

Market and Regulatory Advances in Electricity Storage

Can FERC Order 841, RTOs, States, and Utilities Unlock
a 50GW U.S. Storage Market?

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THE **Brattle** GROUP

Agenda

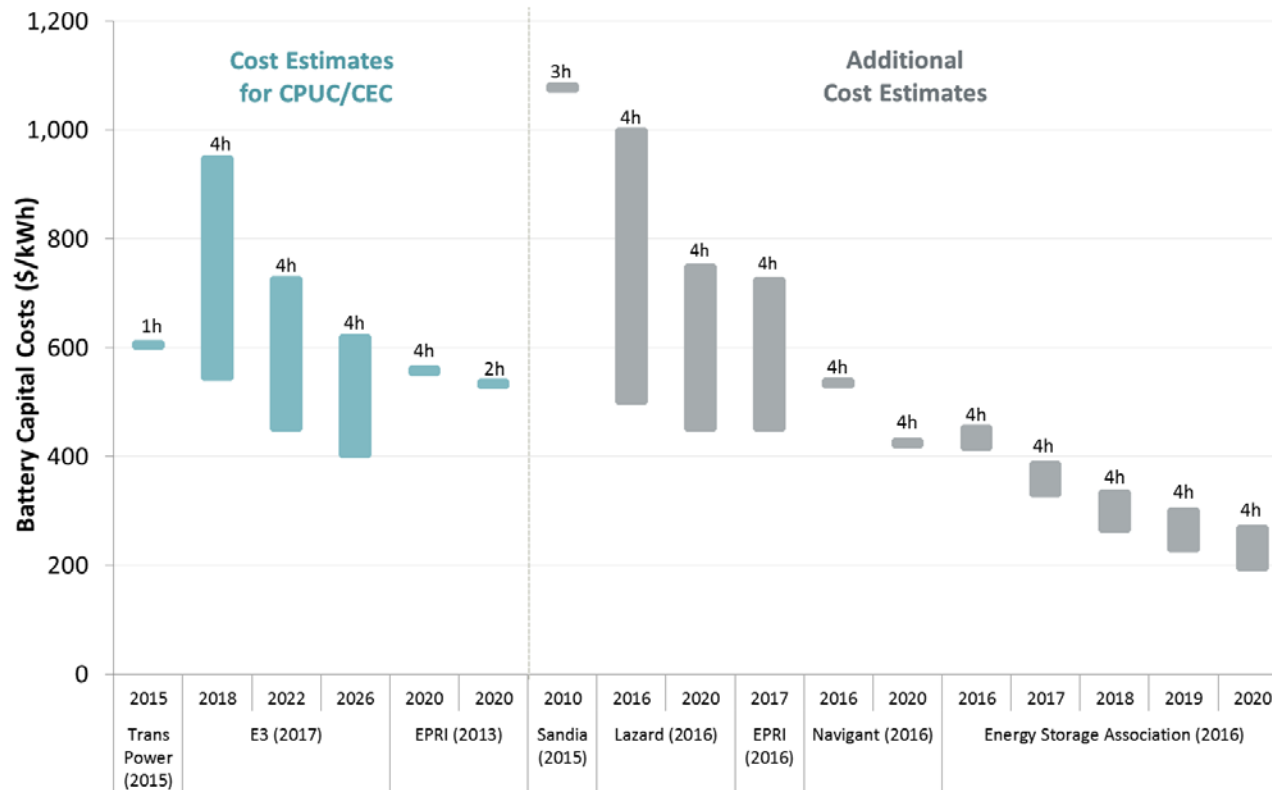
- **Advancing the Storage Value Proposition**
- **Advancing Wholesale Markets: FERC Order 841**
- **Advancing the Roles of State Policies**
- **Getting to 50 GW Storage Potential**
- **Optimizing Existing Storage Resources**
- **Final Thoughts**

Battery Storage: New Roles and Trends

Battery storage systems are gaining momentum as markets begin to recognize their capabilities and contributions. Industry trends favoring storage include:

- **Continued storage cost reductions and technology improvements** make some applications already cost-effective today; as costs fall further, storage will be transformative
- **Retail customers' preference focused on cost reduction and self-control**, including a desire to actively participate in electricity generation through DER
- **Focus on the “value stacking”** and growing recognition of storage's ability to capture multiple value streams
- **Innovative business models** that maximize storage's total value
- **Aggressive decarbonization goals in some regions** combined with electrification will require increasing amounts of electricity storage
- **Growing need for system flexibility** due to wind and solar growth and retirements of traditional generation resources

Battery Storage Costs are Declining Quickly



Notes:

All monetary values are in nominal dollars.

Years along axis represent installation date.

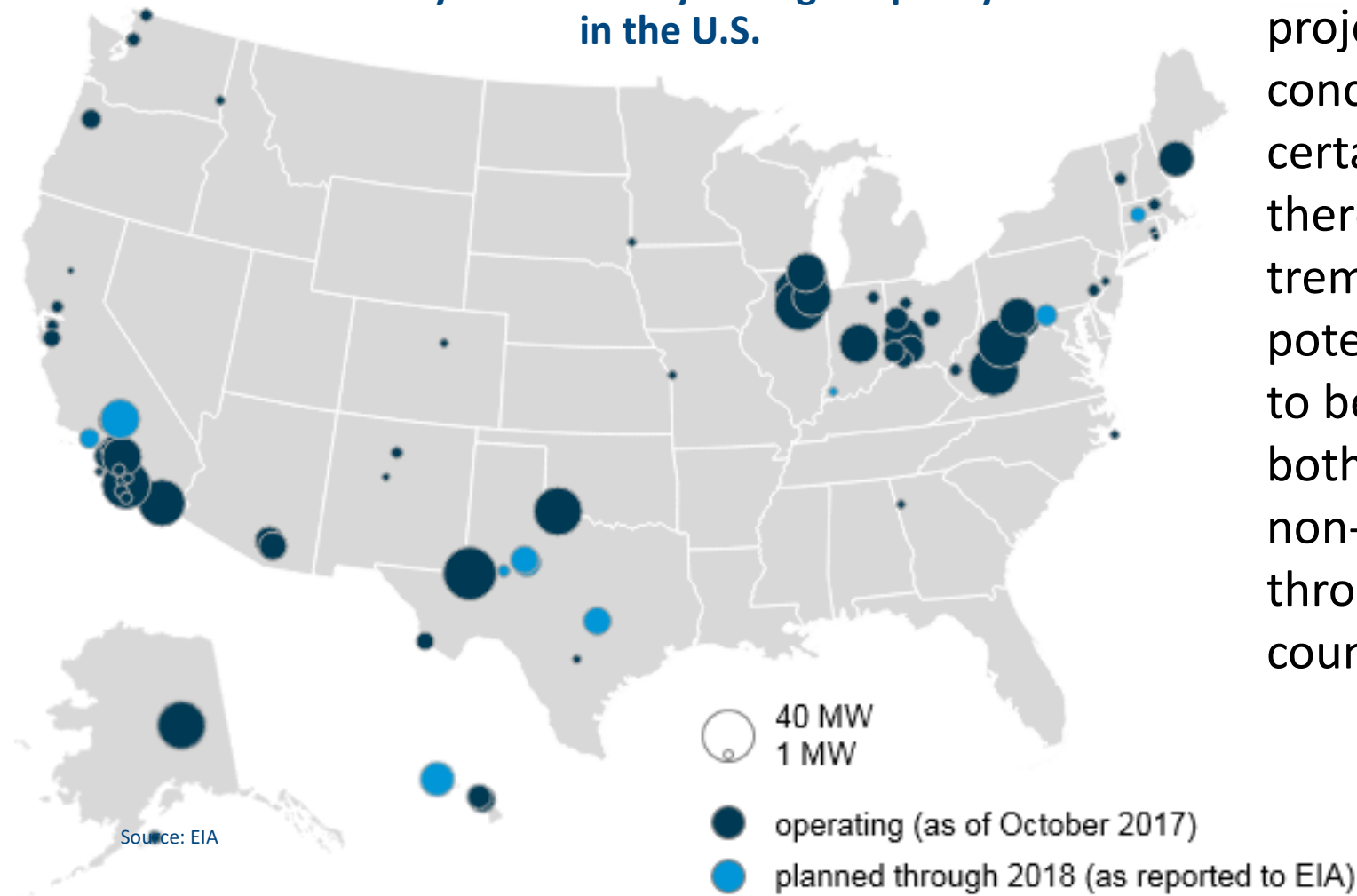
DNV Kema and Sandia studies assume a life of 15 years. The other studies all assume 10 years.

- Capital costs estimates range widely
- Projected to decline by 5 - 15% per year
- May differ due to components included in costs, duration, and asset life
- Annual costs include extended warranty and operating costs
- Many projects include augmentation services to maintain capacity

Example: Utility-Scale Battery Storage by 2018

Existing and Planned Utility-Scale Battery Storage Capacity in the U.S.

