

The Economic Potential for Energy Storage in Nevada

PRESENTED TO

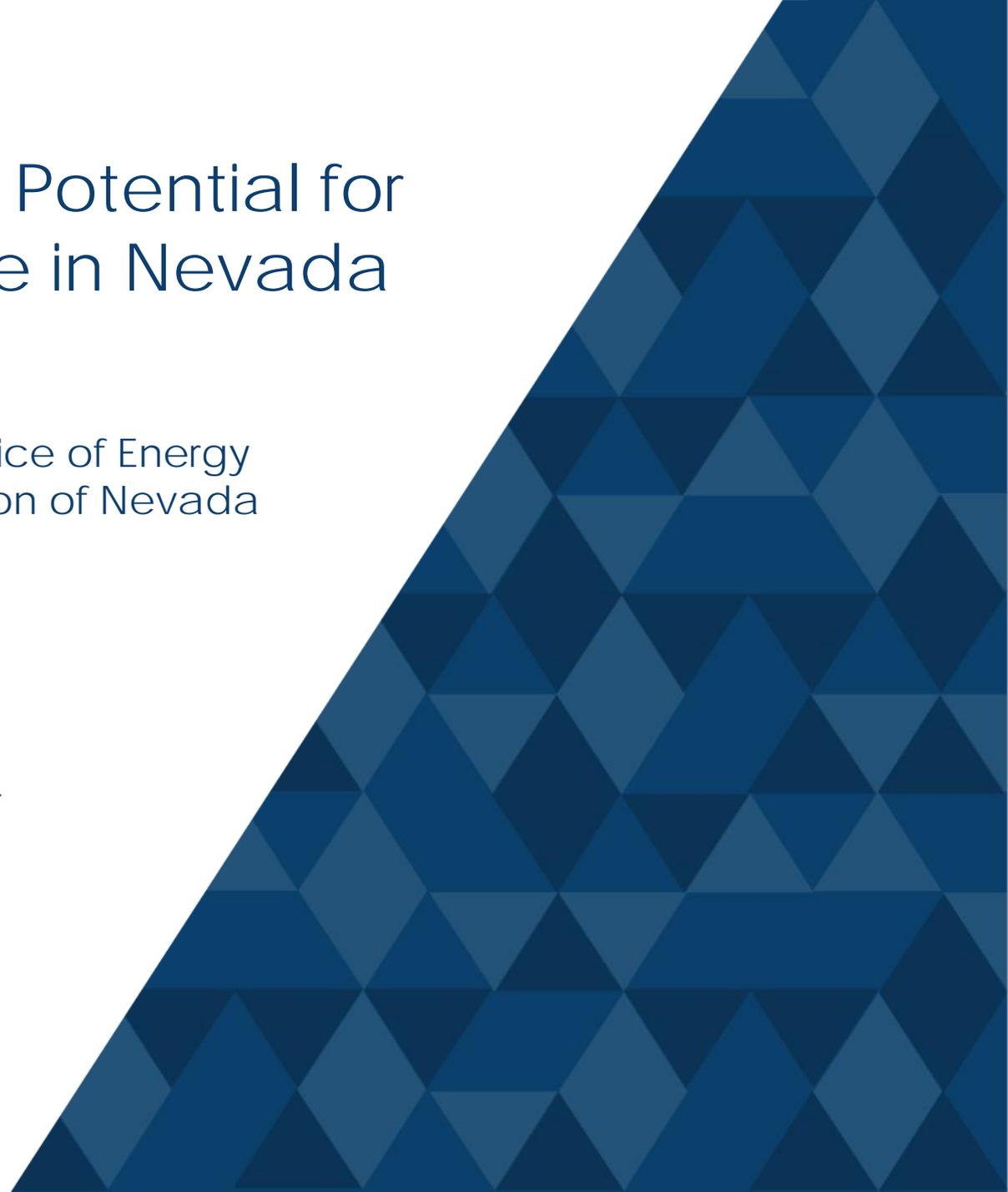
Nevada Governor's Office of Energy
Public Utilities Commission of Nevada

PRESENTED BY

Ryan Hledik
Roger Lueken
Judy Chang
Johannes Pfeifenberger
Jeremy Vollen
John Imon Pedtke

October 15, 2018

THE **Brattle** GROUP



Disclaimer

This report was prepared for Public Utilities Commission of Nevada (PUCN) and the Nevada Governor's Office of Energy (GOE) based on work supported by the Nevada Governor's Office of Energy, and the Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), under Award Number DE-EE0006992. It is intended to be read and used as a whole and not in parts; it reflects the analyses and opinions of the authors and does not necessarily reflect those of The Brattle Group's clients or other consultants.

The authors would like to acknowledge the valuable collaboration and insights of Donald Lomoljo and John Candelaria (PUCN), Angela Dykema (GOE), Patrick Balducci and Jeremy Twitchell (Pacific Northwest National Laboratory), and the contributions of NV Energy staff in providing necessary system data. We would also like to thank Brattle Group colleagues for supporting the preparation of this report, including Jesse Cohen for modeling of behind-the-meeting storage applications.

While this report was prepared as an account of work sponsored by an agency of the United States Government, neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

There are no third party beneficiaries with respect to this report, and The Brattle Group does not accept any liability to any third party in respect of the contents of this report or any actions taken or decisions made as a consequence of the information set forth herein.

Agenda

Study Purpose and Scope

Approach to Estimating Storage Costs and Benefits

Evaluation of Key Storage Value Drivers

Aggregate System-Wide Benefits of Storage

Behind-the-Meter Applications

Comparison to Other Storage Potential Studies

Study Conclusions

Study Purpose and Scope

Study Purpose: “Provide information to be used by the Public Utilities Commission of Nevada (PUCN) in determining whether procurement targets for energy storage systems should be set in Nevada pursuant to Senate Bill (SB) 204 (2017), and at what level”

Scope:

- Evaluate benefits of storage across several uses
- Identify storage use cases, including behind-the-meter at customer sites, on the distribution system, and on the transmission system
- Evaluate the global storage industry landscape, including trends in costs
- Estimate cost-effective storage potential for Nevada for 2020 and 2030

Approach to Estimating Storage Costs and Benefits

Approach and Key Value Drivers Evaluated

We utilize Brattle's bSTORE model to evaluate the key drivers of storage value change as increasing amounts of storage is added to Nevada.

