Behind-the-Meter Storage

STACKED BENEFITS OR THE NEXT DEATH SPIRAL?

PRESENTED TO

EEI Strategic Issues Roundtable

PRESENTED BY

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Pittsburgh, PA

THE Brattle GROUP

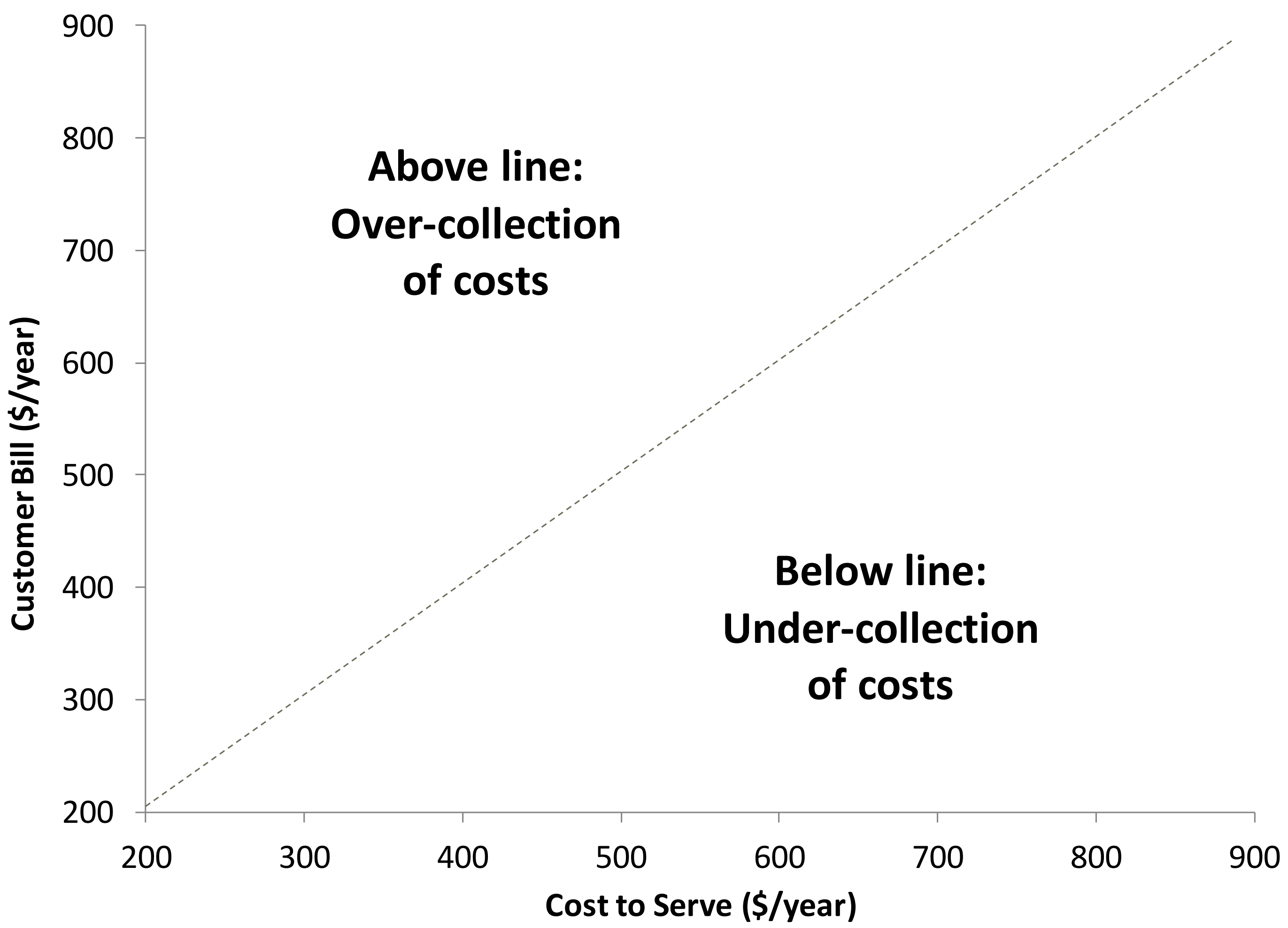
There's a question many are currently noodling over...

Behind-the-meter storage:

Will it provide "stacked benefits"?

Or is it the next risk of a utility "death spiral"?

