Getting to 50 GW?
The Role of FERC Order 841, RTOs, States, and Utilities in Unlocking Storage’s Potential

PREPARED BY
Roger Lueken
Judy Chang
Hannes Pfeifenberger
Pablo Ruiz
Heidi Bishop

February 22, 2018
Agenda

- The Storage Value Proposition
- FERC Order 841
- The Role of States
- Getting to 50 GW Storage Potential
- Optimizing Existing Storage
Industry Trends Favor Storage

- **Continued storage cost reductions and technology improvements** as other technologies have matured. Some applications already cost-effective today, but 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 the marketplace through DER.

- **Focus on the “value stacking”** and growing recognition of storage’s multiple values throughout the delivery chain.

- **Innovative business models** that maximize storage’s total value.

- **Aggressive decarbonization goals in some regions** combined with electrification and the potential that storage will enable low carbon systems.

- **Growing need for system flexibility** due to wind and solar growth and retirements of traditional generation resources.

Storage is increasingly recognized to be integral to the future power system.
Battery Storage Capital Cost Projections

- 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

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.
Battery Storage Value Streams

Maximizing storage’s potential requires capturing multiple value streams. But new regulatory frameworks are needed to capture all value.

Storage Value Components

Customers
- Increased reliability
- Increased engagement in power supply
- Retail bill savings

Utility Infrastructure
- Deferred or avoided investments in distribution and transmission infrastructure

Wholesale Markets
- Traditional value drivers: energy arbitrage, fast-response capabilities, and avoided capacity
- Realizing additional value due to higher quality A/S
- Flexibility products provides additional revenue opportunities

Maximizing storage’s potential requires capturing multiple value streams. But new regulatory frameworks are needed to capture all value.
Assessing Multiple Value Streams

bSTORE MODELING PLATFORM

MARKET FORCES
- End Users’ Objectives
- Policies and Regulations
- Market Rules and Operations
- Storage Capabilities and Costs
- Energy Company Strategic Issues

SYSTEM
- Market Impact
- Capacity Expansion
- Optimal Bidding and Dispatch
- T&D System Benefits
- Customer Reliability Benefits
- Customer Retail Cost

POWERFUL INSIGHTS
- Storage Valuation
- Investment Strategies
- Operational Approaches
- Design of Regulation and Market Rules

www.brattle.com/storage
Agenda

- The Storage Value Proposition
- FERC Order 841
- The Role of States
- Getting to 50 GW Storage Potential
- Optimizing Existing Storage
FERC Order 841: Addressing Wholesale Market Barriers

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 the wholesale price
- 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

Order 841 Implementation by the RTOs

RTOs have flexibility to:

- Establish **new ancillary service products**
- Set appropriate **minimum run-time requirements** for storage
- **Establish bidding parameters** to accommodate storage’s physical and operational characteristics
- Enable storage to **self-manage its state of charge**
- Determine if storage can **sell ancillary services without participating in the energy markets**
- **Address technical details**, e.g. storage make-whole payments and managing conflicting dispatch instructions

How RTOs implement Order 841 will directly affect storage’s market value.
Looking Beyond Order 841

Order 841 does not force RTOs to:
- Change technical requirements, testing, or compensation mechanisms for existing products
- Introduce new products (e.g. ramping products or PJM-style fast regulation)
- Exempt storage from performance requirements (e.g. Capacity Performance)

Neither does Order 841 address state/retail level challenges
- State policy and regulatory initiatives will need to build on FERC Order 841
- Need to reduce barriers to capturing distribution and customer benefits
- Need to avoid over-payment for services that cannot be provided simultaneously
Agenda

- The Storage Value Proposition
- FERC Order 841
- The Role of States
- Getting to 50 GW Storage Potential
- Optimizing Existing Storage
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

