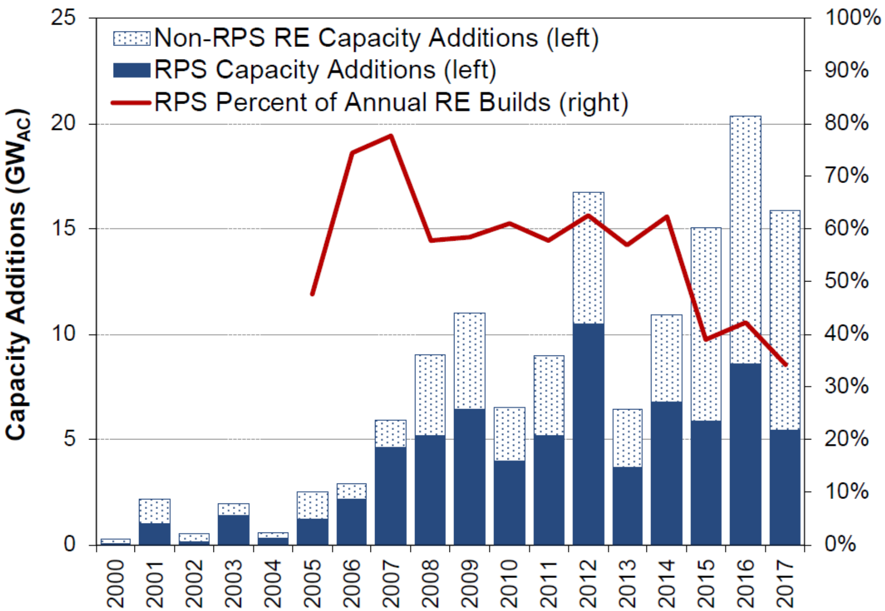
Gas CCs



Sources: Brattle research; LBL Wind Technologies Report 2017; PJM CONE Studies; NREL Q1 2017 PV Benchmark costs.

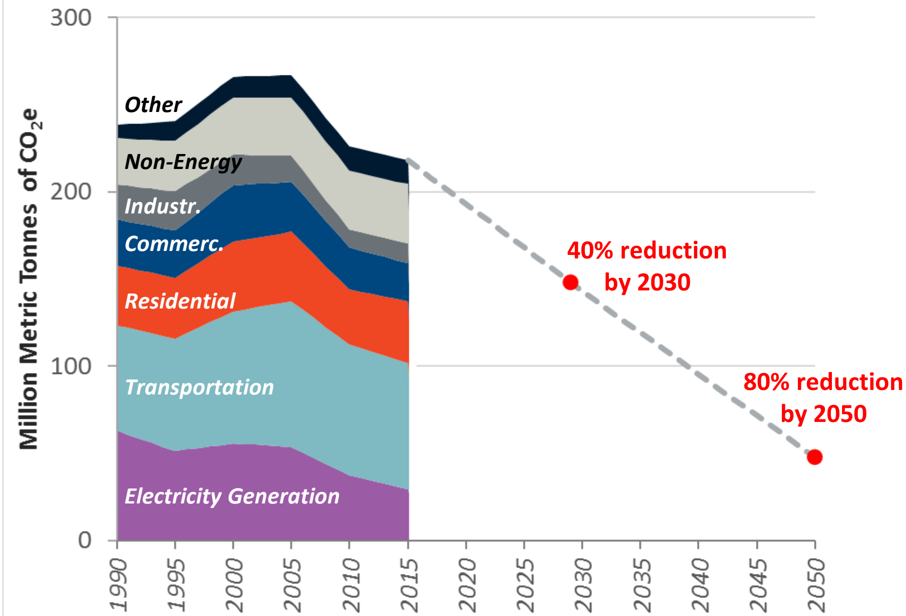
Policy and Customer Drivers

RPS and Non-RPS Renewable Growth



Source: Barbose, G., "U.S. Renewables Portfolio Standards: 2018 Annual Status Report," LBNL, November 2018.