Comparing customer bills and cost-to-serve

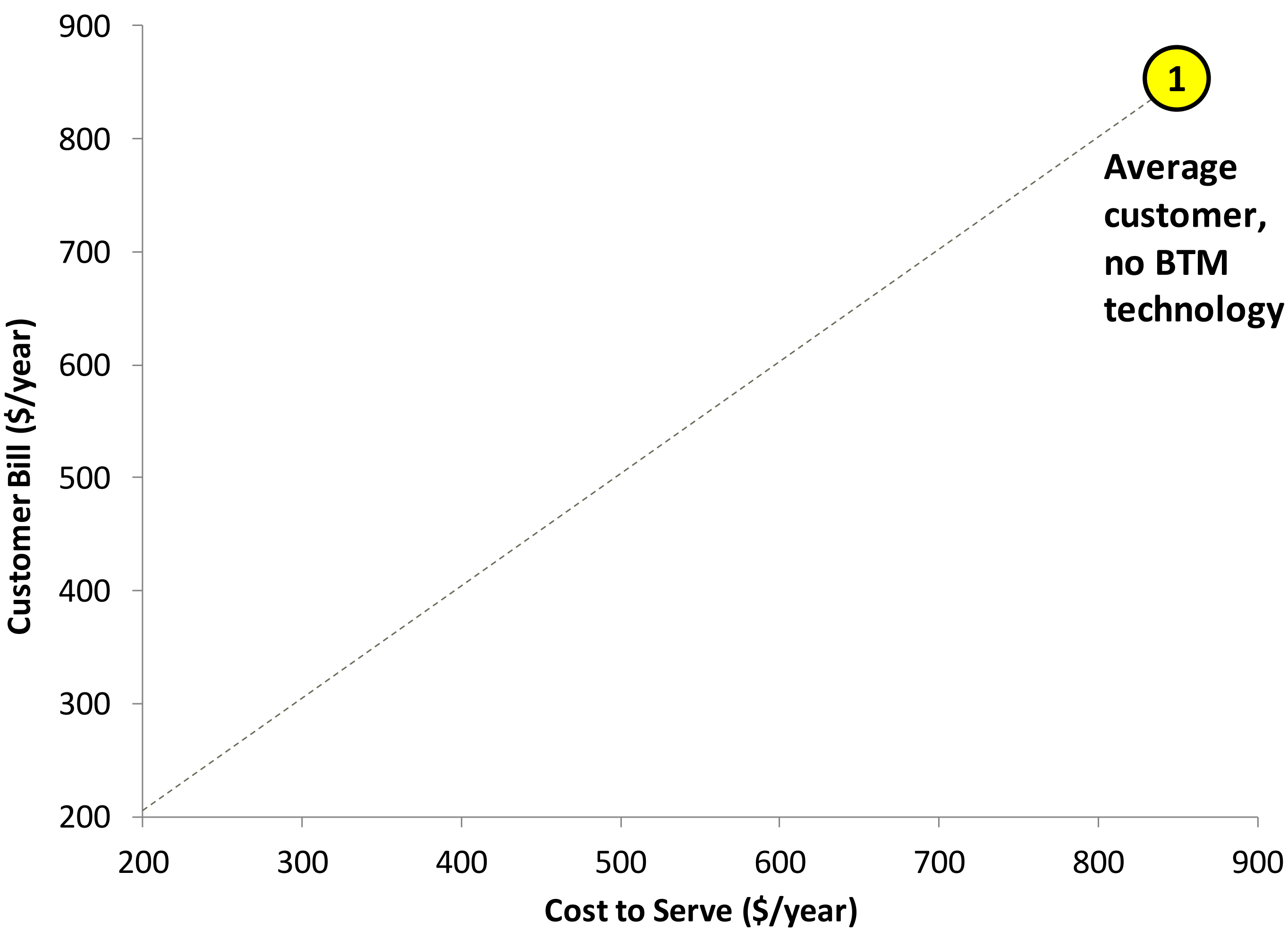


To quantify potential cost under-recovery due to adoption of BTM technologies, we simulate customer bills (i.e., utility revenue) and compare that revenue to their allocated costs

For a given customer, the distance below the dotted line indicates the degree of cost under-recovery

In this example, we use publicly available DOE load data for the Chicago area; see appendix for methodological details