State Storage Policy: Mandates

**California:** Mandate of 1,325 MW total by 2020 (2010)

**Oregon:** Mandate of 5 MW per utility by 2020 (2015)

**Nevada:** Legislation requires PUC to investigate storage target (2017)

**Arizona:** Legislation requires PUC to investigate storage target (2017)

**Massachusetts:** Mandate of 200 MWh by 2020 (2016)

**New York:** Storage target to be set for 2030 (2017), Governor proposes 1,500 megawatts of storage by 2025 (2018)

State Storage Policy: Active Proceedings

Washington
- Incentives
- Formal Statement Supporting Inclusion in IRP

Oregon
- Mandate
- Incentives
- Formal Statement Supporting Inclusion in IRP
- Pending Grid Mod Docket

California
- Mandate
- Incentives (SGIP)
- CA Storage Roadmap
- Working Group
- Distribution Planning
- Interconnection Standards
- Expedited Projects (Aliso Canyon, etc.)

Arizona
- Proposed Storage Target
- Grid Mod Docket
- Commission Order for Load Management Program to Support Storage

Colorado
- Docket on Distribution Planning & Interconnection

Minnesota
- Grid Mod Docket

Missouri
- Grid Mod Docket

New Mexico
- Task Force
- Inclusion in IRP

Texas
- Incentives
- Interconnection

New Hampshire
- Grid Mod Docket

Massachusetts
- Aspirational Target
- Incentives
- Grid Mod Docket
- Stage of Charge Report

Connecticut
- Grid Side Enhancement Projects and DER Integration Plans include Storage

New York
- Pending Mandate & Governor’s Suggested Goal
- Grid Mod Docket (REV) Including Demonstration Projects
- Clean Energy Fund

Vermont
- Grid Mod Docket

Maryland
- Grid Mod Docket
- Tax Credit
- Pending Storage Study

DC
- Grid Mod Docket

Ohio
- Grid Mod Docket

Indiana
- 7-Year Electric Transmission, Distribution & Storage System Improvement (“TDSIC”) Plans

New Hampshire
- Grid Mod Docket

Note: Map illustrates notable policies and is not exhaustive. Grid Mod Docket refers to Grid Modernization Dockets - broad docket 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.
Agenda

- The Storage Value Proposition
- FERC Order 841
- The Role of States
- Getting to 50 GW Storage Potential
- Optimizing Existing Storage
Merchant value exceeds costs for up to 1,000 MW of storage. At larger scales, the wholesale value falls as ancillary service markets are saturated.

**Annual Net Wholesale Market Revenues per kW of Storage (2020)**

<table>
<thead>
<tr>
<th>MW of Storage</th>
<th>Energy Margin ($/kW-yr)</th>
<th>Ancillary Services Margin ($/kW-yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>$120</td>
<td>$50</td>
</tr>
<tr>
<td>3,000</td>
<td>$90</td>
<td>$70</td>
</tr>
<tr>
<td>5,000</td>
<td>$60</td>
<td>$90</td>
</tr>
<tr>
<td>8,000</td>
<td>$30</td>
<td>$120</td>
</tr>
</tbody>
</table>

**Annualized battery cost** ($350/kWh; assumes 3-hour storage and merchant generator financing costs)

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

At a cost of $350/kWh (installed), Order 841 could unlock 7,000 MW based solely on wholesale market participation in RTOs. This increases to 50,000 MW if all benefits can be captured, but will require states to unlock T&D and customer benefits.

Based on extrapolation of ERCOT market simulations and distribution system impact modeling. Does not consider specific market conditions in other regions, such as growing solar deployment, clean energy mandates, EV deployments, existing hydro storage, and continuing region-specific barriers.

Significant Uncertainty driven by differing market fundamentals, realized storage costs, federal and state policies, and competing technologies.