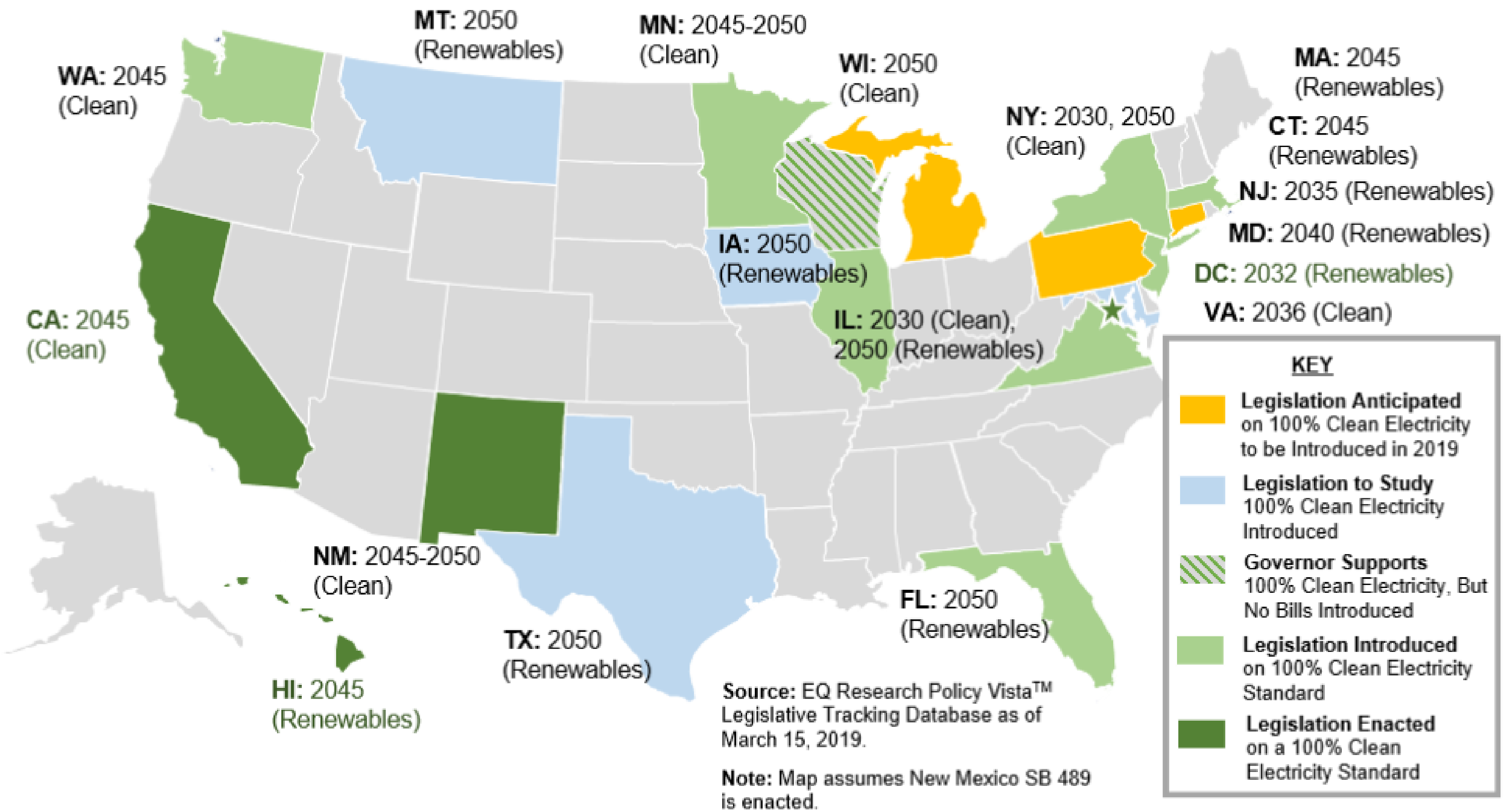
Decarbonization Goals: New York



Sources: New York DEC, "New York State Greenhouse Gas Inventory, 1990-2015," and Brattle Analysis.