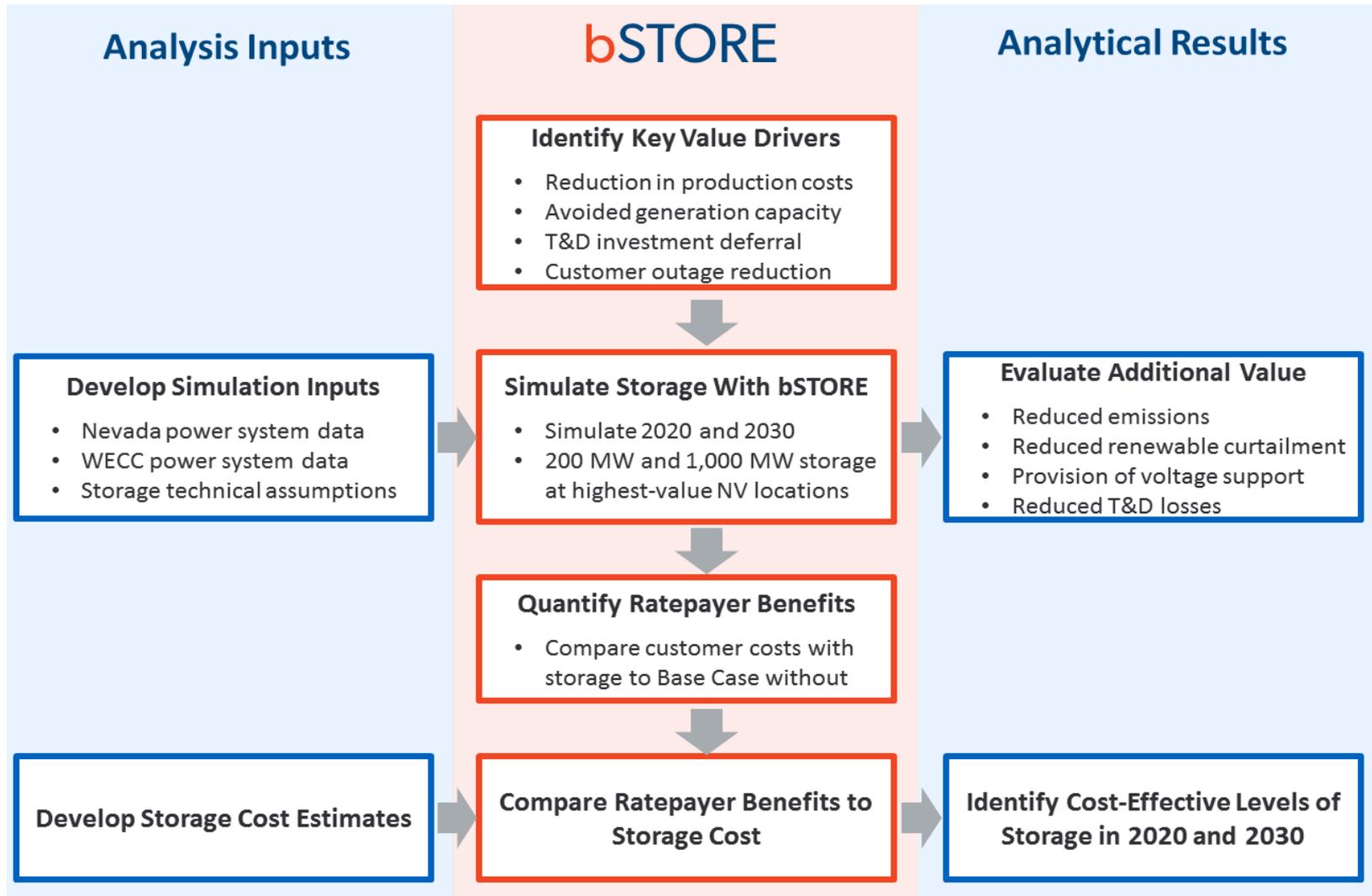
We quantify four key value drivers:

- **Production Cost Savings:** Changes in NV Energy's cost of providing energy and ancillary services
- **Avoided Capacity Investments:** Reduction in generation capacity needed to meet peak load
- **Deferred T&D Investment:** Value of deploying storage to defer upcoming T&D investments
- **Avoided Distribution Outages:** Reductions in load shedding by locating storage on certain distribution feeders

Our approach accounts for likely limitations in the ability to “stack” these values

- **Location limitations:** We assumed that storage can be deployed at certain distribution grid locations either to defer T&D investment or avoid distribution outages, but we have conservatively assumed that both value cannot be captured simultaneously
- **Operational constraints:** Discharging storage to provide one service (e.g. to defer T&D investment), limits its ability to provide other services

Summary of Analytical Approach



Approach

Data Sources

We model Nevada consistent with NV Energy's 2018 IRP and rest of WECC consistent with 2026 TEPPC database (adjusting for 2020 and 2030).

Data Element	Source(s)
Transmission Topology	2026 TEPPC Common Case (as updated in 2017 CAISO TPP)
NV and WECC Generator List	NV Energy's 2018 IRP, 2026 TEPPC Common Case, SNL
NV and WECC Generator Characteristics	NV Energy's 2018 IRP, 2026 TEPPC Common Case
Fuel Prices	NV Energy's 2018 IRP, 2026 TEPPC Common Case, EIA
NV and WECC Demand	NV Energy's 2018 IRP, 2026 TEPPC Common Case, SNL
NV and WECC Reserve Requirements	NV Energy's 2018 IRP, 2026 TEPPC Common Case
NV and WECC RPS Requirements	NV Energy's 2018 IRP, Database of State Incentives for Renewables & Efficiency (DSIRE)
T&D Deferral Analysis	NV Energy's Transmission and Distribution Capital Expenditure Data
Distribution Reliability Analysis	NV Energy's Distribution Outage Data

Storage Technology Assumptions

Although our analysis approach is technology agnostic, we simulate batteries with operational characteristics that resemble Li-Ion chemistry.

— Configuration and siting

- Stand-alone storage, not co-located with solar PV or other generator
- Distribution and transmission connected
- Sited in front-of-meter (behind-the-meter use case evaluated separately)

— Size of individual storage devices: 5 to 10 MW

— MWh:MW ratio: 4:1

- Four hour discharge capability at full output
- Consistent with types of storage systems procured in many recent solicitations

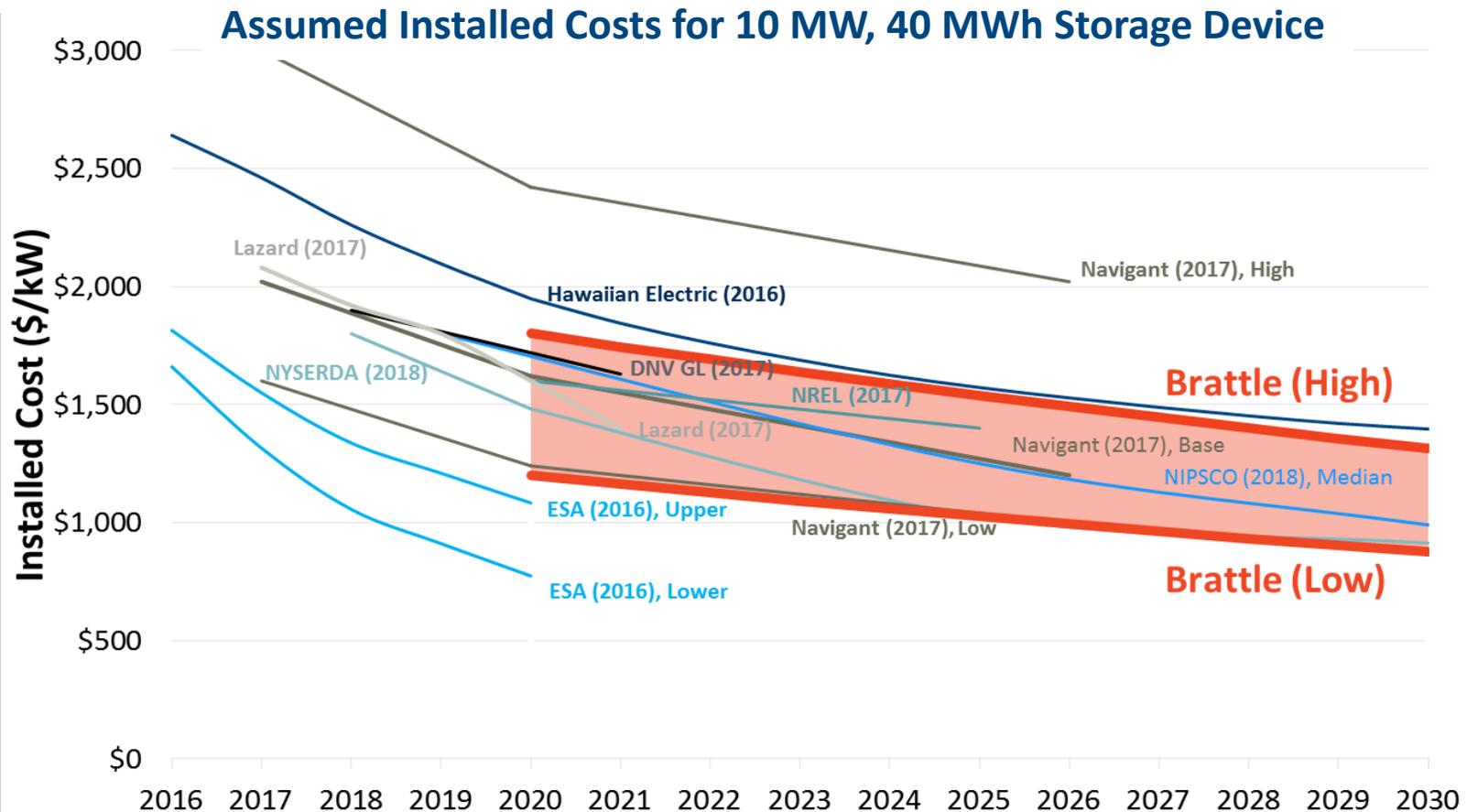
— Round-trip efficiency: 85%

— Lifespan: 15 years

Notes: Assumptions developed with input from the PUCN and PNNL. Our fixed-cost and cost-levelization assumptions include the costs of replacing worn-out battery cells during the 15-year period. We do not assume degradation over time, consistent with the assumption that worn-out battery cells will be replaced throughout the 15-year period.