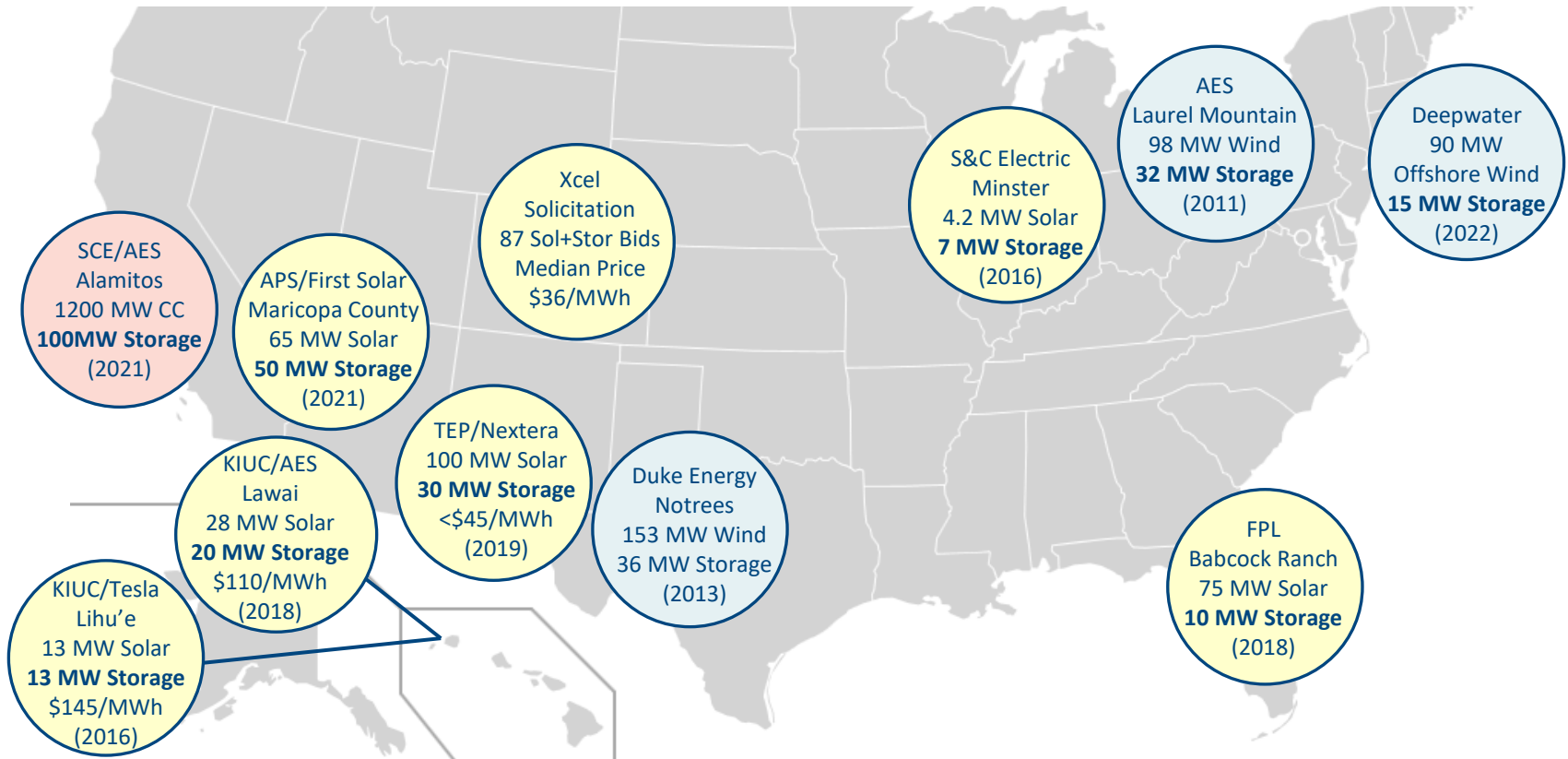
While current projects are concentrated in certain states, there is tremendous potential waiting to be unlocked in both RTO and non-RTO regions throughout the country



Example: Hybrid-Storage Developments

Significant activity in hybrid deployment of battery storage to tailor resource capabilities to market design and tax incentives

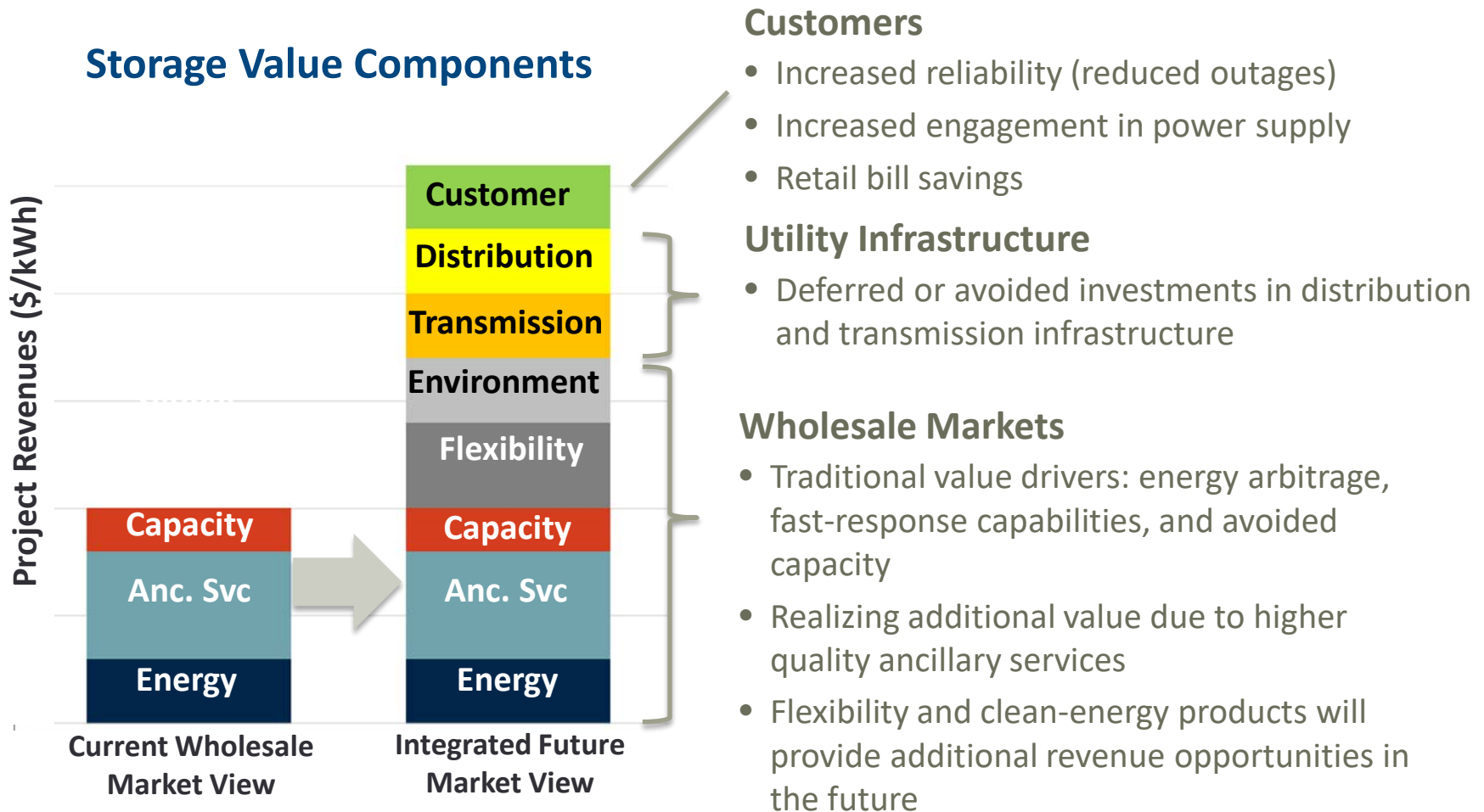
- **Solar+Storage**: most activity in California, the Southwest, and Hawaii
- Additional “hybrid” applications involve **wind+storage** or **gas+storage**



The Multiple Value Streams of Battery Storage

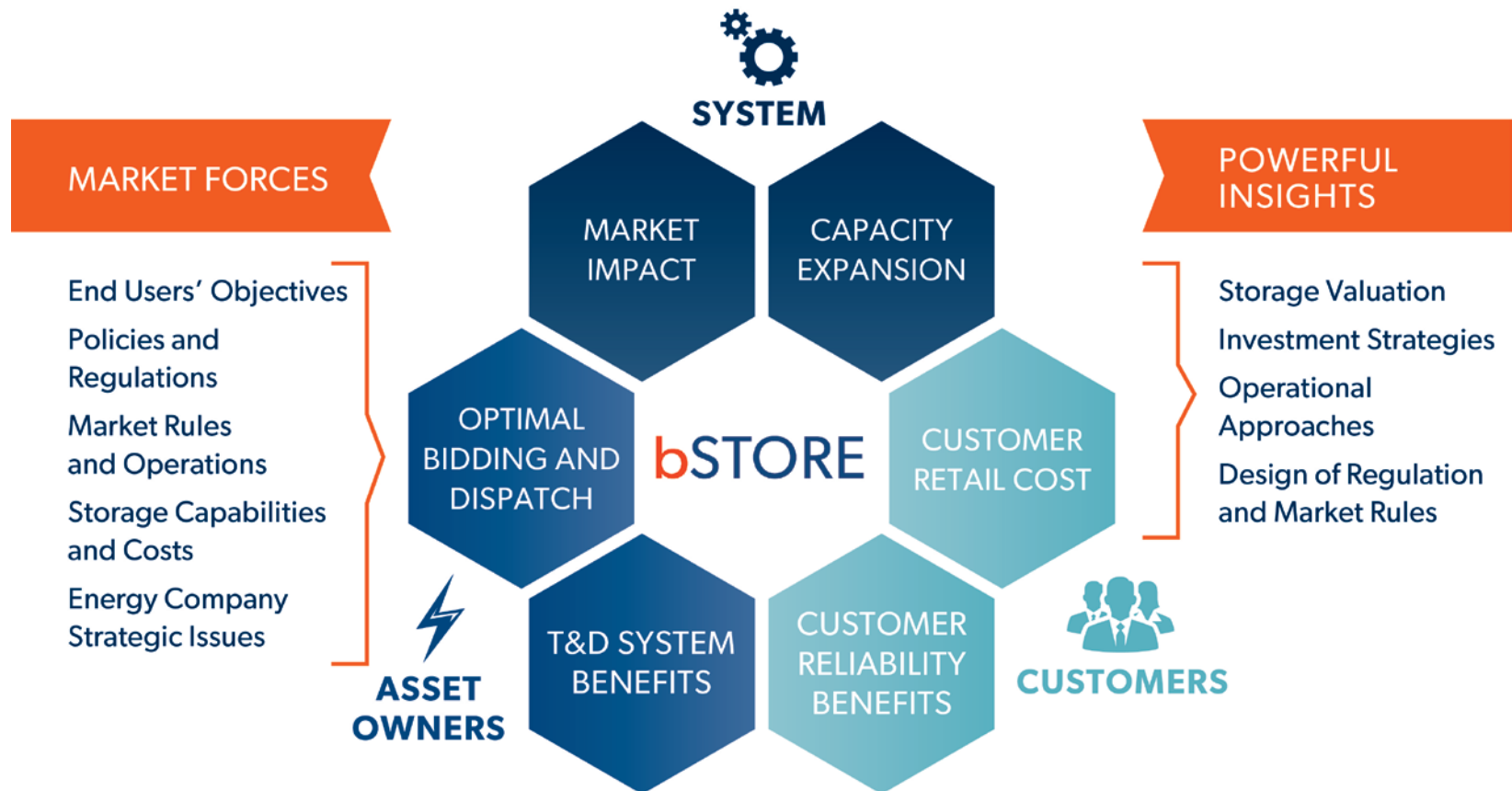
Maximizing storage's potential requires capturing multiple value streams.
New regulatory frameworks are needed.

