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Agenda

Summary

Three Perspectives of Storage Benefits

Aggregate Value of Storage

- Merchant Value
- Societal or System-Wide Benefits
- Consumer Benefits

Proposed Regulatory Framework

Contact Information / About Brattle

Attachments

- Impact on Wholesale Market Prices and Generators
- Tabulation of Costs and Benefits of Grid Integrated Storage

Summary

Deploying grid-integrated electricity storage on distribution systems across Texas could provide substantial net benefits to the state

- Up to 5,000 MW of distributed energy storage cost effective in ERCOT from a system-wide perspective at storage cost \$350/kWh
- Total customer benefits (lower bills and improved reliability) would exceed costs
- Assumes storage deployment reduces but does not eliminate need for new generation

Current market and regulatory mechanisms will not enable costeffective deployment of this innovative technology

- Wholesale market participants cannot capture T&D value (avoided outages, deferred T&D costs)
- Wires companies cannot justify large-scale storage deployment solely based on T&D savings (i.e. without also capturing and passing on to customers the wholesale market value)

Capturing the full value of storage to enable cost-effective investments requires new policy frameworks. For example:

- Allow TDSPs to deploy storage that is optimized to capture T&D and reliability benefits
- Auction off the rights to dispatch that storage into the wholesale market to third parties
- Use the auction revenues to offset storage costs to retail customers
- Ensure expected reliability and T&D benefits of deployment plan exceed net customer costs

Estimating Economic Benefits of Storage from Three Perspectives

Merchant Benefits

- Profits that a private investor could capture in the ERCOT wholesale market
- Driven by energy arbitrage value and ancillary service prices
- Importance: determines (a) whether wholesale market incentives by themselves are sufficient to attract investment in storage; and (b) the offset to storage costs if deployed by wires company for T&D/reliability benefits

"Societal" or "System-Wide" Benefits

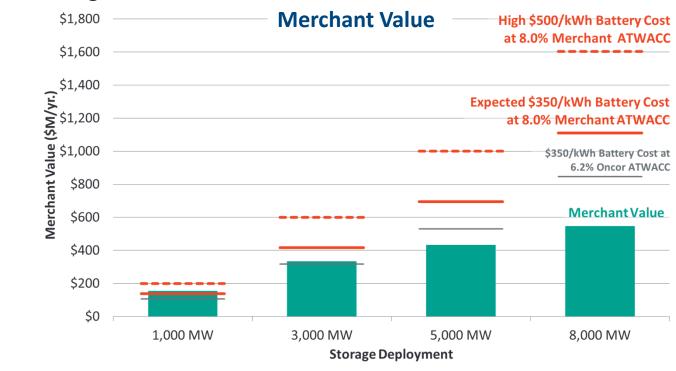
- Economy-wide benefits, including reduction in production, investment, and outage costs (regardless of whether suppliers or customers benefit)
- Also known as "total resource cost" benefits
- Importance: PUCT transmission policy order requires analysis of net "societal" or "system" benefits

Customer Benefits

- Customer bill savings from reduced wholesale prices, deferred transmission and distribution costs, and rebated merchant value
- Increase in realized distribution system reliability (reduced outages)
- **Importance:** customer advocates' and distribution utilities' primary interest, also a key metric from a public policy perspective

Merchant Value of Storage in Wholesale Market

- Even at the low projected battery costs, the wholesale market value of storage (without capturing T&D and reliability benefits) is too limited to support merchant investments at a meaningful scale
- Particularly true if investment risks were to exceed the 8% ATWACC assumed for merchant generators



Notes: Merchant value represents the margins that a merchant investor would receive by participating in ERCOT's energy and ancillary services markets; assuming storage with a 3-hour discharge capability, 85% round-trip efficiency, and no other variable operations and maintenance (VOM) costs. Storage costs of \$350/kW-y are based on battery vendors' estimates of \$200/kWh as quoted to Oncor, plus an Oncor-estimated installation cost of \$150/kWh, plus fixed operations and maintenance costs equal to 1% and 2% of investment costs for the "expected" and "high" cost levels.