Storage Installed Cost Trends

We analyze a range of installed costs for 4-hour storage in 2020 and 2030 to reflect uncertainty we see in current cost projections.



Sources and Notes: Literature review of Navigant (2017), Hawaiian Electric Companies (2016), NREL (2017), NIPSCO (2018), DNV GL (2017), NYSERDA (2018a), ESA (2016), and Lazard (2017). Installed cost estimates for a 4-hour storage system. All values in nominal dollars.

Levelization of Storage Costs

We assume levelized installed costs of \$136-204/kW-yr in 2020 and \$99-149/kW-yr in 2030 for 4-hour storage device.

Financial Assumptions

Financial Assumption		Value
Fixed O&M	<i>% of Installed</i>	1%
Developer After-Tax WACC	<i>%</i>	7%
Battery Asset Life	<i>yrs</i>	15
Balance of Plant Asset Life	<i>yrs</i>	15
Total Income Tax Rate	<i>%</i>	21%
Depreciation Schedule		15-yr MACRS
Annual Inflation Rate	<i>%</i>	2%

Levelized and Installed Cost Assumptions For 10 MW (40 MWh) Storage Device

	Assumed Installed Costs		Implied Levelized Costs
	<i>\$/kW Installed</i>	<i>\$/kWh Installed</i>	<i>\$/kW-year</i>
Assumed Costs			
<i>2020 Low</i>	\$1,200	\$300	\$136
<i>2020 High</i>	\$1,800	\$450	\$204
<i>2030 Low</i>	\$876	\$219	\$99
<i>2030 High</i>	\$1,314	\$328	\$149

Note:

Cost and financing assumptions indicative of new development costs in Nevada. All values in nominal dollars

Cost Effectiveness Framework

We utilize the RIM test to evaluate cost-effectiveness of energy storage, including the value of avoided customer outages.

The Ratepayer Impact Measure (RIM) test provides an indication of how average retail rates will change as the result of a new utility initiative

- Includes all reductions in resource costs (*e.g.*, reductions in fuel and capacity costs)
- Includes savings associated with procuring services more cheaply (*e.g.*, ancillary services)

We also include as a benefit the ratepayer value of avoided distribution outages

- Not traditionally included in RIM test (does not result a cost incurred by the utility), but reflects a benefit to ratepayers who experience fewer outages
- We separately report cost-effective storage levels excluding customer outage value

We quantify, but do not include as ratepayer benefits, the societal cost impacts associated with changes in carbon and other emissions

Evaluation of Key Value Drivers

Reduction in Production Costs

Approach

We use a production cost model – Power System Optimizer (PSO) – to estimate cost of meeting Nevada’s energy and ancillary service needs.

- We simulate entirety of WECC, with focus on Nevada
- To account for changes in Nevada production costs, purchases, and sales, we calculated adjusted production costs (APC) for the Nevada footprint
- We simulate 3 scenarios: base case (no storage), 200 MW, and 1,000 MW of storage

Calculating Nevada Adjusted Production Costs (APC)

$$\text{Nevada Adjusted Production Costs} = \text{Production Costs} + \text{Cost of Purchases} - \text{Revenue from Sales}$$

Production Costs = Cost of Nevada owned generation

- Generation costs include fuel, emissions, variable operating, and startup costs

Cost of Purchases = Deficit in generation \times Price Hub

- Purchases priced at the Malin and Mead hubs for Northern and Southern Nevada, respectively.

Revenues from Sales = Surplus in generation \times Price Hub

- Sales priced at the Malin and Mead hubs for Northern and Southern Nevada, respectively.

WECC Footprint



© 2018 ESIP Global Market Intelligence All rights reserved. Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

Source: SNL

brattle.com | 14

Reduction in Production Costs

Findings

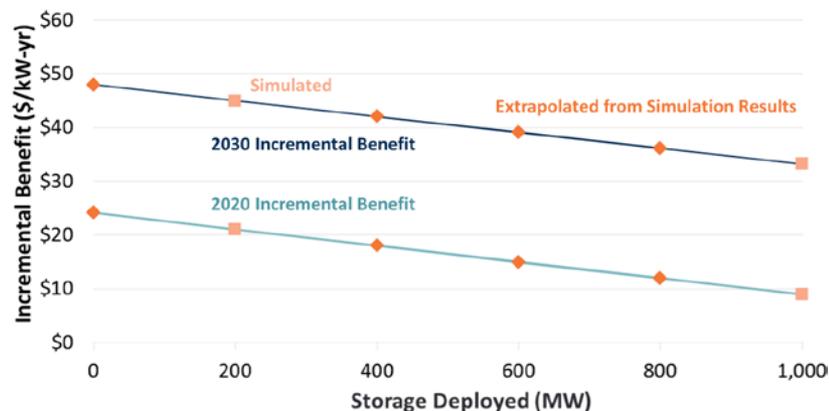
We find APC savings of \$4.5 to \$16.5 million in 2020 (200 MW vs. 1,000 MW storage deployed), and \$9.3 to \$40.6 million in 2030.

- Savings due three factors:
 - Reduced costs of operating NV generators
 - Reduced imports during high priced hours
 - Increased revenues from sales
- Savings account for the value of storage providing ancillary services
- Incremental savings (savings due to adding 1 additional MW of storage) fall as more storage is added and highest-value opportunities saturate

2020 Adjusted Production Cost Savings (in nominal \$million/year)

	Production Cost			Savings (Storage Case minus Base Case)	
	Base	200 MW	1,000 MW	200 MW	1,000 MW
Production Cost	\$421	\$420	\$423	(\$1.1)	\$2.2
Cost of Market Purchases	\$132	\$129	\$124	(\$3.1)	(\$7.9)
Revenues from Sales	(\$46)	(\$46)	(\$57)	(\$0.4)	(\$10.8)
Total	\$507	\$502	\$490	(\$4.5)	(\$16.5)

Estimated Incremental Benefit from APC Savings



Sources and Notes:

All values in nominal dollars. The total APC savings from simulations with 200 MW and 1,000 MW were used to estimate a relationship between storage deployed and total savings, from which we can estimate the relationship between storage deployed and incremental APC savings.

Avoided Generation Capacity

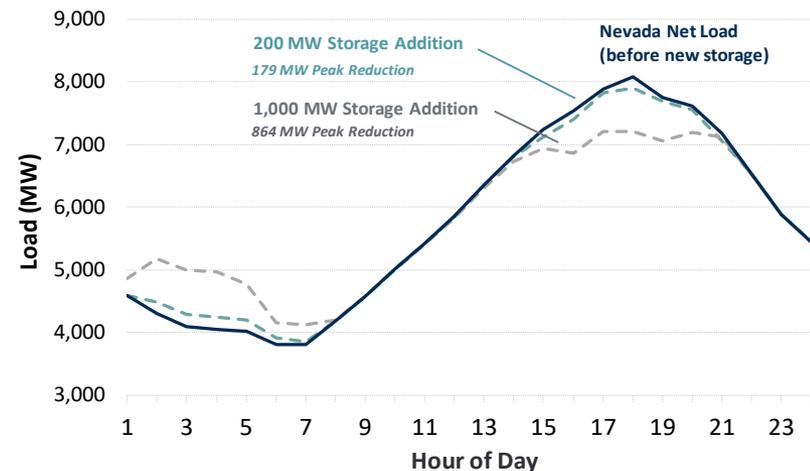
We find storage can effectively offset the need for additional peaking capacity in both 2020 and 2030, across all levels of deployment evaluated.