Storage Value Components



New Tools to Assess Multiple Value Streams

bSTORE MODELING PLATFORM



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FERC Order 841: Addressing Wholesale Market Barriers

Order 841 will help storage compete to provide wholesale services on a level playing field with other technologies

Requires RTOs to establish a participation model that must:

- Ensure participating resources are eligible to provide **all capacity, energy, and ancillary services** the resource is technically capable to provide
- Execute all storage wholesale transactions **at locational marginal price**
- Ensure resource **can be dispatched and set wholesale prices**
- **Recognize physical and operational characteristics** of storage
- Establish a **minimum size requirement** that does not exceed 100 kW
- **Allow storage to de-rate capacity** to meet minimum run-time requirements

Respondents were generally supportive

- Noted their appreciation for FERC addressing storage's wholesale market topics
- RTOs noted their appreciation for the Order's implementation flexibility (some requests clarifications)

Order 841: Stakeholders' Responses

Stakeholders have already raised many questions in response to Order 841. A few have raised important regulatory questions, including:

- **Transmission charges** for energy used in charging storage
- **Interactions between federal and state** oversight of distributed energy storage
- **Jurisdiction over behind-the-meter storage** used for both retail and wholesale purposes
- **Responsibilities for ensuring distribution-level reliability** when distribution-connected storage's participation in wholesale markets has implications for the distribution system
- **Metering requirements for behind-the-meter storage** participating in wholesale market

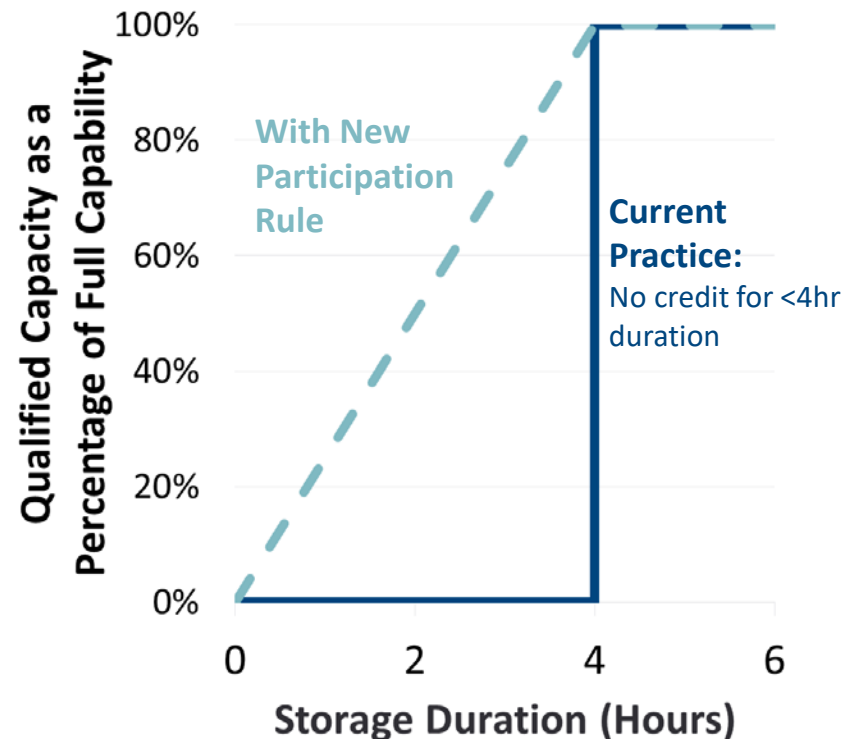
Resolving jurisdictional and control issues will be important to unlocking the full potential for storage's value proposition.

Market Design Implications

Capacity Market Value

- **RTOs will have the flexibility to determine their own min discharge duration to qualify as a capacity resource**
 - MISO and NYISO: Currently require 4 hours
 - PJM and ISO-NE: Primarily only allow long duration storage via performance incentives
- **New participation models will likely allow storage to set the capacity to meet minimum discharge duration requirement**
 - De-rates based on the MW storage can discharge continuously over the “minimum run-time”
- **Storage’s resource adequacy value will also vary based on market conditions, for example:**
 - Incremental capacity value decreases as more storage is added to the system
 - Observed in Brattle’s Texas storage study
 - Unforced capacity ratings would likely incorporate system needs and conditions

Illustrative Example: Storage Capacity Value Before and After 841



Sources:

MISO: Business Practices Manual 11, Section 4.2.4.1

NYISO: ICAP Manual, Section 4.8.2

Ancillary to 841: PJM's RegD Market

- **In 2015, PJM made changes to their RegD operations that:**
 - **Decreased the benefits factor** for all RegD resources in all hours and added a cap to RegD resources in some peak hours
 - **Altered the RegD signal**, changing the original energy-neutral logic and sometimes requiring Operators to manually move the RegD signal
- **Storage operators claimed signal changes harmed batteries by altering the “expected” charge and discharge cycle**
 - Some operators needed to derate battery capacity to preserve battery life
 - EDF derated McHenry Storage by 32%; AES claimed a “huge derate of MW capacity” (most companies’ derate amounts were confidential)
- **In March 2018, FERC ruled the PJM’s updated tariff is not acceptable**
 - PJM’s tariff must describe the calculation of the benefits factor curve
 - PJM’s tariff must also include signal parameters
 - FERC will lead a technical conference on regulation design

Market Design Implications

RTO Efforts to Incentivize Flexibility

Stakeholder initiative to explore flexibility enhancements in E&AS and capacity markets (work stream pursued alongside capacity market implementation)

5-min intertie scheduling, unbundled AS, new ramping product, scarcity pricing, footprint expansion for imbalance market

Increased regulation requirement to account for variability

Price cap at \$9,000/MWh, scarcity pricing, proposal to reform AS products (postponed/rejected)

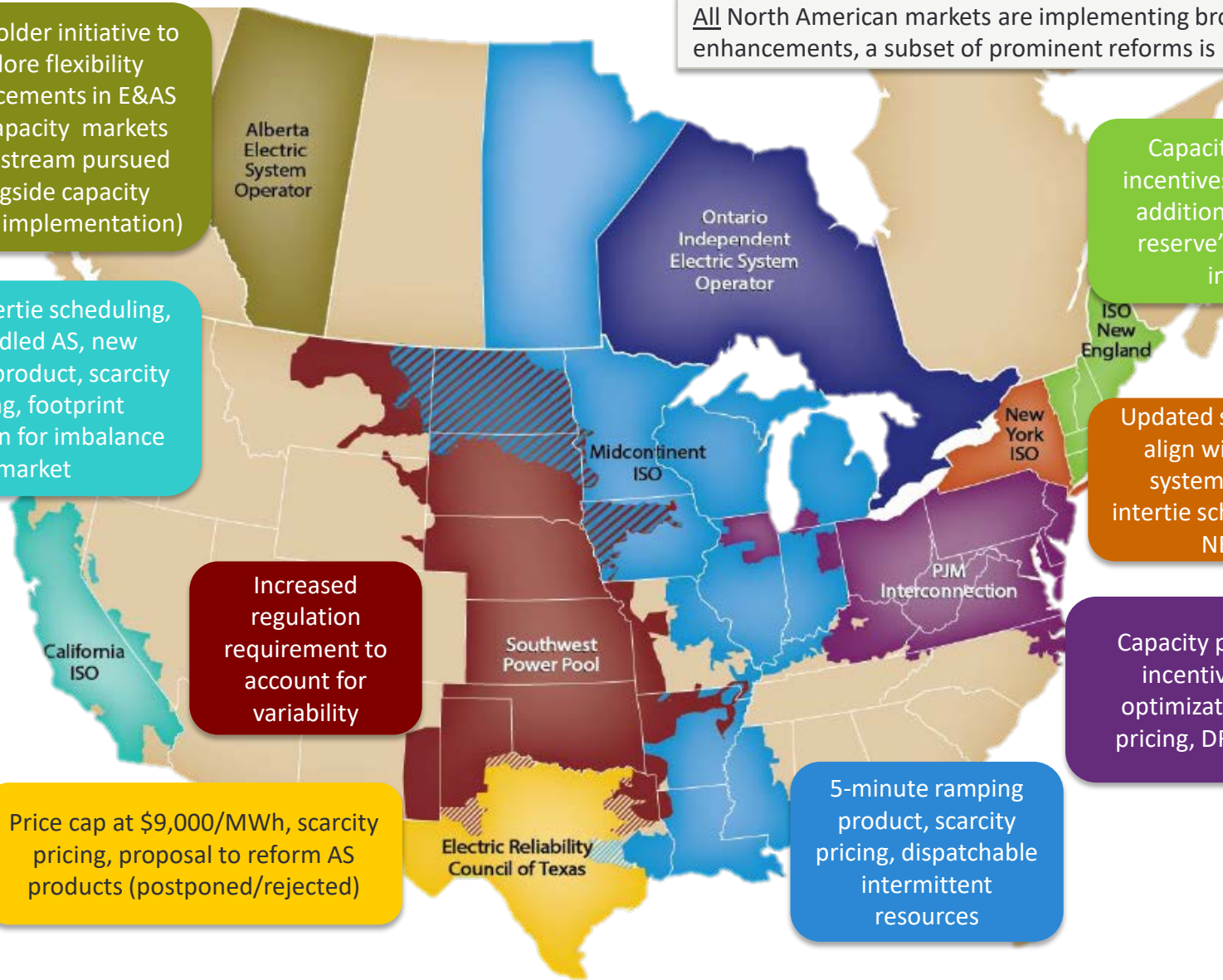
All North American markets are implementing broad flexibility enhancements, a subset of prominent reforms is reported here.