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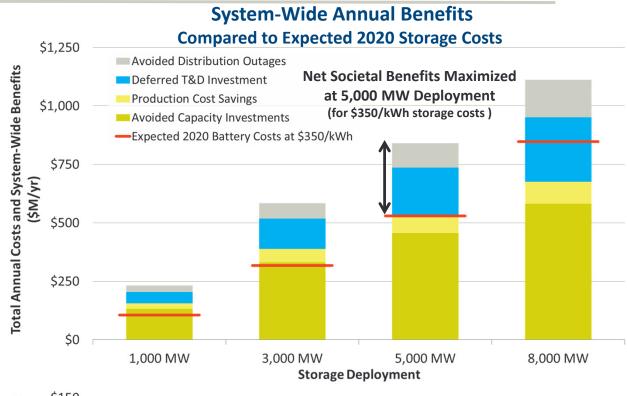
Societal / System-Wide Benefits

- Incremental value of storage exceeds its cost up to approx. 5,000 MW
- Beyond that point, incremental investment is not beneficial unless the cost of storage drops below \$350/kWh

Storage Deployment \$150 Incremental Net Benefit **Incremental Net Benefit from** 1 MW of Additional Storage \$100 (\$/kW-yr) \$50 \$0 -\$50 3,000 MW 5,000 MW 1,000 MW 8.000 MW 6 | brattle.com

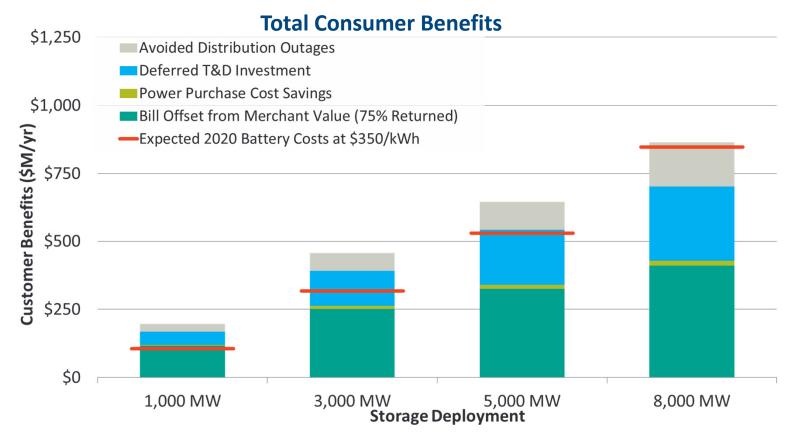
Storage Deployment

Notes: The expected 2020 battery costs are annualized based on Oncor's 6.3% ATWACC, with 15- and 30-year assumed lifetime for the battery and balance of plant respectively.



Consumer Benefits

- Customers experience overall benefits through lower bills and improved reliability
- With the proposed policy framework, customer costs are offset by the merchant value a third-party market operator obtains in the ERCOT wholesale markets

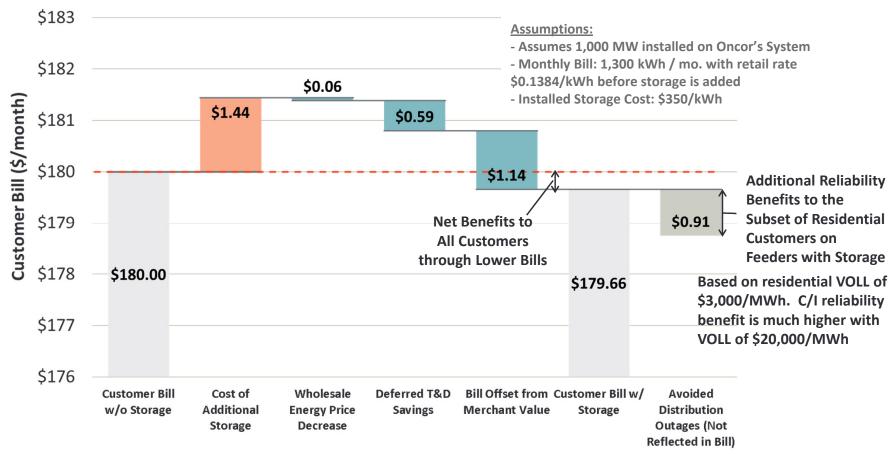


Notes: The expected 2020 battery costs are annualized based on Oncor's 6.3% ATWACC, with 15- and 30-year assumed lifetime for the battery and balance of plant respectively.