100% Clean or Renewable Electricity Targets

Anticipated, Proposed or Enacted 100% Standards and Studies
As of March 2019



Source: EQ Research, LLC

How to Build So Much Clean Energy at Reasonable Costs?...Using Competition

More Regulation and Planning Oriented

More Reliant on Price Signals to Effectuate Broad Competition

Regulated Planning

PPAs

Clean Energy Attribute Markets

Carbon Pricing

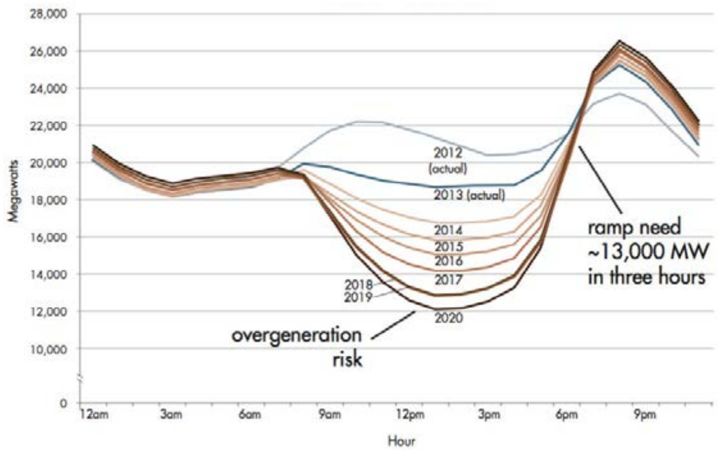
Are We Headed for Blackouts When the Sun Doesn't Shine or the Wind Dies?

Myths	Realities
Intuition may give a sense that the grid won't stay reliable unless we….	**It's not all hype. It will be a challenge to maintain reliability while going clean…**
• Save baseload plants from retirement • Save a specific "favored" plant • Stop building renewables • Build a gas pipeline • Impose on-site fuel requirements	• Customers & states want to go clean • But intermittent renewables require balancing and do not provide the same grid services as thermal plants • Market design can support operations and investment if ISOs define needed grid services and let all capable technologies compete to provide them; prices signal scarcity • Customers may prefer to save money by allowing a tiny bit higher risk of temporary supply shortages