Cost recovery: Average residential customer

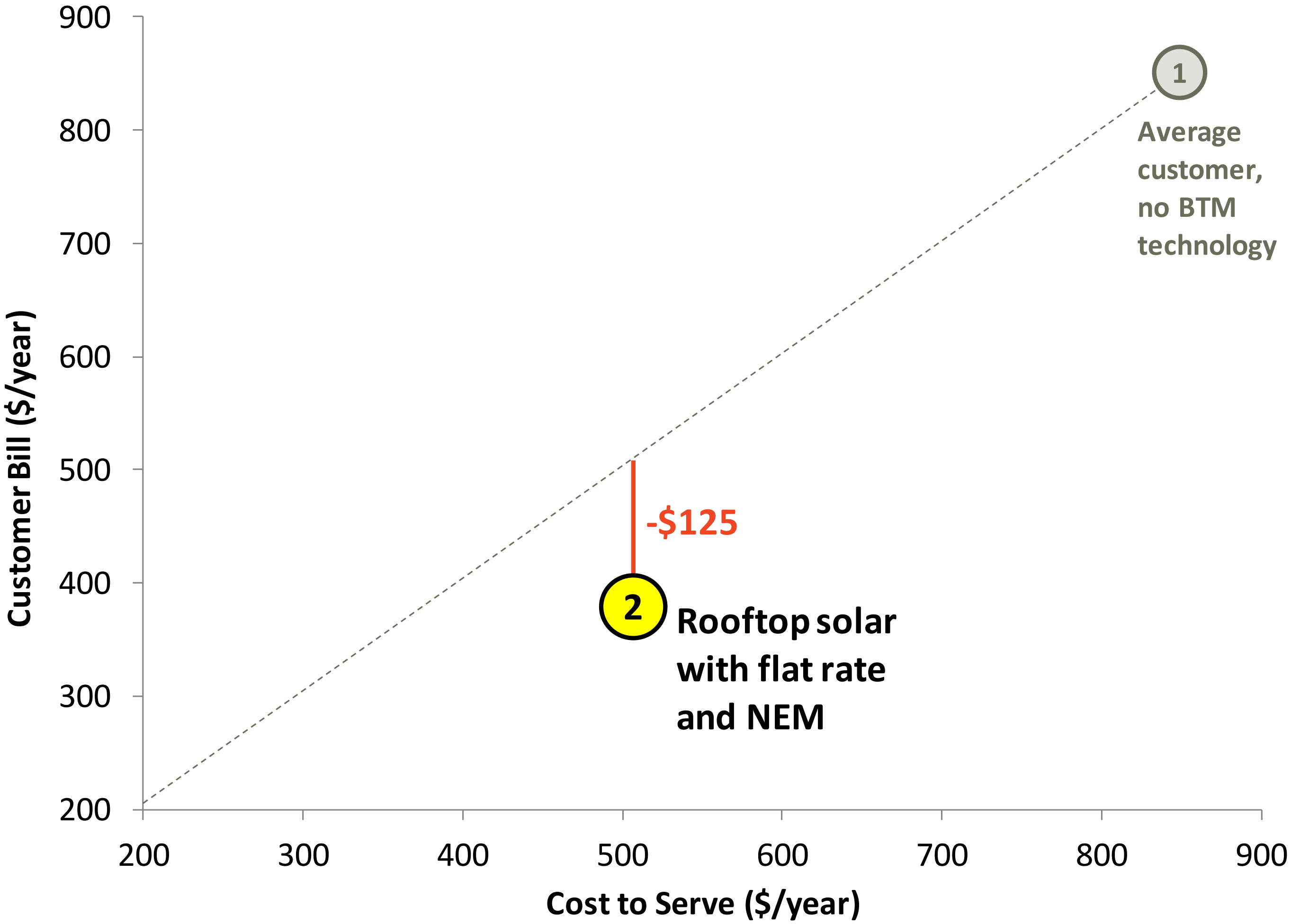


1 Current flat rates are designed to fully collect allocated costs from the average residential customer (without BTM technologies)