Capacity performance incentives, scarcity pricing, additional “replacement reserve” AS product, DR integration

Updated scarcity pricing to align with neighboring systems, coordinated intertie scheduling with ISO-NE and PJM

Capacity performance incentives, AS co-optimization, scarcity pricing, DR integration

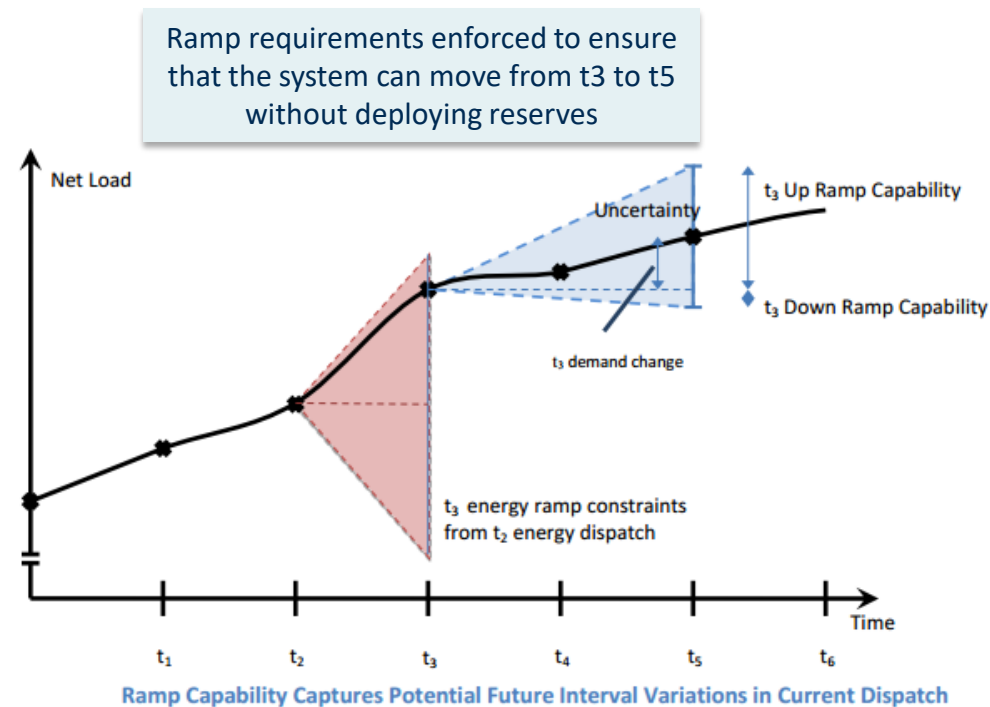
5-minute ramping product, scarcity pricing, dispatchable intermittent resources



Example of Flexibility Enhancements

- **MISO & CAISO added similar flexible ramp products in 2016**
 - Account for growing uncertainty in short-term net load forecasts due to growing wind and solar levels
 - Ensure sufficient ramp capability is held back for potential future net load levels
- **MISO's product**
 - Both day-ahead and real-time
 - Ensures each 5-min interval meets energy requirement
 - Holds back sufficient ramp capability for the subsequent 10 minutes
- **CAISO's product**
 - Designed to meet 5-min ramping need
 - Separate ramp-up and ramp-down products
 - Procured in real time, not day-ahead

MISO Ramp Capability Products



Sources:

Nivad Navid and Gary Rosenwald, [Ramp Capability Product Design for MISO Markets](#), July 10, 2013

MISO, [Business Practices Manual 002, Energy and Operating Reserve Markets](#)

Market Design Principles

Wholesale markets should remain as technology neutral as possible and maximize participation and encourage competition from all resources technically capable of providing needed services

Market prices should send clear signals for all resources to operate in a way that maximizes their value

Market rules should support efficient investment from resources that will create the most value at the lowest cost

For markets to remain efficient and sustainable, RTO reforms to incorporate storage should continue to follow fundamental design principles.

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State Regulators Play a Significant Role in Unleashing the Value of Storage

Beyond jurisdictional questions, state regulatory action are important to address T&D and customer-related barriers and benefits.

Topics include:

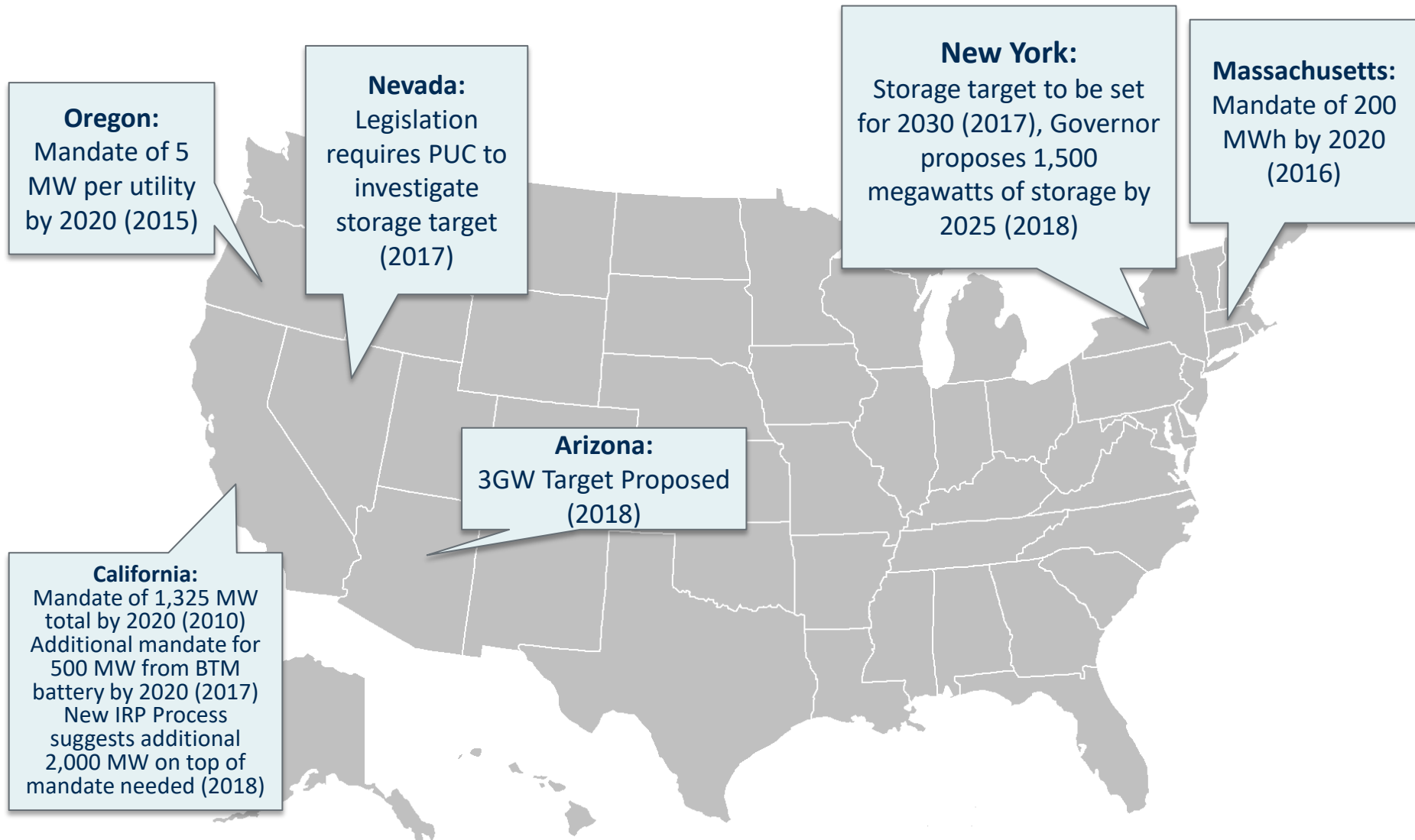
- Limitations on [utility ownership](#) and operation of storage
- Storage when considering [resource-adequacy](#) and T&D planning processes
- Methodologies for [valuing T&D](#) and customer level benefits
- [Procurement](#) processes and considerations for benefits of storage
- [Services](#) that distribution-connected and behind-the-meter storage can provide
- [Dispatch priority](#) for storage simultaneously providing multiple services (e.g., T&D reliability services vs. wholesale market participation)
- [Obligations and contracts](#): avoid double compensation for providing simultaneous services
- [Rate design](#)
- Eligibility for [Net Energy Metering](#)
- Eligibility to [aggregation](#) and participation in utility programs