- If discharging during system peak load hours (net of renewable generation), storage offsets the need for other capacity
- Net peak load reductions valued at the market price for capacity assumed in 2018 NV Energy IRP
- We find 4-hour storage can effectively offset the need for new generation capacity
 - Net load peaks concentrated in July and August
 - Net load peaks are relatively short duration, due to high PV generation in summer months
 - 1 MW of storage equivalent to 0.86 MW of capacity for simulated deployment of 1,000 MW

2020 and 2030 Net Peak Reduction due to 200 MW and 1,000 MW of Storage

	MW	%
200 MW	179	90%
1,000 MW	864	86%

Nevada Net Load Peak Day Reduction (July 27, 2020)



Transmission & Distribution Investment Deferral Approach

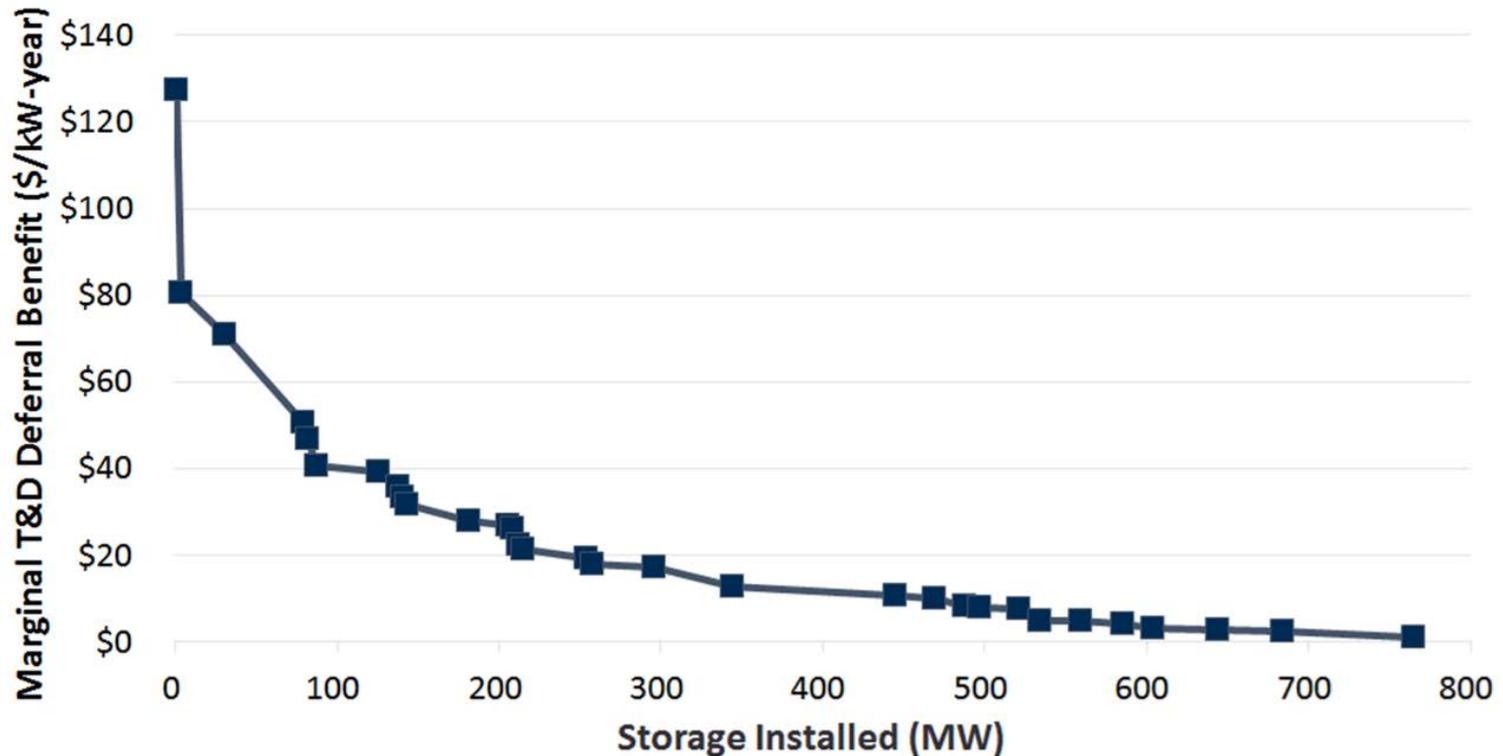
We used NV Energy capital expenditure data to identify high-value T&D deferral opportunities and evaluate how storage could defer investments.

- NV Energy provided cost data and descriptions for 260 capital projects from 2014-2027
- We estimate the subset that could be deferred by storage
 - We identified 35 projects (14% of total) are potentially deferrable by storage
 - Primarily transformer upgrades needed to support local load growth
 - We estimate the value of deferring each investment by 15 years
- We make several assumptions to approximate how much storage may be require to defer an investment
 - **Initial Peak Load:** based on NV Energy's project descriptions
 - **Rate of Load Growth:** Assumed 2%
 - **Hourly Load Shape:** Based on average residential or C&I load shapes
- We size the storage to 15 year load growth

Transmission & Distribution Investment Deferral Findings

We identify a small number of high-value opportunities to defer specific T&D investments.

Marginal T&D Deferral Benefit of Storage for Individual T&D Projects (\$/kW-year)



Notes:

Points reflect individual projects from NV Energy's 2018 transmission and distribution capital expenditure outlook identified as deferrable by storage. Although NV Energy's outlook is over a 10-year span, we annualize the size and value of opportunities. We order projects by \$/kW-year value, and plot to estimate the marginal benefit for storage from T&D investment deferral. Values in nominal dollars.

Customer Outage Reduction Value

Approach

We evaluate the reliability value to customers of deploying storage on specific feeders that historical experience relatively high levels of outages.

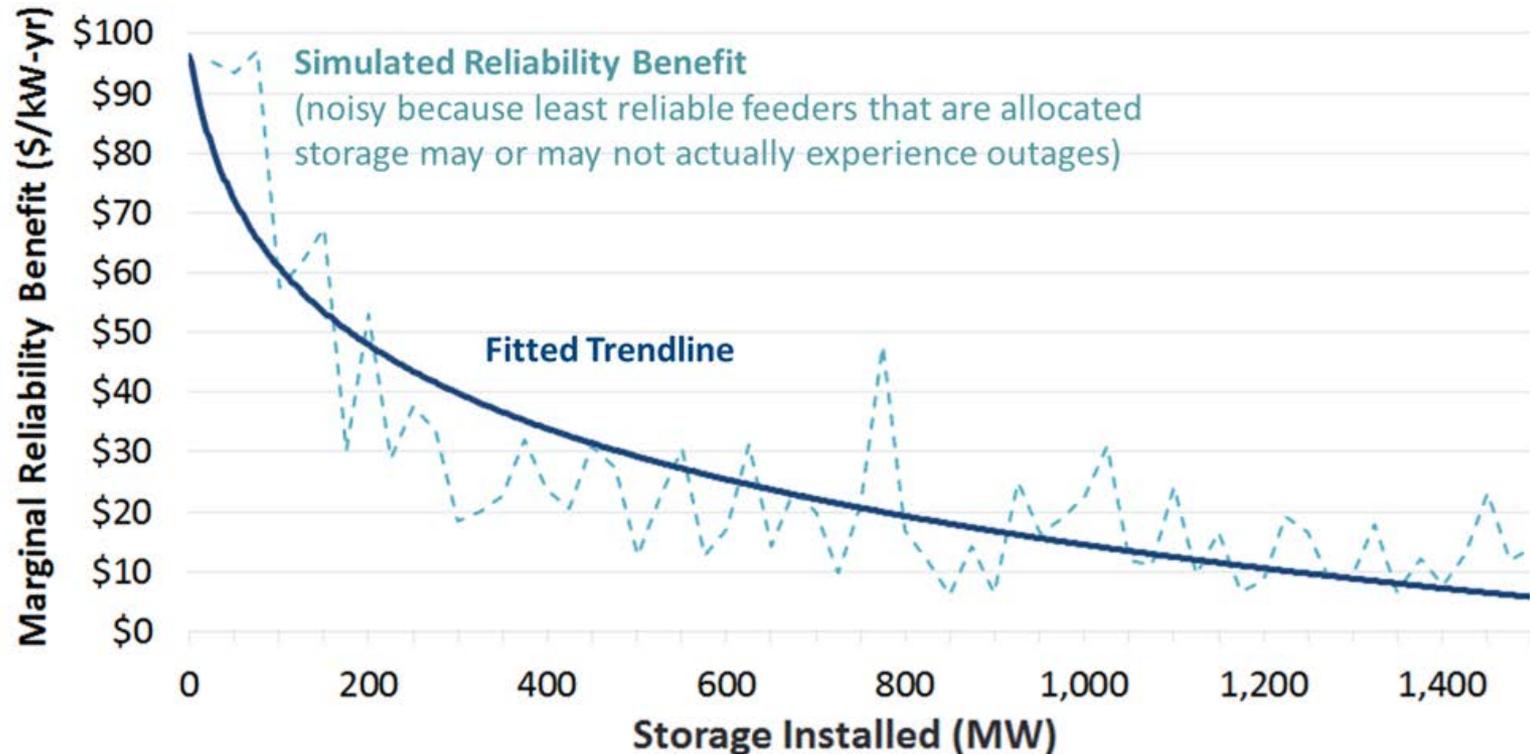
- NV Energy provided data on 43,000 distribution-level outages for 2014-2018
- We evaluate customer outage reduction benefits of siting storage at least-reliable feeders
 - We simulate storage deployed at each identified feeder, sized at average feeder peak load
 - Account for both the duration (hours) and magnitude (MWh) of each outage
 - Account for unpredictability of outages
 - Assume customers value improved reliability at \$12,500/MWh value of lost load (VOLL)
- Analysis assumes feeders can be “islanded” in event of an outage
 - Requires grid modernization investments, e.g. microgrids, automated distribution switching
 - We separately report cost-effective storage levels if grid modernization efforts not made and customer outage value cannot be captured