In this example, the average customer's annual bill is $850/yr

Note: For simplicity, we have assumed no inter-class subsidies

Cost recovery:
Rooftop solar customer with NEM

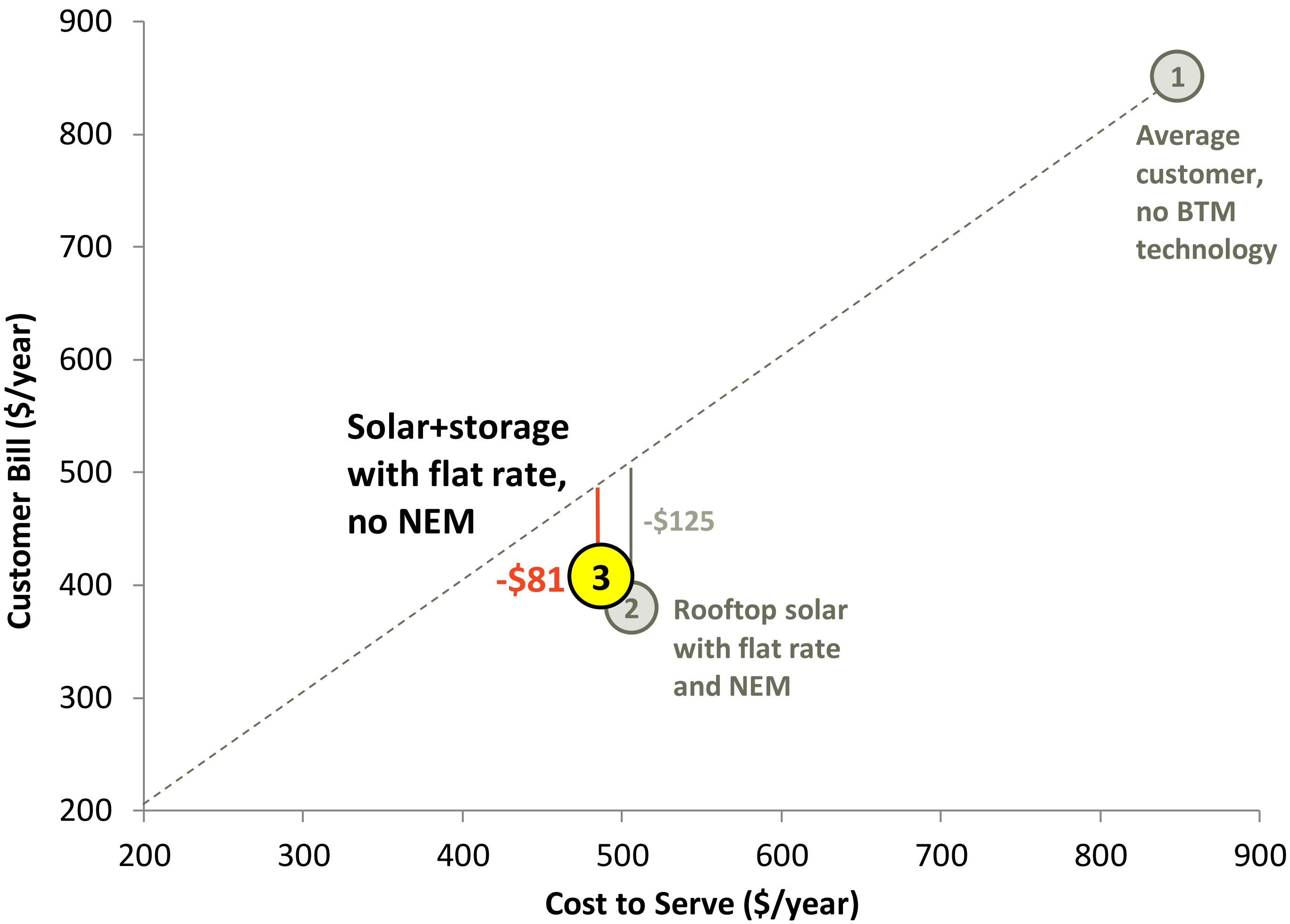


2 Net energy metering (NEM) allows customers with rooftop solar to avoid paying the full retail rate, while utility costs are reduced only by a fraction of that amount

In this example, bills decrease by $475 but costs only decrease by $350

The result is a loss in net revenue of $125/yr

Cost recovery:
Solar + storage with flat rate, no NEM



3 When NEM is phased out, BTM storage may fill in as a substitute – and solar customers continue to avoid the full retail rate

With a flat rate, customers have no incentive to manage the battery in a way that reduces system costs, though peak demand is reduced to a degree

In this example, substituting BTM storage for NEM decreases cost under-recovery to $81/yr