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Consumer Benefits – Bill Impact

Impact on Typical 2020 Residential Bill for 3,000 MW (9,000 MWh) of Storage ERCOT-wide



Notes: We assume that Oncor installs 1,000 MW out of 3,000 MW of storage deployed on an ERCOT-wide basis, with storage costs and wholesale-market proceeds reflecting the same proportion of installations. Oncor customers realize deferred transmission and distribution investment benefits based on the 1,000 MW installed on Oncor's system. The avoided distribution outage value shown is for a typical residential customer on a feeder with storage. Customers not located on a feeder with storage would not realize these reliability benefits.

Proposed Regulatory Framework

- Targeted distribution-level deployment and operations needed to allow the utility to realize reliability, T&D, and wholesale market benefits
- Utility-based deployment can simultaneously capture these benefits without regulated utilities transacting in competitive wholesale markets
 - Wires companies would <u>auction off</u> wholesale market participation to unregulated entities who would then bid the storage assets into the markets
 - Auction proceeds used to offset regulated storage costs, thereby reducing customer costs
 - Commission would evaluate and approve storage deployment plan only if beneficial from a net customer cost perspective (e.g., based on experience from limited initial deployment)
- Framework allows wires companies to make investments in electricity storage and recover investment costs through regulated rates as long as:
 - A significant fraction of the value of these storage assets is associated with reliability and
 T&D benefits that are not captured through wholesale market participation
 - The incremental reliability and T&D benefits are expected to exceed net customer costs by a sufficient margin
- Approach solves the barriers created by fragmented value streams that will otherwise lead to under-investment in electric energy storage

Contact Information



JUDY CHANG

Principal and Director | Cambridge, MA

Judy.Chang@brattle.com

+1.617.234.5630



JOHANNES PFEIFENBERGER

Principal | Cambridge, MA

Hannes.Pfeifenberger@brattle.com
+1.617.234.5624



KATHLEEN SPEES

Principal | Cambridge, MA

Kathleen.Spees@brattle.com
+1.617.234.5783



MATTHEW DAVIS
Associate | Cambridge, MA
Matt.Davis@brattle.com
+1.617.234.5637

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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, rigorous analyses, and principled techniques 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 & Regulatory Finance
- Demand Forecasting & Weather Normalization
- Demand Response & Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation & Risk Management
- Energy Contract Litigation
- Environmental Compliance
- Fuel & Power Procurement
- Incentive Regulation

- Market Design & Competitive Analysis
- Mergers & Acquisitions
- Rate Design, Cost Allocation, & Rate Structure
- Regulatory Compliance & Enforcement
- Regulatory Strategy & Litigation Support
- Renewables
- Resource Planning
- Retail Access & Restructuring
- Strategic Planning
- Transmission

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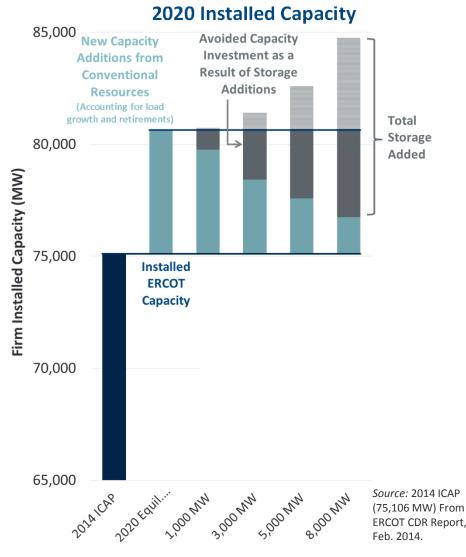