Customer Outage Reduction Value

Findings

The marginal benefit from avoided distribution outages declines as storage is added to the least-reliable feeders.

Incremental Reliability Benefit of Storage (\$/kW-year)



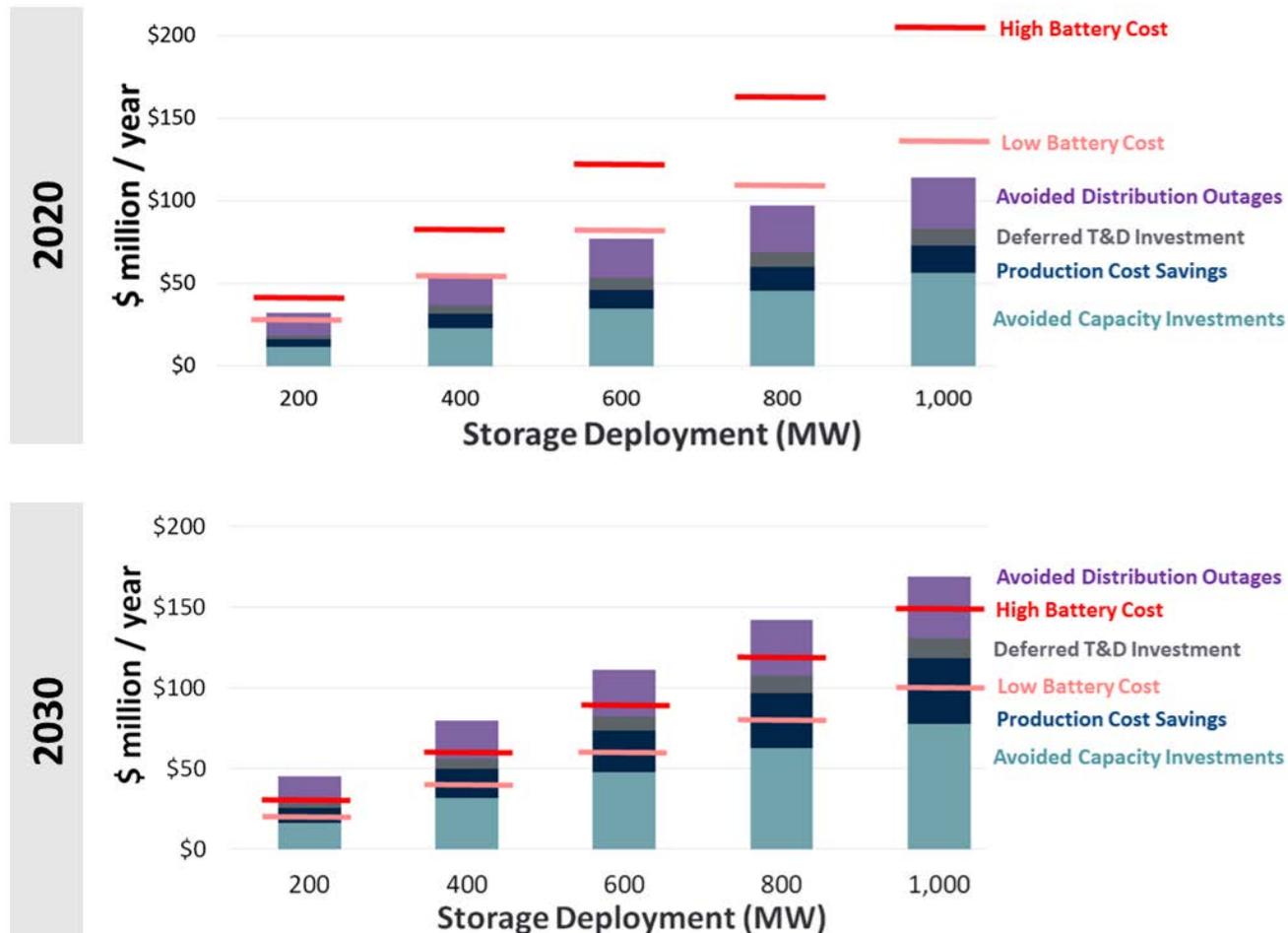
Note:

All values in nominal dollars.