Addressing T&D and Customer Value

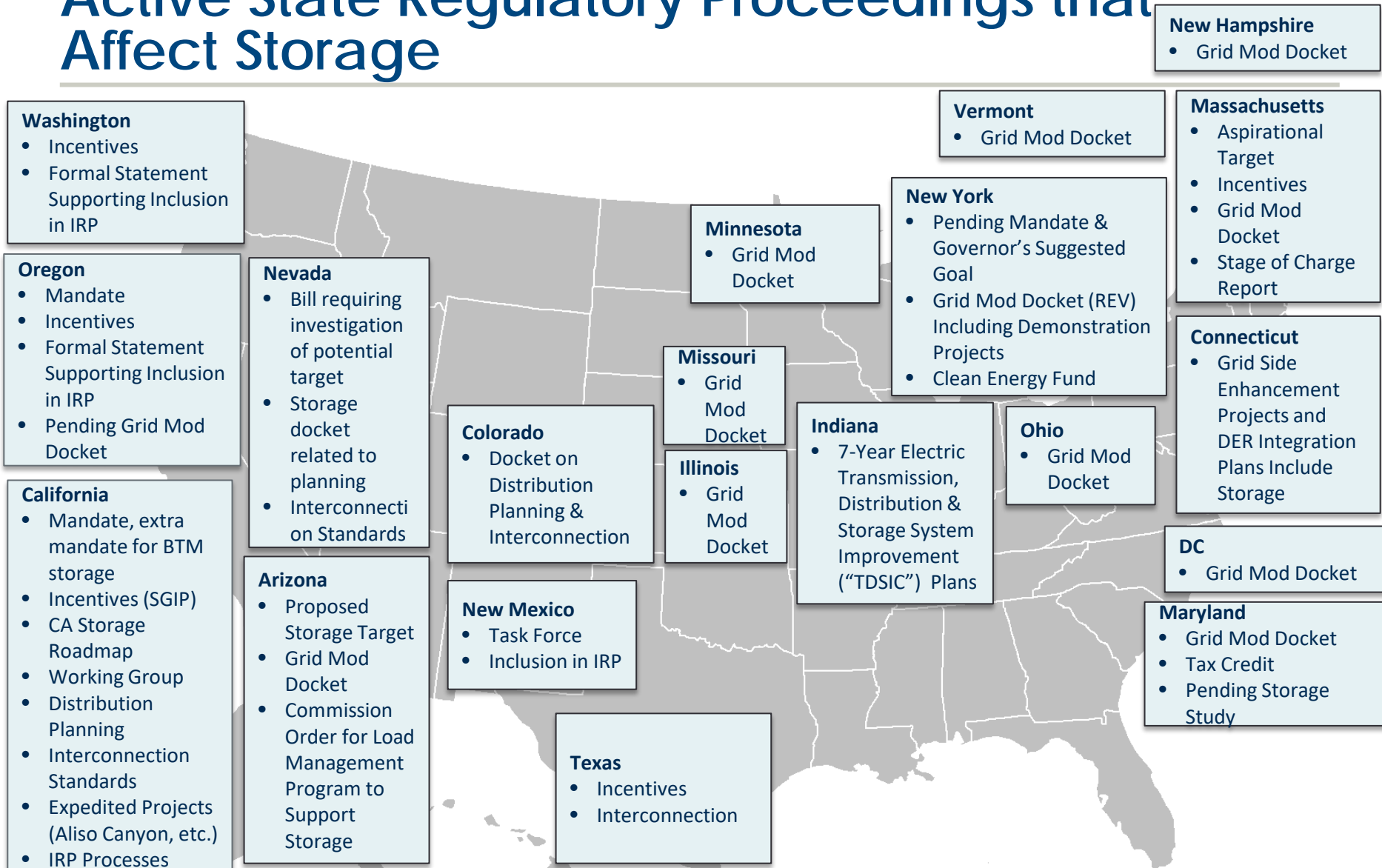
Order 841 addresses wholesale barriers, but state regulatory action is needed to address T&D and customer-related barriers and benefits.

- Unclear limitations on utility ownership and operation of storage
- Storage often not considered in resource-adequacy and T&D planning processes
- No well-defined and accepted methodology for valuing T&D and customer level benefits
- Storage procurements may not appropriately consider all benefits storage can provide
- Unclear what services distribution-connected and behind-the-meter storage can provide
- No clear definition of the dispatch priority for storage simultaneously providing multiple services (e.g., T&D reliability services vs. wholesale market participation)
- Risk of storage entering into conflicting obligations or contracts; need to avoid double compensation for providing mutually-exclusive services
- Need for more granular, cost-based, and stable rate design
- Unclear renewables+storage rules, such as eligibility for Net Energy Metering (NEM)
- Uncertainty on storage's eligibility to aggregate and participate in utility programs

Storage-Specific State Policies



Active State Regulatory Proceedings that Affect Storage



Note: Map illustrates notable policies and is not exhaustive. Grid Mod Docket refers to Grid Modernization Dockets- broad dockets that address changing technologies (usually including storage) and their impacts of utility planning, business models, or regulation. Image source same as previous slide.

Implications for Retail Rate Design

- As the cost of behind-the-meter (BTM) storage falls, retail rate design will become a key determinant of storage economics and utility impacts
- Many utilities are currently redesigning retail rates to address unintended subsidies of customers with rooftop solar
 - Often involves adding demand charges and/or time-varying energy charge
 - Also involves reducing compensation for net exports to the grid
- Avoidance of demand charges is one of the primary business cases for BTM storage among U.S. commercial and industrial customers
- The removal of feed-in tariffs for rooftop PV in countries like Germany, Spain, and the UK, has accelerated the development of BTM “solar+storage” markets
- If retail rates are not closely aligned with costs, customer bill reductions will exceed or fall short of avoided costs, creating barriers or making storage the recipient of unintended subsidies

Need to understand the tipping point at which BTM storage is likely to be adopted in large quantities under proposed rate design modifications

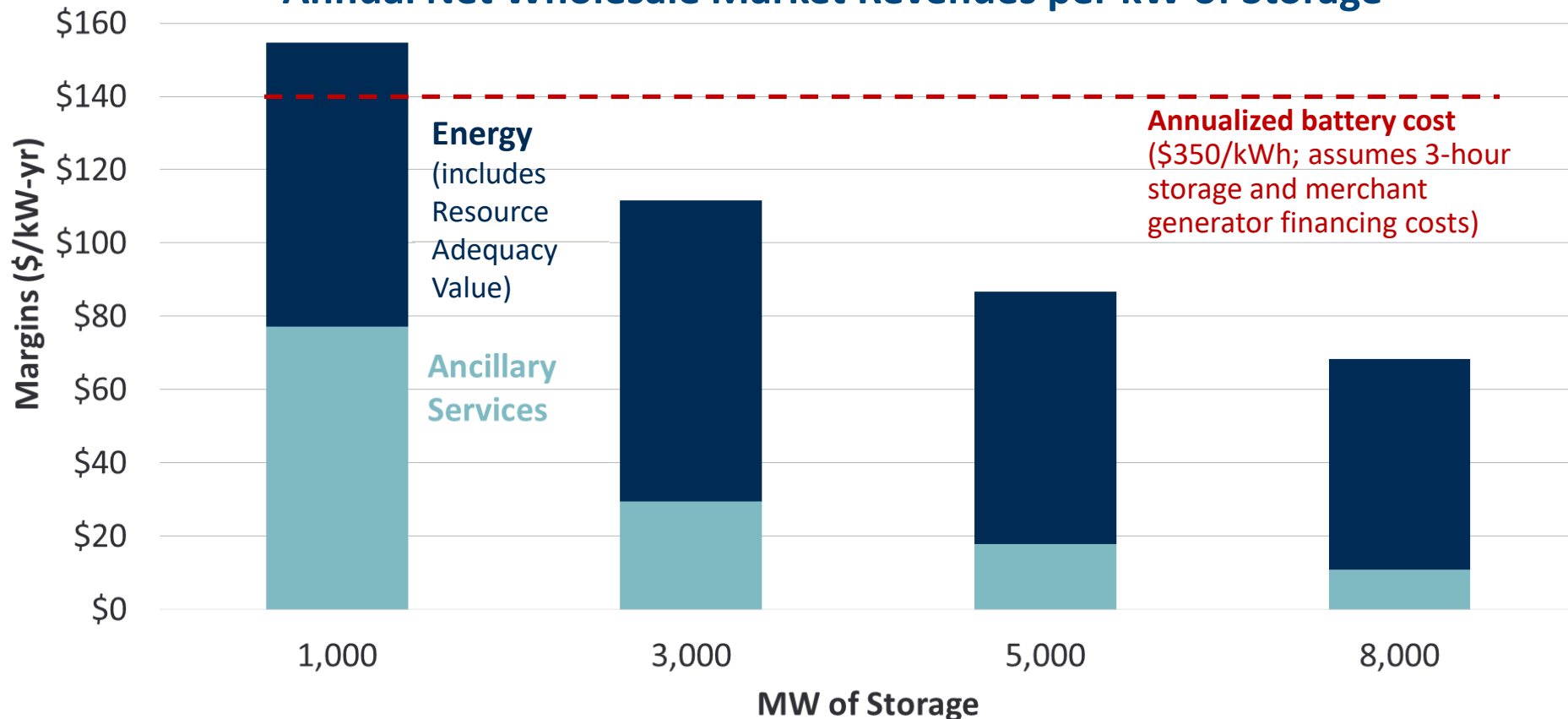
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Storage Wholesale-Market Value in ERCOT