Rome

Attachment 1: Impact on Wholesale Market Prices and Generators

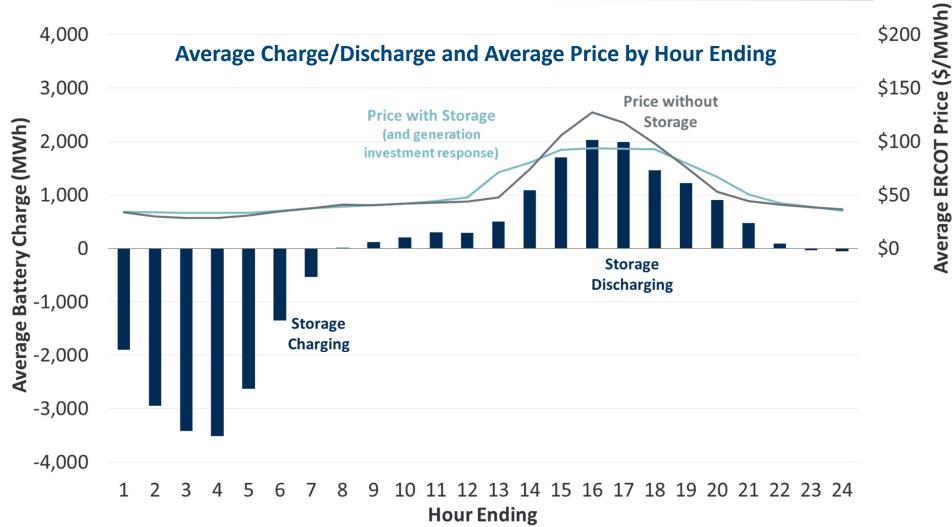
Impact on Wholesale Market and Generators Simulating Generation Investment Response

- Simulated ERCOT's energy-only market in 2020:
 - With full ORDC curve
 - With 2011 and 2012 weather years to arrive at realistic distribution of CC margins
- Evaluated the likely investment response by conventional generation if storage is added to the ERCOT system
- Yields reserve margin consistent with a market outcome at the CONE of combined cycle (CC) unit (estimated at \$149/kW-yr in 2020)
 - 5,000 MW of storage results in 3,100
 MW of reduced generation investment (or increased retirements)



Storage Penetration (MW) 14 | brattle.com

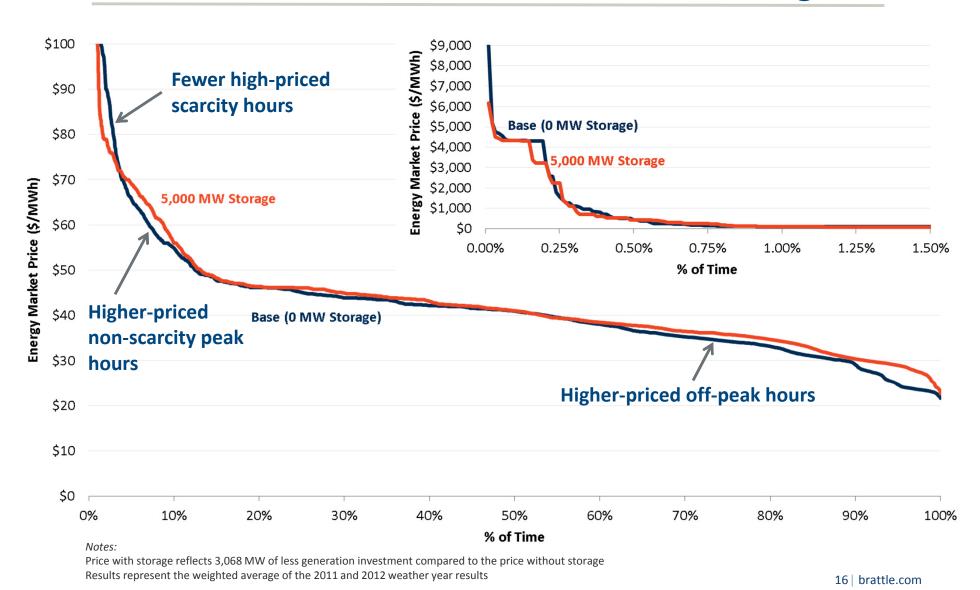
Impact on Wholesale Market and Generators Charging/Discharging Impact on Price