Reliability Challenges w/Transforming Fleet

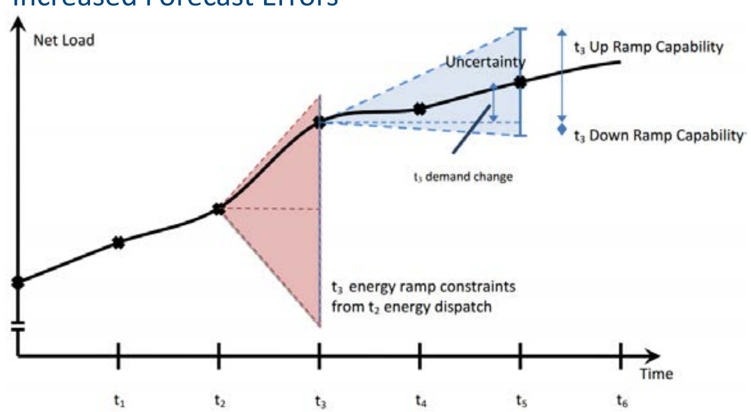
Operations

Increased Ramping



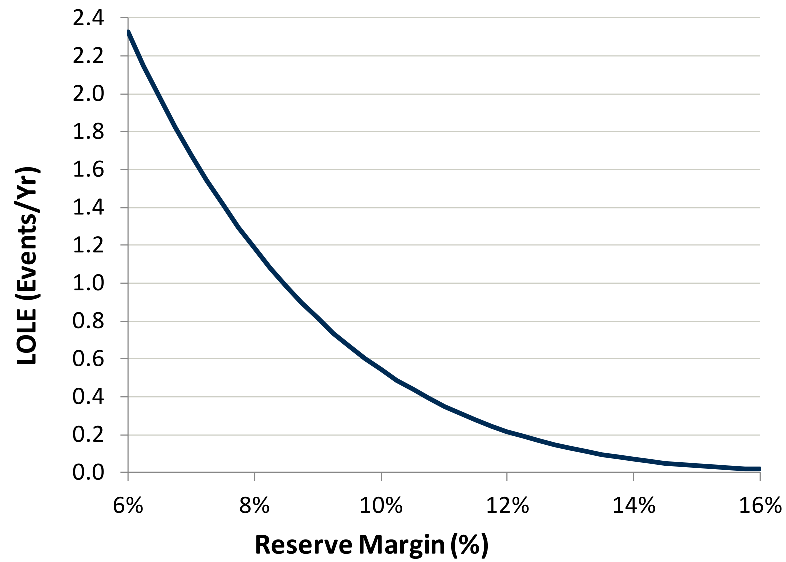
Source: CAISO

Increased Forecast Errors



Source: MISO. "Ramp Capability Product Design for MISO Markets," Dec 22, 2013

Resource Adequacy



Source: *Estimation of the Market Equilibrium and Economically Optimal Reserve Margins for the ERCOT Region*, prepared by The Brattle Group for ERCOT, Oct 12, 2018

"Resilience"

TBD by ISOs

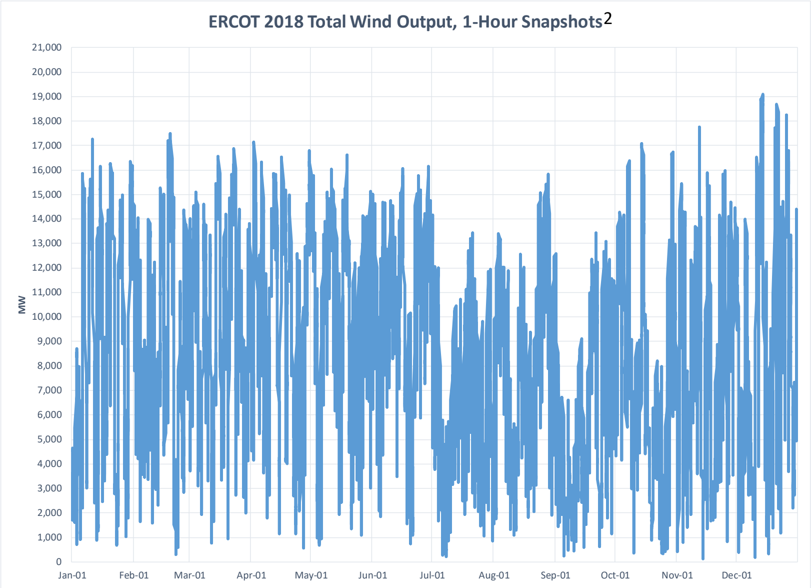
Operational Challenges...Being Met

ERCOT is managing with lots of variable wind

- 20% of annual energy, at times over 55%
- Achieving *higher* operational reliability[1]
- Supported by transmission (CREZ) and better forecasting / data
- Much more wind expected by 2022

Generally, higher penetration can work with:

- Advanced operations
- Enhanced energy and AS markets
- Transmission, and dynamic exchange with neighbors
- Complementary flexible resources (batteries, demand side, and natural gas)



Sources:
1.http://mis.ercot.com/misapp/GetReports.do?reportTypeId=13424&reportTitle=Hourly%20Aggregated%20Wind%20Output&showHTMLView=&mimicKey

2. https://www.eia.gov/conference/2018/pdf/presentations/beth_garza.pdf

Resource Adequacy and Investment

Intermittent renewables generate clean energy, but complementary resources must be attracted and retained to provide grid services

Challenges

- They provide little resource adequacy at high penetration
- They impose flex needs on the system and don't provide much flex themselves
- Their 0-variable costs depresses energy prices
- The major role of policy adds regulatory risk

Solutions

- Discount UCAP value
- Enhance E&AS products and scarcity pricing
- Allow other value streams to increase if scarce (next slide)
- Steadily follow long-term goals