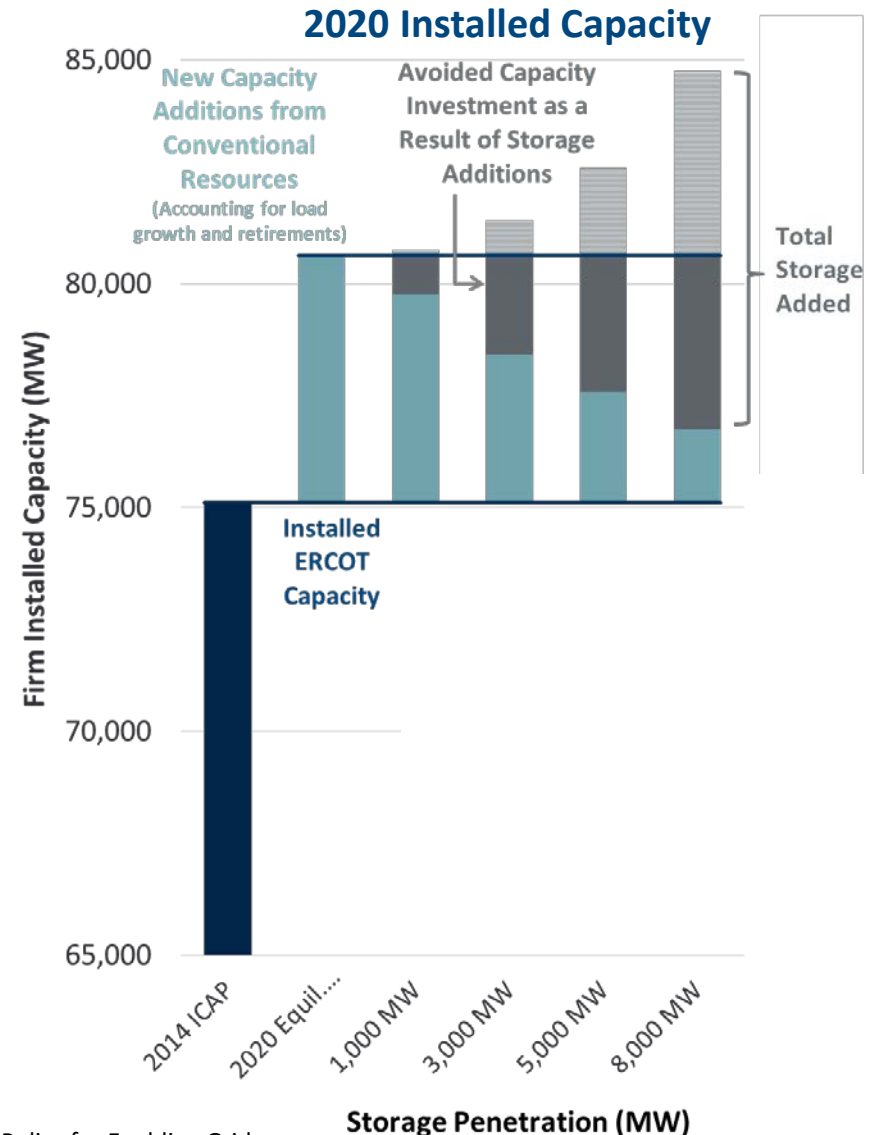
The wholesale market value exceeds costs of \$350/kWh for up to 1,000 MW of storage. Adding storage reduces that value as ancillary services get saturated.

Annual Net Wholesale Market Revenues per kW of Storage



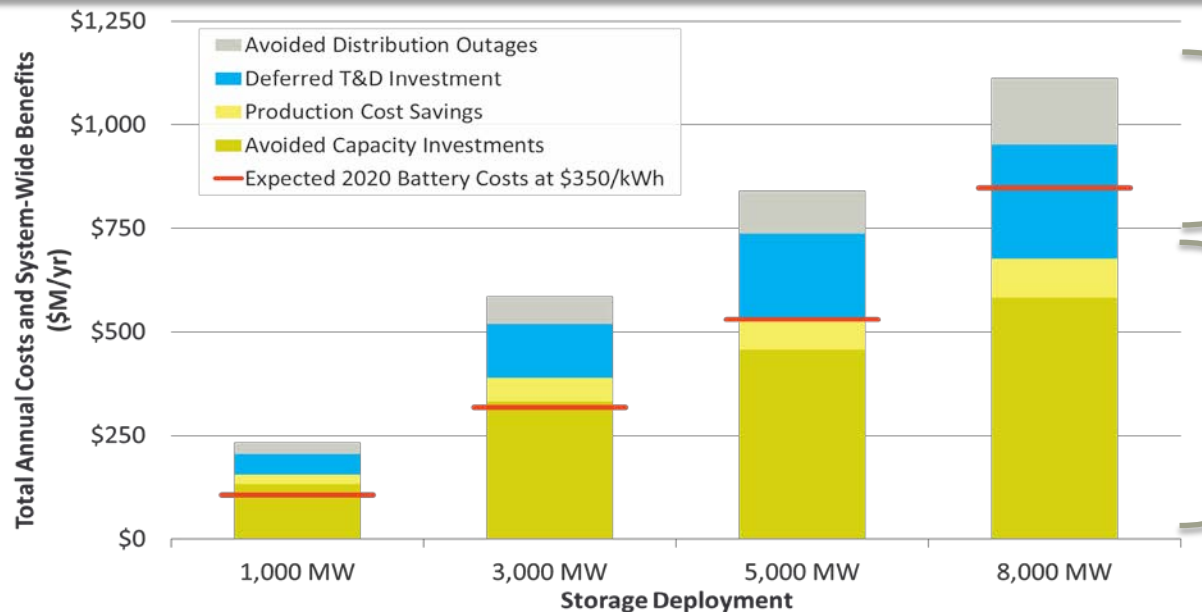
Capacity Value of Storage in ERCOT

- Detailed simulations of generation investment responses to storage deployment show that the capacity value of (energy-limited) storage declines with market penetration
- ERCOT example: resource adequacy value of 3-hour storage devices:
 - 1,000 MW of storage equivalent to 1,000 MW of conventional generation
 - 5,000 MW of storage has a resource adequacy value equivalent to 3,100 MW conventional generation
 - 8,000 MW equivalent to 4,500 MW



System-Wide Benefits in ERCOT

Incremental system-wide benefits exceed incremental costs for up to 5,000 MW. ~40% of benefits from T&D deferral and improved reliability.

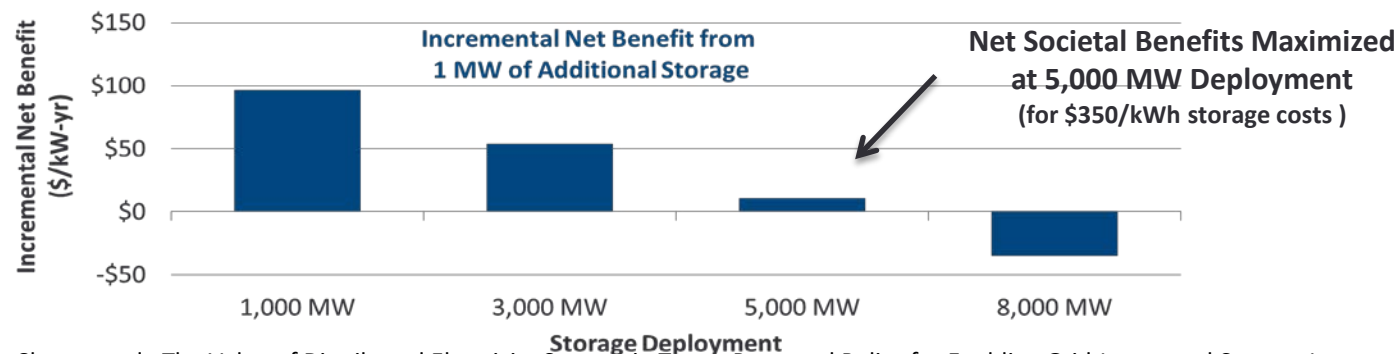


T&D and Customer Value

- Highest value opportunities if targeted to underperforming T&D circuits and customers with high outage costs