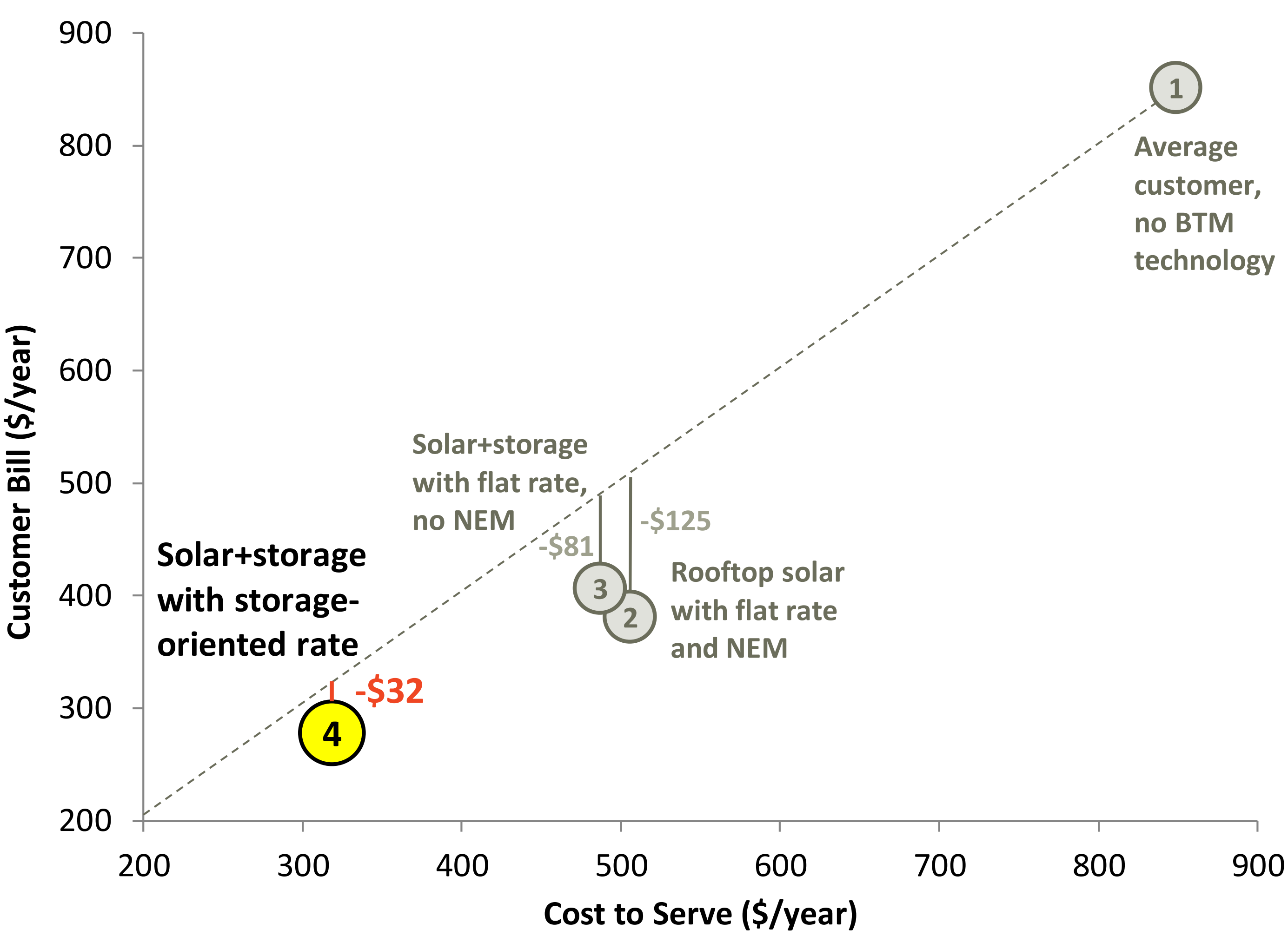
Introducing storage-oriented rate design

Cost-based rates with granular price signals can better accommodate the operational characteristics of storage

Rate feature	Charge	Description
Supply Charge	$5/kW	Pass-through of wholesale capacity charge; based on customer demand in hours coincident with the utility peak and the ISO peak
Distribution Charge	$7/kW-month	Based on customer's maximum demand
Energy Charge	Varies hourly	Pass-through of day-ahead wholesale energy prices
Fixed Charge	$15/month	Unavoidable through changes in usage patterns

Notes: Storage-oriented rate is revenue neutral with the two-part rate used in this example. It produces the same bill for the class-average residential customer (without BTM technology).