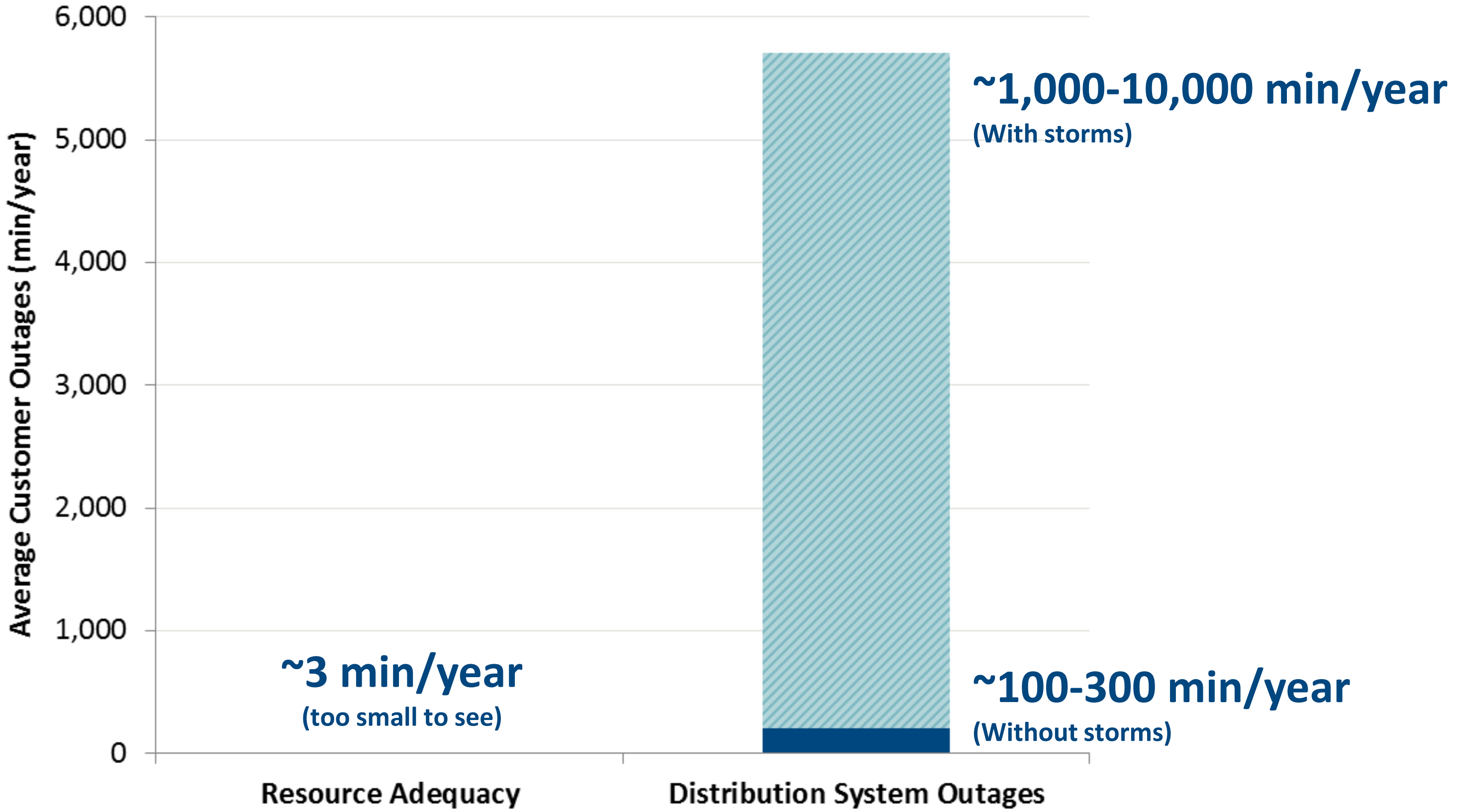
Revenue Sources Will Shift from Energy to Other Products and Services

Market	Value	Market Implications
Energy	↓	▪ Lower energy prices on average and in most hours ▪ But higher price spikes, driven by scarcity pricing, high reservation price for demand response/storage
Flexibility & Scarcity Pricing	↑	▪ Need for greater quantities and new types of flexibility products ▪ Higher price volatility and spikes reward flexibility
Capacity	↓↑	▪ Value may go up or down ▪ Down if additional clean energy contributes to excess supply for a period, or if new capacity sellers are attracted by other value streams ▪ Up if new fossil plants are needed for capacity, but only a small portion of their capital costs can be recovered from other markets
Carbon and Clean	↑	▪ Some form of CO_2 pricing and/or clean energy payments introduced to meet policy and/or customer demand ▪ Value must be large enough to attract new clean resources
Adjacent Consumer Products & Services	↑	▪ Technology and consumer-driver demand for adjacent products and services (smart home, electric vehicles) ▪ Participation may reside in wholesale, clean, and/or retail/distribution markets