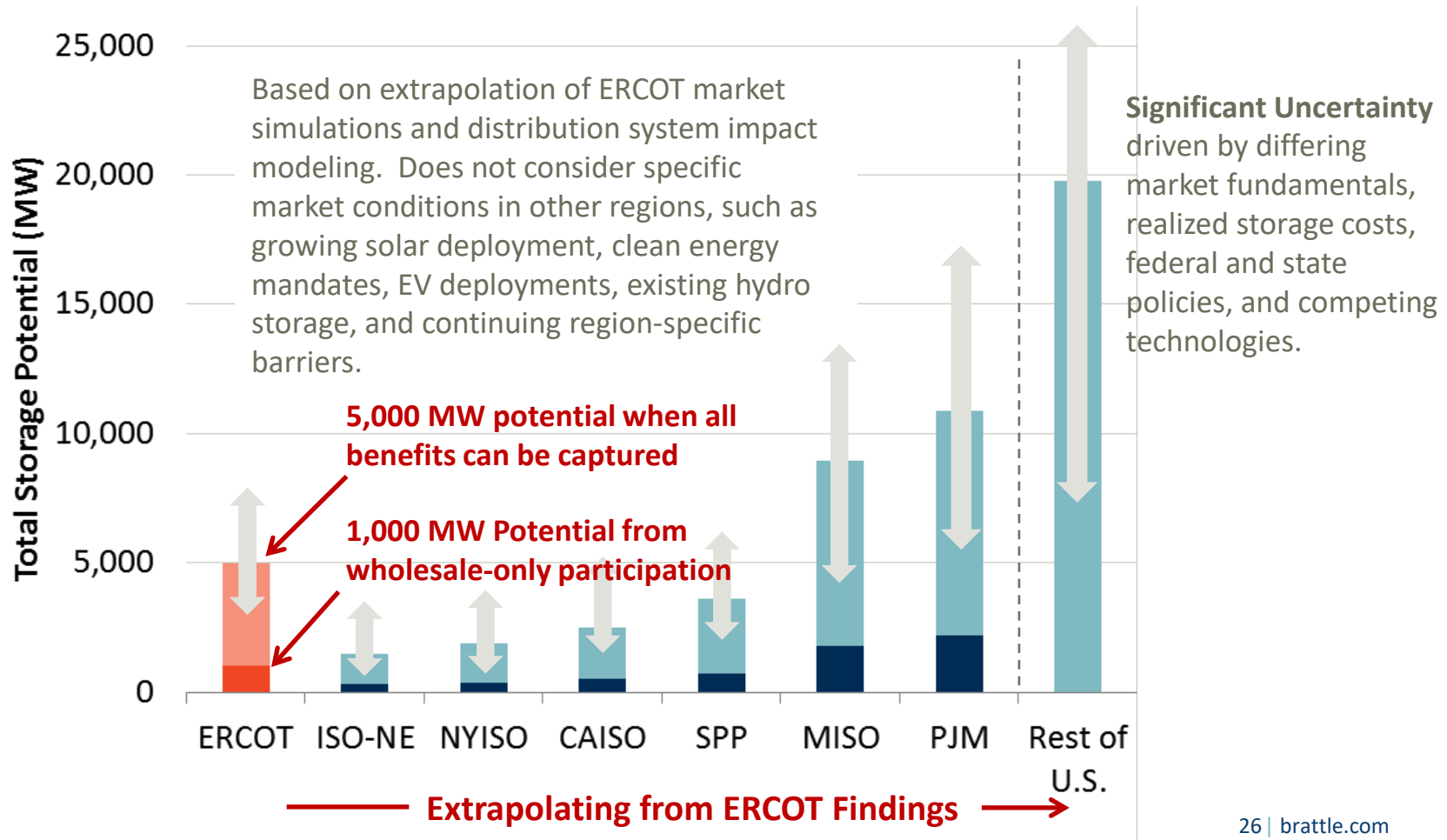
Merchant Value

- Highest-value opportunities (in particular ancillary services) saturate quickly as deployments rise



U.S.-Wide Storage Potential

Opportunities for storage could increase to 50,000 MW US-wide if all value can be captured. But this will require further action by the states.

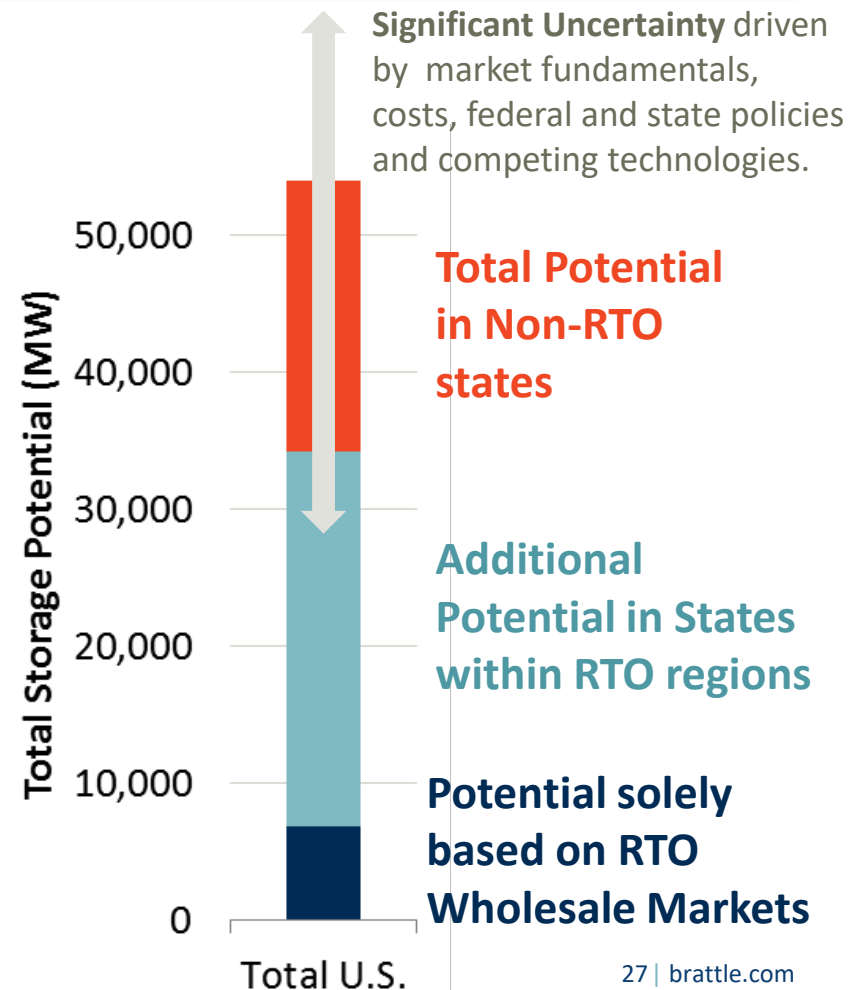


Notes: Extrapolated from ERCOT study based on average 2016 system load

Storage Potential in RTO and Non-RTO Areas

Integrated Resource Planning can affect the implementation of storage in many states, particularly those with high renewable deployment.

- Resource planning is beginning to recognize that storage can help utilities improve their systems' reliability and economics
- IRP evaluations do not yet capture the full value of storage
 - Do not capture full wholesale value
 - Do not generally address T&D and customer reliability value streams
- Much of the opportunities will depend on utility planning and states' views on the value of storage



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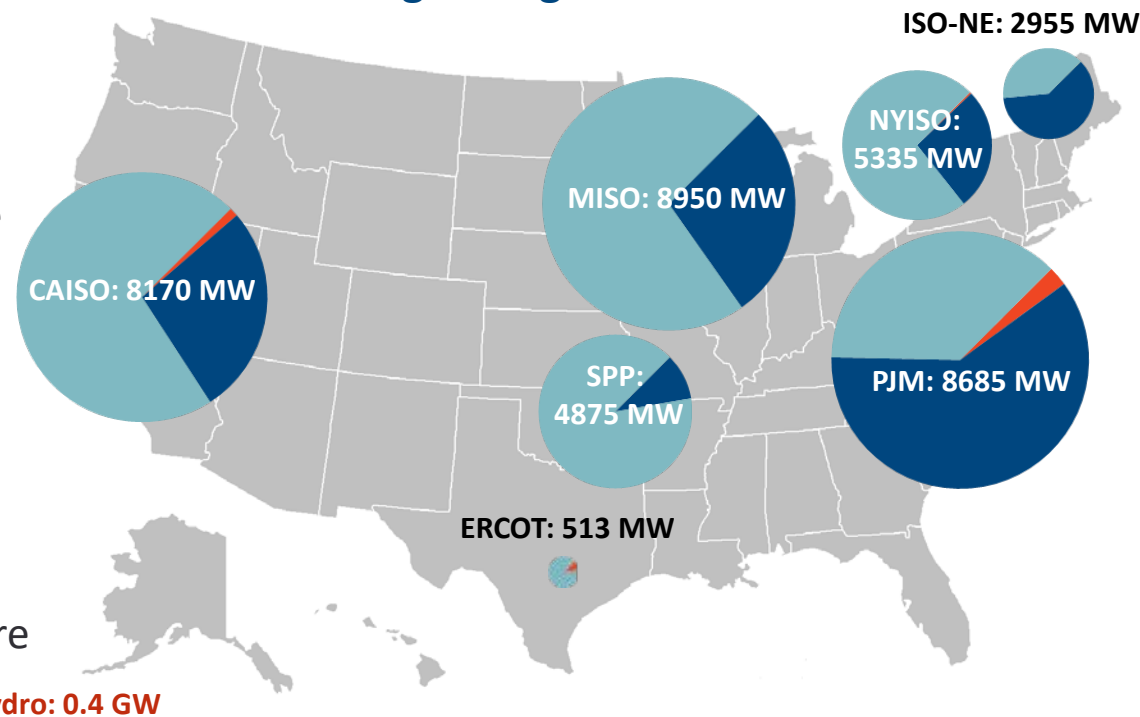
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Implications for Existing Storage Resources

Existing storage resources, mostly hydro, can provide substantial new capabilities if operated more flexibly than it is today.