Aggregate System-Wide Benefits of Storage

Total System Benefits and Costs of Storage at Various Deployment Levels

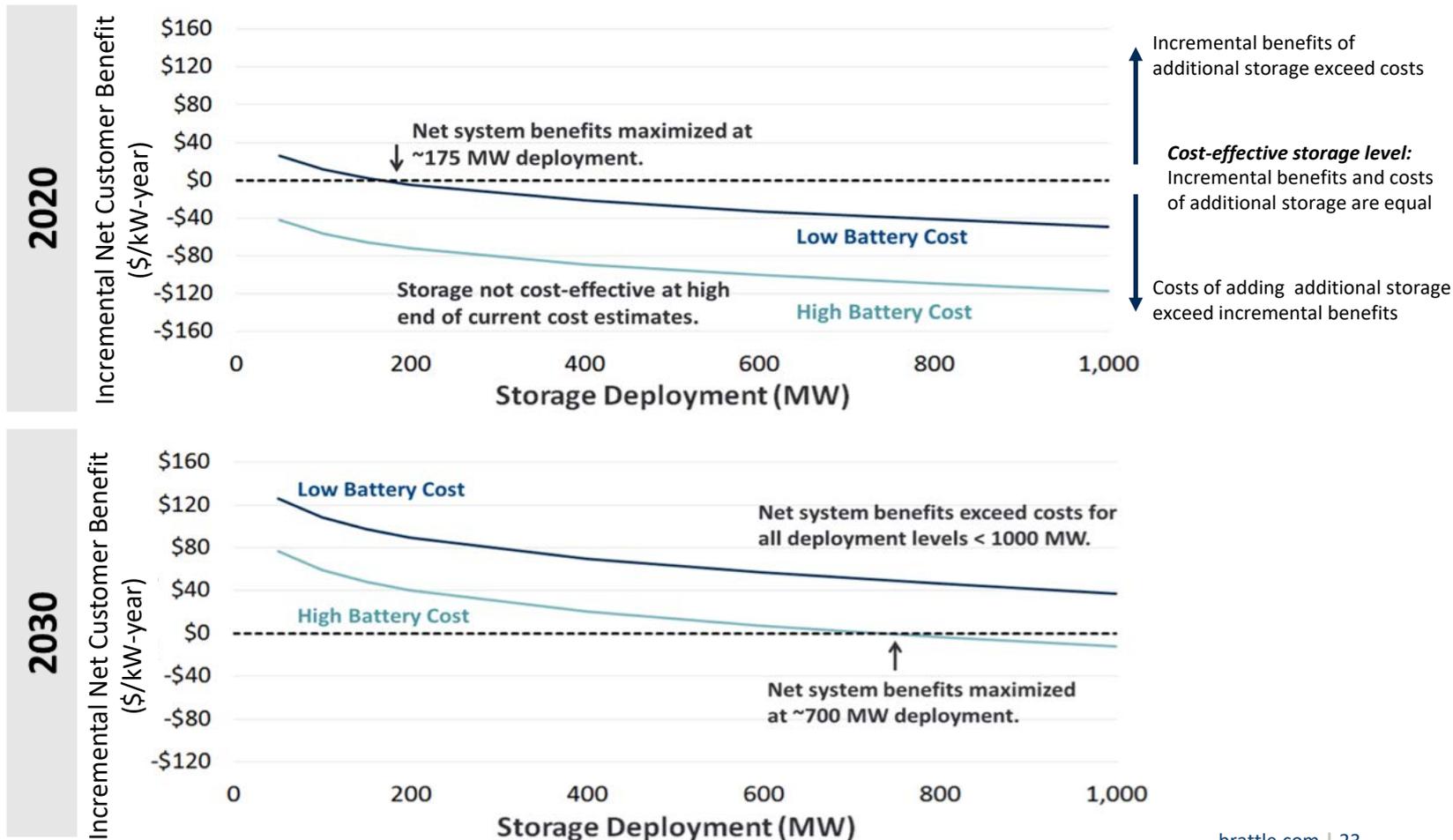
In 2020, storage benefits are less than costs if more than 200 MW deployed. In 2030, benefits exceed costs beyond 1,000 MW.



Note: All values are in nominal dollars

Incremental Net Benefits of Storage Deployment in Nevada

2020 cost-effective storage levels are up to 175 MW, depending on storage costs. In 2030, cost-effective levels are greater than 700 MW.



Note: All values are in nominal dollars

Renewable Integration and Emission Benefits

Storage reduces WECC-wide emissions in both 2020 and 2030.
Storage also reduces Nevada solar curtailments in 2030.

Reduction in Nevada Renewable Generation Curtailments, 2030

	GWh		[Change] - [Base]		
	Base	200 MW	1,000 MW	200 MW	1,000 MW
Nevada					
Total Solar Generation	6,630	6,633	6,659	3	29
Solar Curtailment	57	54	28	-3	-29
Percent Change in Curtailment				-5%	-51%

- In 2020, minimal curtailments with or without storage
- In 2030, 1,000 MW of storage significantly reduces curtailments

Impact on WECC-Wide Emissions

	Change in Emissions (tons)		Change in Emissions (%)	
	200 MW	1,000 MW	200 MW	1,000 MW
2020 Cases				
CO2	-46,974	-131,998	-0.02%	-0.06%
NOX	135	117	0.06%	0.05%
SO2	161	351	0.12%	0.26%
2030 Cases				
CO2	-63,162	-234,955	-0.03%	-0.10%
NOX	-79	-455	-0.03%	-0.17%
SO2	8	-480	0.00%	-0.26%

- Storage reduces WECC-wide CO₂ emissions in all cases
- Societal savings of \$2.6 to \$7.2 million in 2020 and \$5.0 to \$18.5 million in 2030*

* Emission reductions valued consistent with U.S. Government Interagency Working Group on the Social Cost of Carbon. Baseline 2020 value of \$54/ton and 2030 value of \$79/ton (3% discount rate scenario). See report for results under 5% and 2.5% discount rate scenarios.

Aggregate System-wide Benefits Sensitivities

Storage is likely to be cost effective by 2030 across a variety of tested sensitivity cases.

Sensitivity	Cost-Effective Storage Level	
	2020	2030
Base Case	Up to 175 MW	>700 MW
Zero Outage Reduction Value <i>Storage outage reduction value not considered in RIM test or not realized due to lack of distribution upgrades</i>	0 MW	>300 MW
Regional Market <i>Implementation of regional market reduces regional production costs, halving storage production cost savings</i>	n/a	>400 MW
Zero Avoided Generation Capacity Value <i>No need for additional generation capacity, e.g. declining load growth and no open capacity position</i>	n/a	Up to 300 MW

Behind-the-Meter Storage Applications

BTM Applications

Overview

We evaluate the economic potential for BTM storage adoption by C&I customers with and without a utility-administered program.

C&I customers most likely to adopt BTM storage in the near- to medium-term

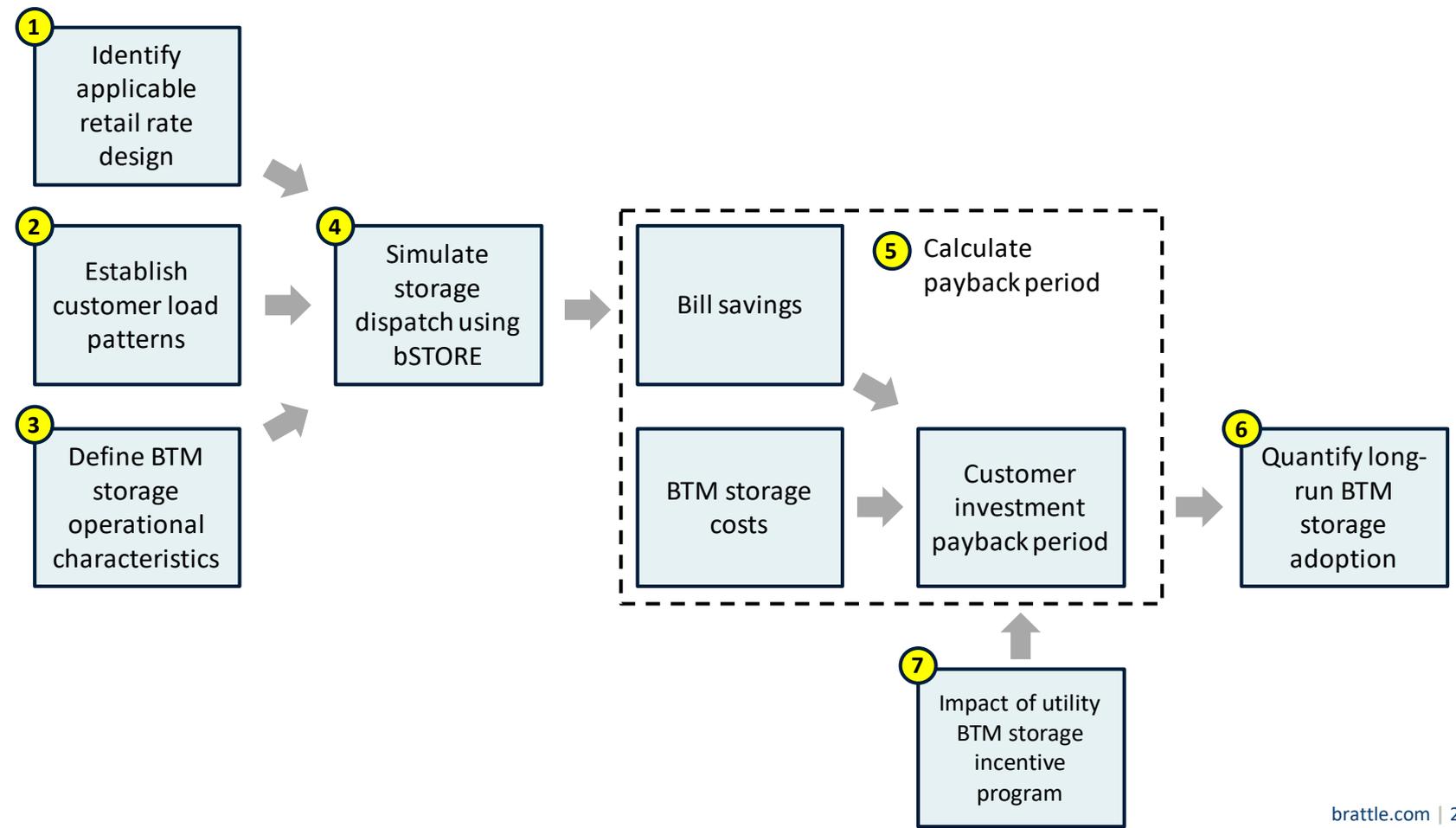
- Uses include retail bill reduction, backup generation, and aggregation as DR
- Significant residential adoption unlikely, absent changes to retail rate design and NEM policy