- Scarcity of any service should lead to high prices and attract investment
- Any resource may provide a bundle of services
- The market should identify the least cost portfolio to meet the full suite of needs

Rethinking Resource Adequacy Standards

Supply shortages account for a tiny fraction of customer outages relative to distribution failures. Is the "optimal" amount of resource adequacy lower, particularly if it gets harder to achieve?



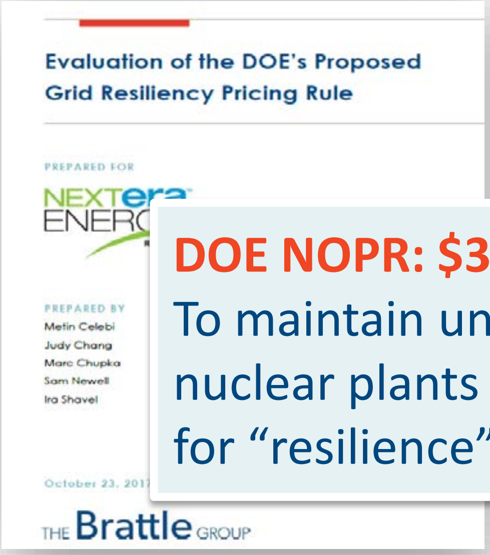
Resilience Challenges: What are they? DOE's Proposals Could Cost Billions

Proposals have been widely criticized:

- Threat scenarios are not clearly specified and lack analysis of the nature of those threats and how best to mitigate them
- Implicit assumption that specific resource types are the only solution
- Lacking mechanisms for competition to identify cheaper solutions
- Lacking benefit-cost analysis

Positive outcome of the DOE NOPR:

- Raised the question about threats
- Let ISOs identify their particular threats and evaluate solutions consistent with their market frameworks
- ISO-NE and PJM focus on winter security



DOE NOPR: $3-$11 Billion/year
To maintain uneconomic coal & nuclear plants in RTO regions for "resilience"

DOE Memo: $10-35 billion/year
To maintain uneconomic coal & nuclear plants nation-wide for "national security"

Sources: Celebi, *et al.* Evaluation of DOE's Proposed Grid Resiliency Pricing Rule, October 2017; and Celebi, *et al.* The Cost of Preventing Baseload Retirements, July 2018.

Takeaways: Cost-Effectively Meeting Both Reliability & Policy Goals is a Big Challenge...

...But one that can be addressed through:

- A transition to **market-based and market-compatible carbon and clean attribute mechanisms** to achieve state & customer carbon goals
- **Unbundling grid services** that were traditionally provided "free" as a byproduct of thermal generation, and defining grid services in a **technology-neutral** fashion
- Rigorous analysis of **reliability** needs & resources' reliability contributions, and of the **cost-effective level** of reliability we should aim for

PRESENTED BY

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Dr. Samuel Newell is a Principal and co-leader of The Brattle Group's Electricity Practice.

He has 20 years of experience supporting electricity industry clients in regulatory, litigation, and business strategy matters. His expertise is in wholesale electricity market design and analysis, generation and transmission asset valuation, and energy/environmental policy analysis. Most of his work is in the context of the industry's transformation to clean energy. Dr. Newell frequently provides testimony and expert reports to Independent System Operators (ISOs), the Federal Energy Regulatory Commission (FERC), state regulatory commissions, and the American Arbitration Association.

He earned a Ph.D. in Technology Management & Policy from the Massachusetts Institute of Technology, an M.S. in Materials Science & Engineering from Stanford University, and a B.A. in Chemistry & Physics from Harvard College.

Prior to joining Brattle in 2004, Dr. Newell was the Director of the Transmission Service at Cambridge Energy Research Associates. Before that, he was a Manager in the Utilities Practice at A.T. Kearney.

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- Energy Storage
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