- Increasing flexibility of existing hydro can be very valuable, reducing the need for new investments
- Currently, some existing hydro resources cannot or do not provide full benefits due to:
 - Lack of operational flexibility
 - Not located in markets that could most benefit from storage
 - Not in locations that provide T&D and customer benefits
 - Market rules or operations software limit participation

Existing Storage in RTO Markets



Non-Hydro: 0.4 GW

Storage Capacity
in U.S. RTO Areas

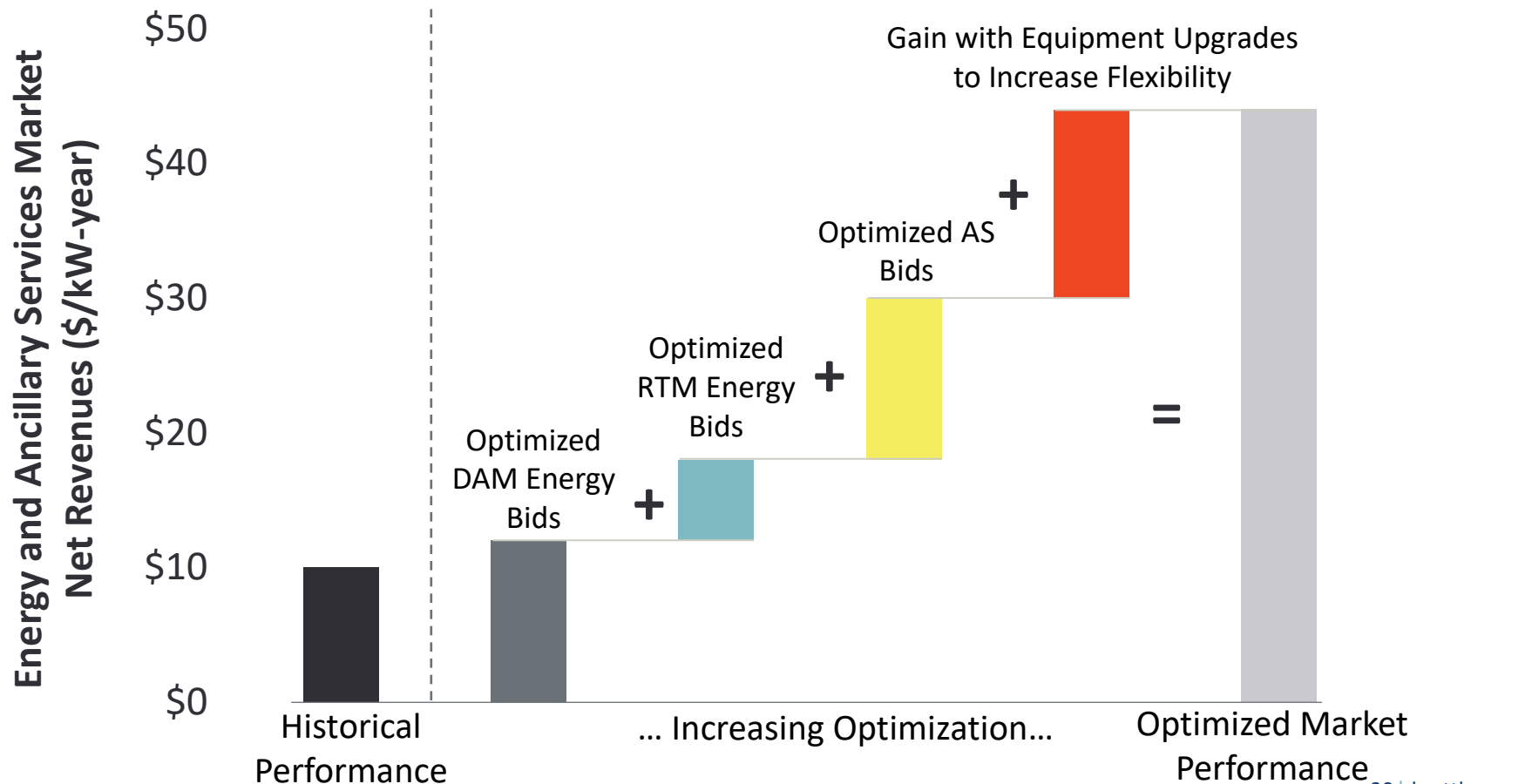
Pumped Hydro: 13.6 GW

Pondage and Reservoir Hydro: 25.5 GW

Increasing Value of Existing Storage Resources

Optimized operating strategies, accounting for existing market rules and DA/RT uncertainties, can increase storage revenues 2–5 times.

Analysis of Optimized Net Revenues of Large Pumped-Storage Hydro Plant



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Other Questions that will Affect Market Potential

- **How is storage competing or synergistic with other resources?**
 - Gas-fired combined cycles, combustion turbines, or diesel engines?
 - Demand response?
- **How can storage provide environmental value?**
 - Store excess (otherwise curtailed) renewable and clean energy?
 - Reduce inefficiencies of cycling fossil-fueled generators?
 - Reduce local air pollution in urban areas?
- **How is storage considered in retail rate design?**
 - How might storage shift costs between customers?
 - How do utilities and state regulatory commissions address incentives questions around customers' storage investments?
 - How do we avoid stranding investments in the future as storage costs decrease and retail rates change?
- **What is the role of regulated utilities?**
 - Should utilities (e.g., regulated wires companies) participate in storage initiatives?
 - Can utilities help the industry increase scale and move down the learning curve?
 - How can competitive forces be harnessed to provide utilities the right incentives?

Takeaways

Doubling the value of accessible storage benefits (or cutting storage costs in half) increases the storage market potential by a factor of 5!

As costs decline, the market potential for storage grows significantly

- At an installed cost of \$350/kWh, the estimated storage market would grow to:
 - ERCOT Study: 1,000 MW (3,000 MWh) in ERCOT solely based on wholesale market benefits, increases to 5,000 MW (15,000 MWh) if all value streams can be captured
 - 7,000 MW in U.S. RTO markets solely based on wholesale market benefits
 - 35,000 MW in U.S. RTO markets and 50,000 MW nation-wide if all value streams (wholesale markets, T&D, customer and outage reduction benefits) can be captured
- Despite the significant potential benefits, storage still faces economic, regulatory, and market barriers that limit its overall market potential
 - Costs are still relatively high today
 - FERC Order 841 is a helpful step in reducing barriers in wholesale markets
 - State policies and regulations will be necessary to unlock T&D and customer values
- Many important policy, market, and business-model questions will need to be addressed

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Additional Reading

[“Maximizing the Market Value of Flexible Hydro Generation”](#), Pablo Ruiz, James A. Read, Jr., Johannes Pfeifenberger, Roger Lueken, and Judy Chang, Comments in Response to DOE's Request for Information DE-FOA-0001886, April 4, 2018

[“Getting to 50 GW? The Role of FERC Order 841, RTOs, States, and Utilities in Unlocking Storage's Potential,”](#) Roger Lueken, Judy Chang, Johannes P. Pfeifenberger, Pablo Ruiz, and Heidi Bishop, Presented at Infocast Storage Week, February 22, 2018

[“Battery Storage Development: Regulatory and Market Environments,”](#) Michael Hagerty and Judy Chang, Presented to the Philadelphia Area Municipal Analyst Society, January 18, 2018

[“U.S. Federal and State Regulations: Opportunities and Challenges for Electricity Storage,”](#) Romkaew Broehm, Presented at BIT Congress, Inc.'s 7th World Congress of Smart Energy, November 2, 2017

[“Stacked Benefits: Comprehensively Valuing Battery Storage in California,”](#) Ryan Hledik, Roger Lueken, Colin McIntyre, and Heidi Bishop, Prepared for Eos Energy Storage, September 12, 2017

[“The Hidden Battery: Opportunities in Electric Water Heating,”](#) Ryan Hledik, Judy Chang, and Roger Lueken, Prepared for the National Rural Electric Cooperative Association (NRECA), the Natural Resources Defense Council (NRDC), and the Peak Load Management Alliance (PLMA), February 10, 2016

[“Impacts of Distributed Storage on Electricity Markets, Utility Operations, and Customers,”](#) Johannes Pfeifenberger, Judy Chang, Kathleen Spees, and Matthew Davis, Presented at the 2015 MIT Energy Initiative Associate Member Symposium, May 1, 2015

[“The Value of Distributed Electricity Storage in Texas - Proposed Policy for Enabling Grid-Integrated Storage Investments,”](#) Ioanna Karkatsouli, James Mashal, Lauren Regan, Judy Chang, Matthew Davis, Johannes Pfeifenberger, and Kathleen Spees, Prepared for Oncor, March 2015

About The Brattle Group

The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governmental agencies worldwide.

We combine in-depth industry experience and rigorous analyses to help clients answer complex economic and financial questions in litigation and regulation, develop strategies for changing markets, and make critical business decisions.

Our services to the electric power industry include:

- Climate Change Policy and Planning
- Cost of Capital
- Demand Forecasting Methodology
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
- Fuel and Power Procurement
- Incentive Regulation
- Rate Design and Cost Allocation
- Regulatory Strategy and Litigation Support
- Renewables
- Resource Planning
- Retail Access and Restructuring
- Risk Management
- Market-Based Rates
- Market Design and Competitive Analysis
- Mergers and Acquisitions
- Transmission

Brattle's Storage Experience

Asset Valuation

- Valuing and sizing renewables + storage facilities
- Valuing storage across multiple value streams
- Developing bid/offer strategies to maximize value
- Accommodating storage into IRPs
- Supporting due diligence efforts of investors

Market Intelligence

- The state and federal policy landscape
- Electricity market fundamentals and opportunities
- Storage cost and technology trends
- Current and emerging business models

Policy, Regulatory, and Market Design

- Wholesale market design
- Market and regulatory barriers
- Utility ownership and operation models
- Retail rate implications of distributed storage
- Implications of storage on wholesale markets

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