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

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

Significant Uncertainty driven by market fundamentals, costs, federal and state policies and competing technologies.
Agenda

- The Storage Value Proposition
- FERC Order 841
- The Role of States
- Getting to 50 GW Storage Potential
- Optimizing Existing Storage
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

- **Pumped Hydro:** 13.6 GW
- **Pondage and Reservoir Hydro:** 25.5 GW
- **Non-Hydro:** 0.4 GW

### Storage Capacity in U.S. RTO Areas

- **CAISO:** 8170 MW
- **PJM:** 8685 MW
- **SPP:** 4875 MW
- **MISO:** 8950 MW
- **ISO-NE:** 2955 MW
- **NYISO:** 5335 MW
- **ERCOT:** 513 MW

Sources: The Brattle Group analysis based on SNL and other data.
# Increasing Value of Existing Storage Resources

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

### Analysis of Optimized Net Revenues of Pumped Storage Hydro Plant

<table>
<thead>
<tr>
<th>Energy and Ancillary Services Market Net Revenues ($/kW-year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$50</td>
</tr>
<tr>
<td>$40</td>
</tr>
<tr>
<td>$30</td>
</tr>
<tr>
<td>$20</td>
</tr>
<tr>
<td>$10</td>
</tr>
<tr>
<td>$0</td>
</tr>
</tbody>
</table>

- **Optimized DAM Energy Bids**
- **Optimized RTM Energy Bids**
- **Optimized AS Bids**

Gain with Equipment Upgrades to Increase Flexibility

Source: Based on analysis with Brattle’s bSTORE modeling platform.
Many More Questions Need to be Answered

- **How is storage competing with other resources?**
  - Gas-fired combined cycles, combustion turbines, or diesel engines?
  - Demand response?

- **How can storage provide environmental value?**
  - Store excess (curtailed) renewable and clean energy?
  - Reduce inefficiencies of cycling traditional generators?
  - Reduce local air pollution in urban areas?

- **What is the role of 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 costs decrease and/or retail rates change?

- **What is the role of the utility?**
  - Can they participate in the storage initiatives?
  - Can they help the industry increase scale and move down the learning curve?
  - How can competitive forces be harnessed to provide utilities the right incentives?
Takeaways

As costs decline, the market potential for storage will grow exponentially

- At an installed cost of $350/kWh, we estimate that the storage market would grow to:
  - 1,000 MW (3000 MWh) in ERCOT solely based on wholesale market benefits
  - 5,000 MW (15,000 MWh) in ERCOT if all value streams (wholesale markets, T&D, customer benefits) can be captured
  - 50,000 MW U.S.-wide potential?

- 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 (as recently implemented in CA) will be necessary to unlock T&D and customer values

- Many important policy, market, and business-model questions still need to be addressed
The views expressed in this presentation are strictly those of the presenter(s) and do not necessarily state or reflect the views of The Brattle Group, Inc. or its clients.
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**

<table>
<thead>
<tr>
<th><strong>Asset Valuation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Valuing and sizing renewables + storage facilities</td>
</tr>
<tr>
<td>• Valuing storage across multiple value streams</td>
</tr>
<tr>
<td>• Developing bid/offer strategies to maximize value</td>
</tr>
<tr>
<td>• Accommodating storage into IRPs</td>
</tr>
<tr>
<td>• Supporting due diligence efforts of investors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Market Intelligence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• The state and federal policy landscape</td>
</tr>
<tr>
<td>• Electricity market fundamentals and opportunities</td>
</tr>
<tr>
<td>• Storage cost and technology trends</td>
</tr>
<tr>
<td>• Current and emerging business models</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Policy, Regulatory, and Market Design</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wholesale market design</td>
</tr>
<tr>
<td>• Market and regulatory barriers</td>
</tr>
<tr>
<td>• Utility ownership and operation models</td>
</tr>
<tr>
<td>• Retail rate implications of distributed storage</td>
</tr>
<tr>
<td>• Implications of storage on wholesale markets</td>
</tr>
</tbody>
</table>

[www.brattle.com/storage](http://www.brattle.com/storage)
Additional Reading

“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 P. 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


Offices

BOSTON
NEW YORK
SAN FRANCISCO
WASHINGTON, DC
TORONTO
LONDON
MADRID
ROME
SYDNEY