Notes:

Price with storage reflects 3,068 MW of less generation investment compared to the price without storage Results represent the weighted average of the 2011 and 2012 weather year results

Impact on Wholesale Market and Generators Price Duration Curve with/without Storage

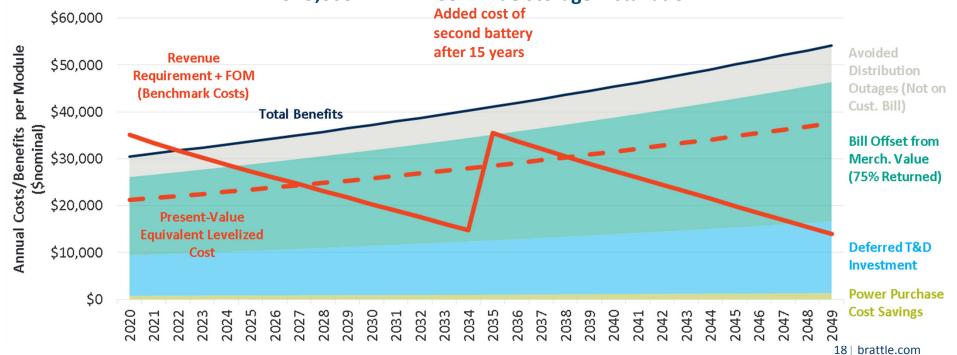


Attachment 2: Tabulation of Costs and Benefits of Grid Integrated Storage

Costs and Benefits of a Single 600kWh Module

- Assumes 2020 benefits increase with inflation (2%)
- Revenue requirements decline until second battery set is installed in year 15, then declines further
- 2 years where revenue requirements exceed total benefits, 5 years where costs exceed benefits that are realized on a consumer's bill

Annual Costs (Revenue Requirement) and Benefits of Battery Module for 9,000 MWh ERCOT-wide Storage Installation



Calculating "Levelized" Annual Costs

- For a utility, cost of installation would be recovered from rates
 - For battery portion (with replacement) and inverter, economic life is 15 years
 - For balance of plant (power system electronics, communications, siting, and installation) economic life is 30 years
 - Assumed that a utility would have a 30-year revenue requirement to recover the capital outlay for two 15-yr battery systems and one 30-yr balance of plant
- Calculating "levelized costs"

Financing Assumptions and Annual Costs for Utility Installation

Cost Recovery Assumptions							
Economic Life (Total Installation)	(years)	30					
Economic Life (Battery Portion)	(years)	15					
Debt Fraction	(%)	60%					
Debt Rate	(%)	6.20%					
Equity Rate	(%)	10.25%					
Tax Rate	(%)	40%					
Property Taxes	(%)	1.50%					
Inflation Rate	(%)	2%					
First Year Capital Carrying Cost Rate	(%)	10.0%					
2020 Levelized Cost Increasing with Inflation							
2020 Cost (per-kW)	(\$/kW-yr)	\$105.93					
2020 Cost (per Module)	(\$/module-yr)	\$21,186					

Note: \$s are \$2020

- Transform NPV of Revenue requirement into an annuity, paying the same in all years (\$2020, increasing with inflation)
- If this levelized cost schedule is collected (similarly to a power purchase agreement), the total costs will be recovered over the 30 year life

Detailed Costs and Benefits

2020 Levelized Cost (Annual, Increasing with Inflation)

		1,000 MW	3,000 MW	5,000 MW	8,000 MW
Benchmark Projection (\$106/kW-yr)	(\$M/yr)	\$106	\$318	\$530	\$847
Higher Projection (\$160/kW-yr)	(\$M/yr)	\$160	\$480	\$800	\$1,280

Annual Societal Benefits (\$2020)