The utility could incentivize further adoption of BTM storage

- Incentive could take the form of a cost-effective payment
- In return, utility would control device for a limited number of days per year to address resource adequacy needs

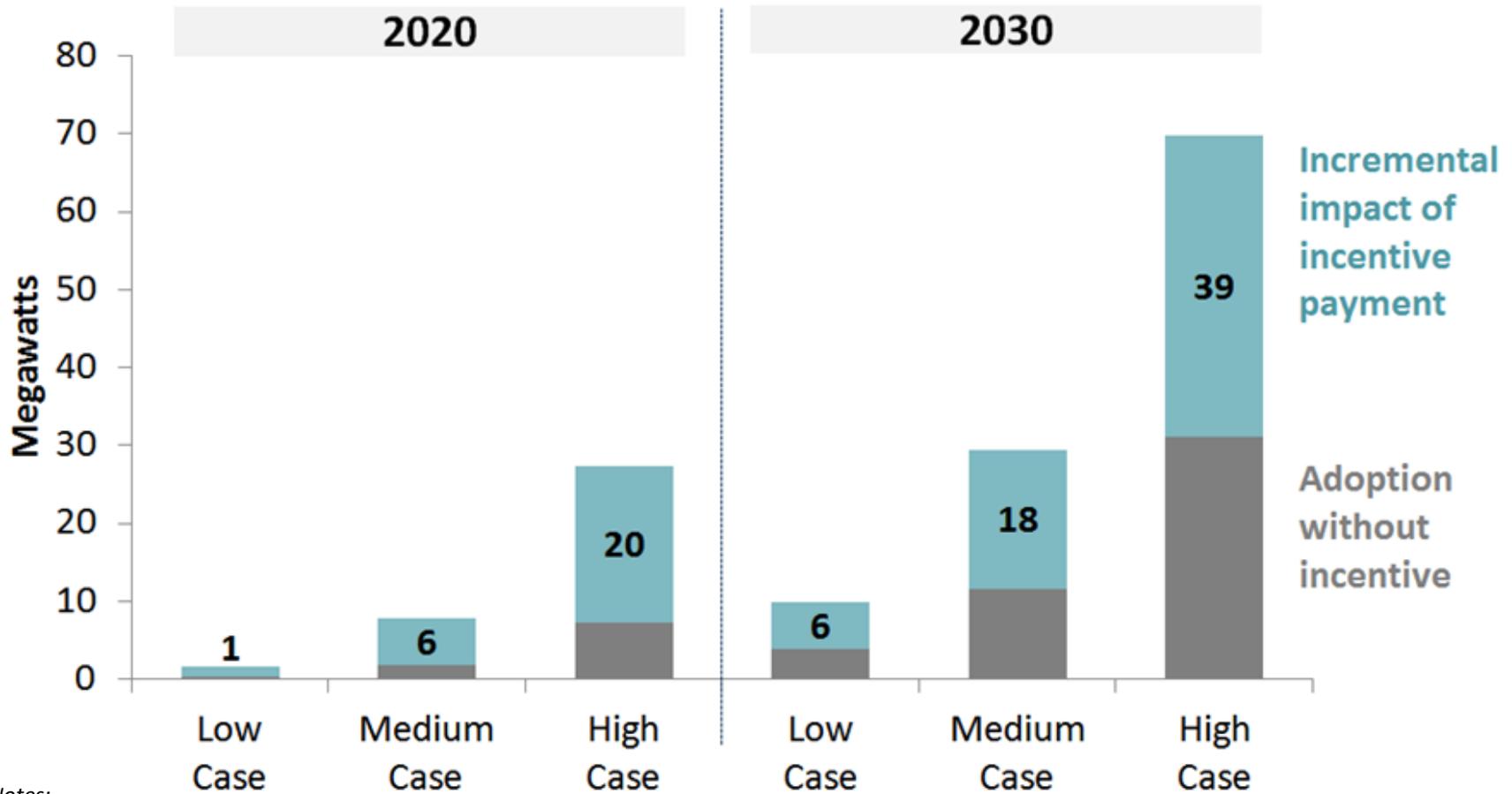
Approach to Quantifying BTM Storage Potential

We use a 7-step process to evaluate BTM adoption with and without a utility-administered program



Projected Cumulative BTM Storage Adoption with and without Utility Incentive Programs

A utility BTM storage program could increase adoption by up to 20 MW in 2020 and 39 MW in 2030.



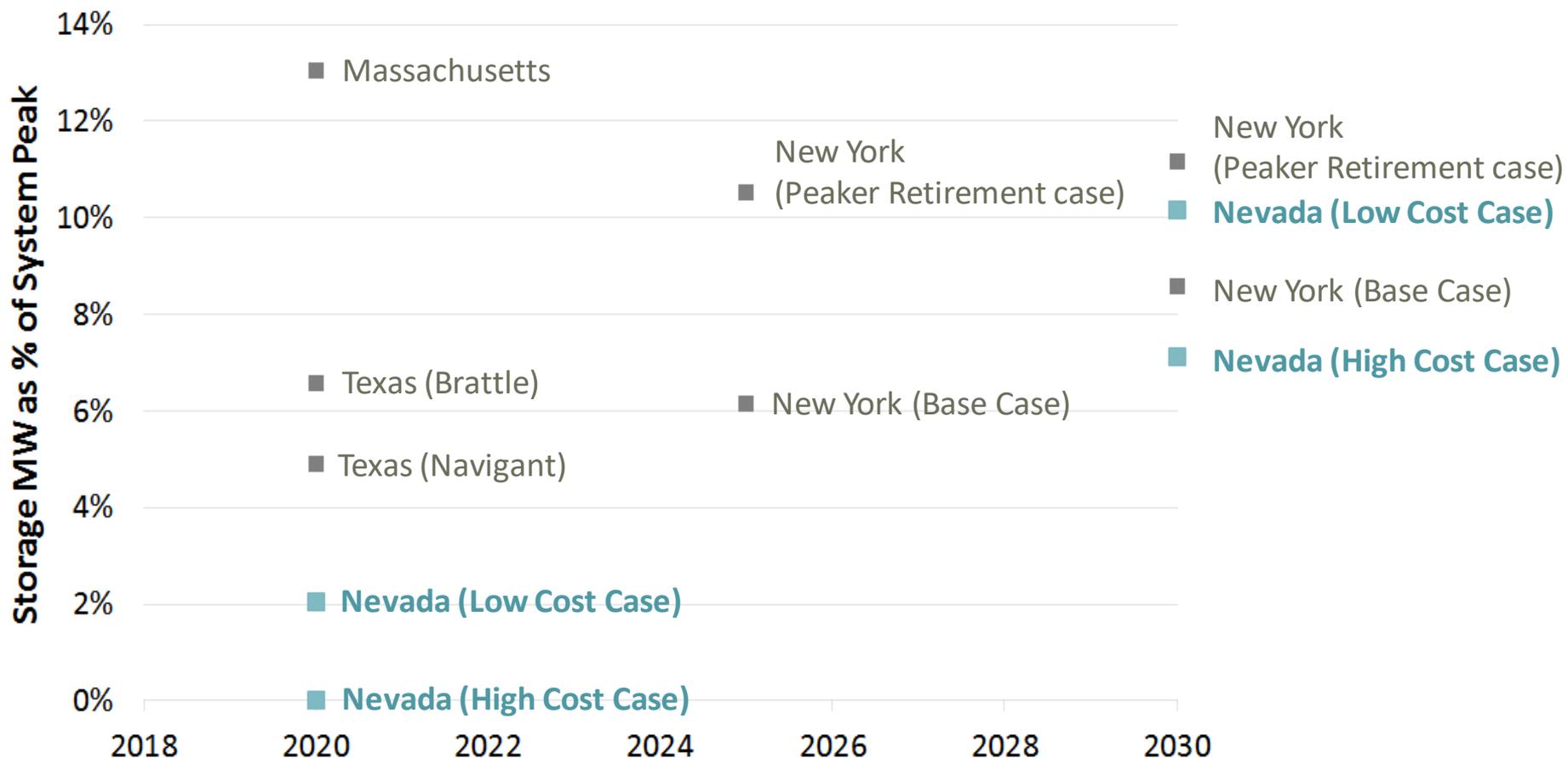
Notes:

The potential estimates represent long-run adoption potential based on assumed storage costs for the years shown in the figure. It would take several years to reach these adoption levels.