		1,000 MW	3,000 MW	5,000 MW	8,000 MW
Total ERCOT Annual System-Wide Savings					
Production Cost Savings	(\$M/yr)	\$23	\$58	\$78	\$94
Avoided Capacity Investments	(\$M/yr)	\$133	\$331	\$457	\$582
Avoided Distribution Outages	(\$M/yr)	\$29	\$66	\$105	\$161
Deferred T&D Investment	(\$M/yr)	\$48	\$129	\$202	\$275
Total	(\$M/yr)	\$233	\$584	\$841	\$1,112

Annual Consumer Benefits (\$2020), and Annual Merchant Value

		1,000 MW	3,000 MW	5,000 MW	8,000 MW
Total Merchant Value (Total Margins Captured by the Market)	(\$M/yr)	\$155	\$335	\$434	\$547
Total ERCOT Annual Customer Savings					
Power Purchase Cost Savings	(\$M/yr)	\$4	\$11	\$15	\$17
Bill Offset from Merchant Value (75% Returned)	(\$M/yr)	\$116	\$251	\$325	\$411
Avoided Distribution Outages	(\$M/yr)	\$29	\$66	\$105	\$161
Deferred T&D Investment	(\$M/yr)	\$48	\$129	\$202	\$275
Total	(\$M/yr)	\$197	\$458	\$646	\$864

Total Costs and Benefits with 3,000 MW (9,000 MWh) Installed ERCOT-Wide

	Costs and Benefits with 3,000 MW 9,000 MWh Installed				
		Per Unit of Storage	Per Module	Oncor's 36% Share of Installation	ERCOT Installation
		1 kWh	600 kWh	3,240 MWh	9,000 MWh
<u>Notes</u> ,	/Units	\$	\$	\$	\$
Costs					
Battery	[1]	\$200	\$120,000	\$648,000,000	\$1,800,000,000
Balance of Plant	[2]	\$150	\$90,000	\$486,000,000	\$1,350,000,000
Total Cost	[3]	\$350	\$210,000	\$1,134,000,000	\$3,150,000,000
Average Annual Cost for Customer	[4]	\$35	\$21,000	\$113,000,000	\$315,000,000
Annual Benefits					
Power Purchase Cost Savings	[5]	\$1	\$1,000	\$4,000,000	\$11,000,000
Merchant Revenues Returned to Customers	[6]	\$28	\$17,000	\$90,000,000	\$251,000,000
T&D Deferral	[7]	\$14	\$9,000	\$46,000,000	\$129,000,000
Subtotal: Benefits that Appear on Cust. Bill	[8]	\$43	\$27,000	\$140,000,000	\$391,000,000
Avoided Distribution Outages	[9]	\$7	\$4,000	\$24,000,000	\$66,000,000
Total Benefits for Customers where Storage	[10]	\$50	\$31,000	\$164,000,000	\$457,000,000
Installed					
Cost/Benefit Comparison					
Benefits that Appear on Cust. Bill minus Costs	[11]	\$8	\$6,000	\$27,000,000	\$76,000,000
Total Benefits for Cust. Where Storage Installed minus Cost	[12]	\$15	\$10,000	\$51,000,000	\$142,000,000

Notes on Slide 6

Notes to Previous Slide

Line Note

- [1]: Cost of battery including cost of inverter
- [2]: Cost of charge controller, energy management system/communications, siting, and installation
- [3] = [1] + [2]
- [4] = [3] \times 9.99% (First year capital carrying cost rate, levelized), Average annual cost calculated as a 2020 levelized charge that increases with inflation (similar to benefits), yielding the same cost recovery and present value as traditional utility ratemaking
- [5]: Study result
- [6]: Study result
- [7]: Study result
- [8] = [5] + [6] + [7]
- [9]: Study result, value only accrues for customers at locations where storage is installed
- [10] = [8] + [9]
- [11] = [8] [4], represents the benefits in excess of costs that all customers would observe
- [12] = [10] [4], represents the benefits in excess of costs that a customer located at a feeder where storage is install would observe