Comparison to Other Storage Potential Studies

Comparison of Cost-Effective Storage Deployment Levels Across Studies

We find lower cost-effective storage levels than other studies in 2020 (proportional to system peak). 2030 findings similar to NY study.



Study Conclusions

Study Conclusions

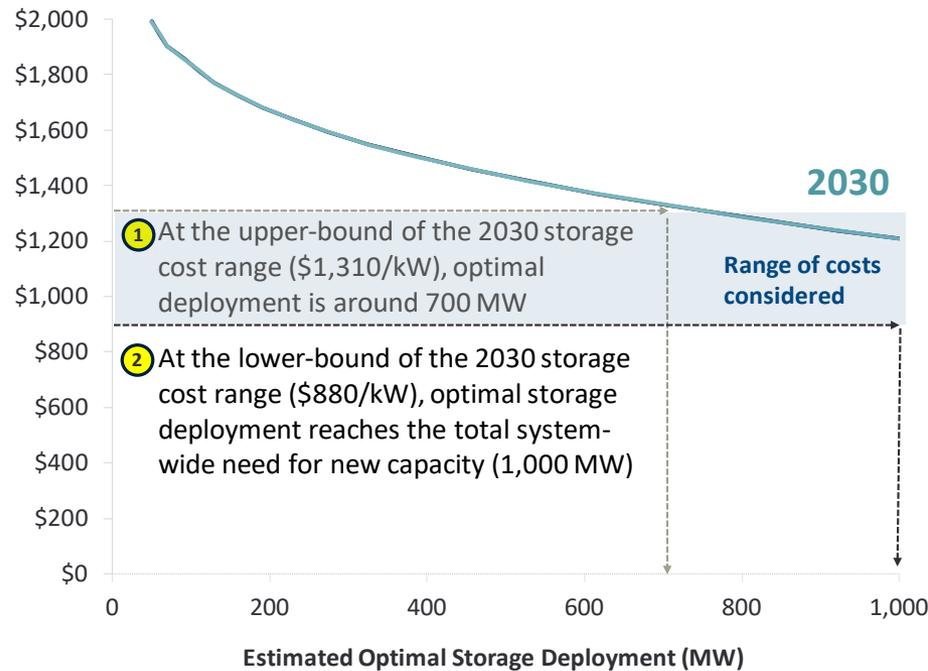
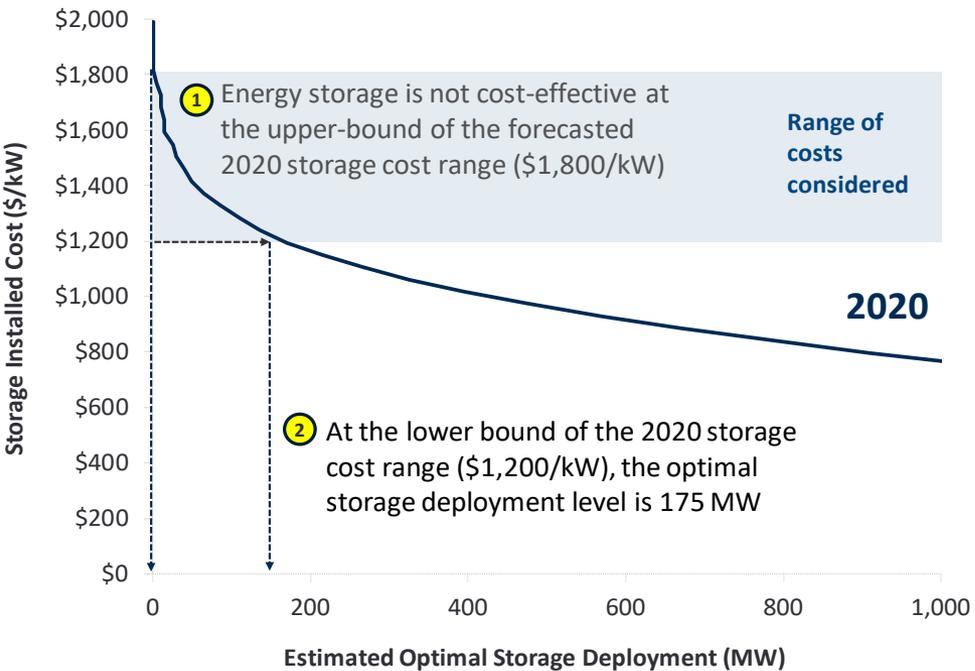
Conclusions

Energy storage deployments can be cost-effectively incorporated into Nevada's future power supply mix.

- Energy storage can provide value across several applications. This finding is robust across a range of modeled scenarios
- In 2020, up to 175 MW could be cost-effective if storage at lower end of projected cost range
- By 2030, cost-effective levels exceed 700 MW
- Utility BTM incentive programs could increase adoption by up to 20 MW in 2020 and up to 39 MW in 2030
- Additional feasibility studies would be valuable to further validate these conclusions

Optimal Storage Deployment Curves

Future procurements could be expressed as an “optimal deployment curve” to account for cost uncertainty and changing system conditions.



Notes:

Costs are shown in nominal dollars. Values are based on an assumed energy storage configuration of 10 MW / 40 MWh.

Author Contact Information



RYAN HLEDIK

Principal | New York, NY

Ryan.Hledik@brattle.com

415.789.3684



ROGER LUEKEN

Associate | Washington, DC

Roger.Lueken@brattle.com

+1.202.419.3321



JUDY CHANG

Principal and Director | Boston, MA

Judy.Chang@brattle.com

+1.617.234.5630



JOHANNES PFEIFENBERGER

Principal | Boston, MA

Hannes.Pfeifenberger@brattle.com

+1.617.234.5624

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.

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

Our Practices and Industries

ENERGY & UTILITIES

Competition & Market Manipulation
Distributed Energy Resources
Electric Transmission
Electricity Market Modeling & Resource Planning
Electrification & Growth Opportunities
Energy Litigation
Energy Storage
Environmental Policy, Planning and Compliance
Finance and Ratemaking
Gas/Electric Coordination
Market Design
Natural Gas & Petroleum
Nuclear
Renewable & Alternative Energy

LITIGATION

Accounting
Analysis of Market Manipulation
Antitrust/Competition
Bankruptcy & Restructuring
Big Data & Document Analytics
Commercial Damages
Environmental Litigation & Regulation
Intellectual Property
International Arbitration
International Trade
Labor & Employment
Mergers & Acquisitions Litigation
Product Liability
Securities & Finance
Tax Controversy & Transfer Pricing
Valuation
White Collar Investigations & Litigation

INDUSTRIES

Electric Power
Financial Institutions
Infrastructure
Natural Gas & Petroleum
Pharmaceuticals & Medical Devices
Telecommunications, Internet, and Media
Transportation
Water

Our Offices



BOSTON



NEW YORK



SAN FRANCISCO



WASHINGTON



TORONTO



LONDON



MADRID



ROME



SYDNEY

THE POWER OF **ECONOMICS**

brattle.com

THE **Brattle** GROUP