Cost recovery:
Solar + storage, with storage-oriented rate



4 With a storage-oriented rate, the customer has greater bill savings opportunities, and these bill savings may translate into long-run cost savings for the utility

The net loss from solar+storage customers is more than cut in half in the long-run due to the new rate

The remaining $32/yr in cost under-recovery depends heavily on the extent to which the distribution demand charge aligns with the underlying cost drivers

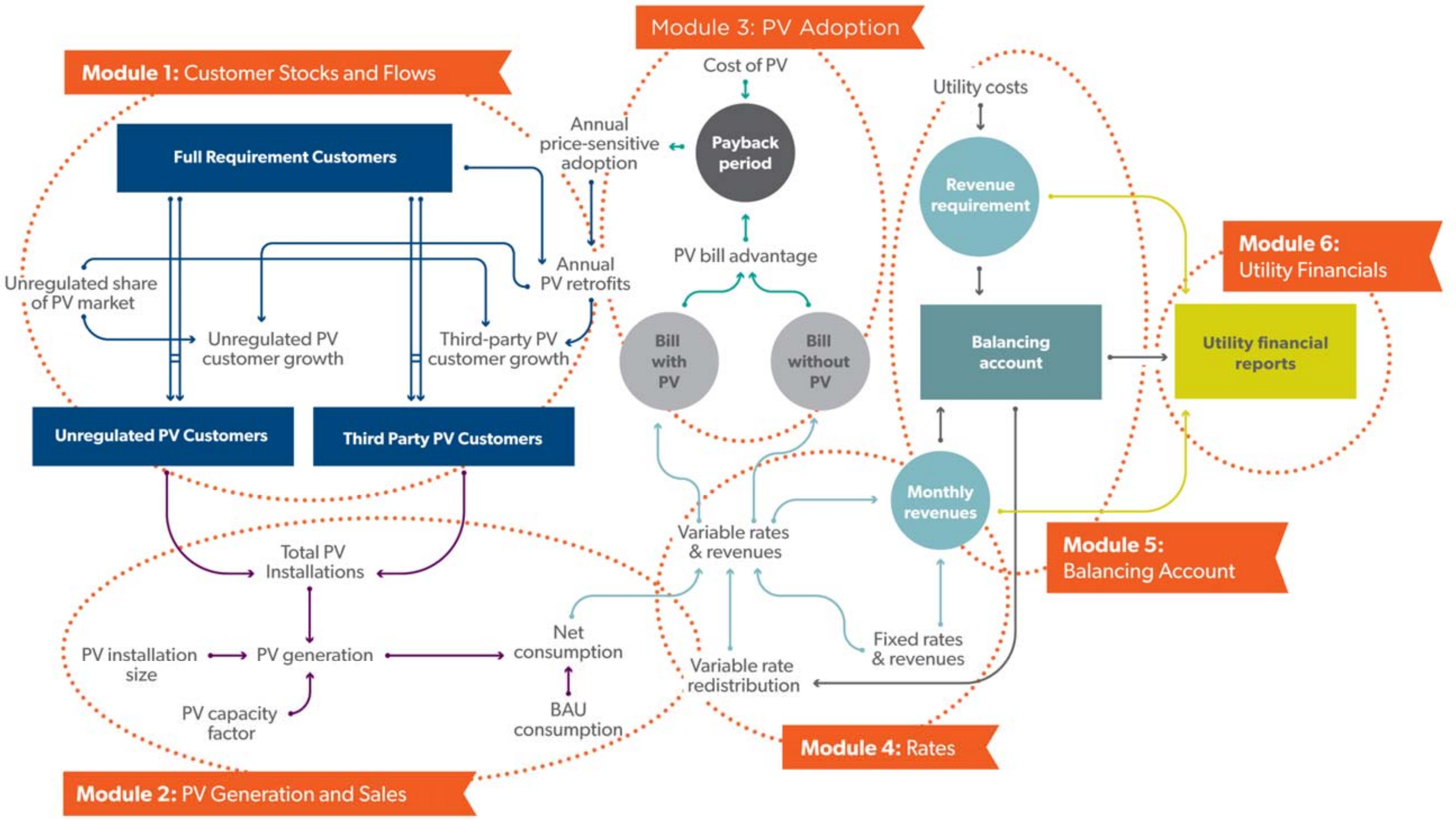
Strategic questions remain

- What are the **financial consequences of the lag** between near-term reduced bills and long-term avoided costs?
- How would **changes in the underlying rate design** further mitigate or exacerbate cost under-recovery?
- To what extent will the bill savings opportunities translate into **adoption** of BTM storage?
- Can the benefits of BTM storage be captured better through the provision of an **advanced demand response program**?
- Is there an **adoption "tipping point"** if storage technology costs continue to decline at a rapid pace?
- How can the **dynamic relationships** between each of the above issues be accounted for?

"System dynamics" can help to untangle these complex questions

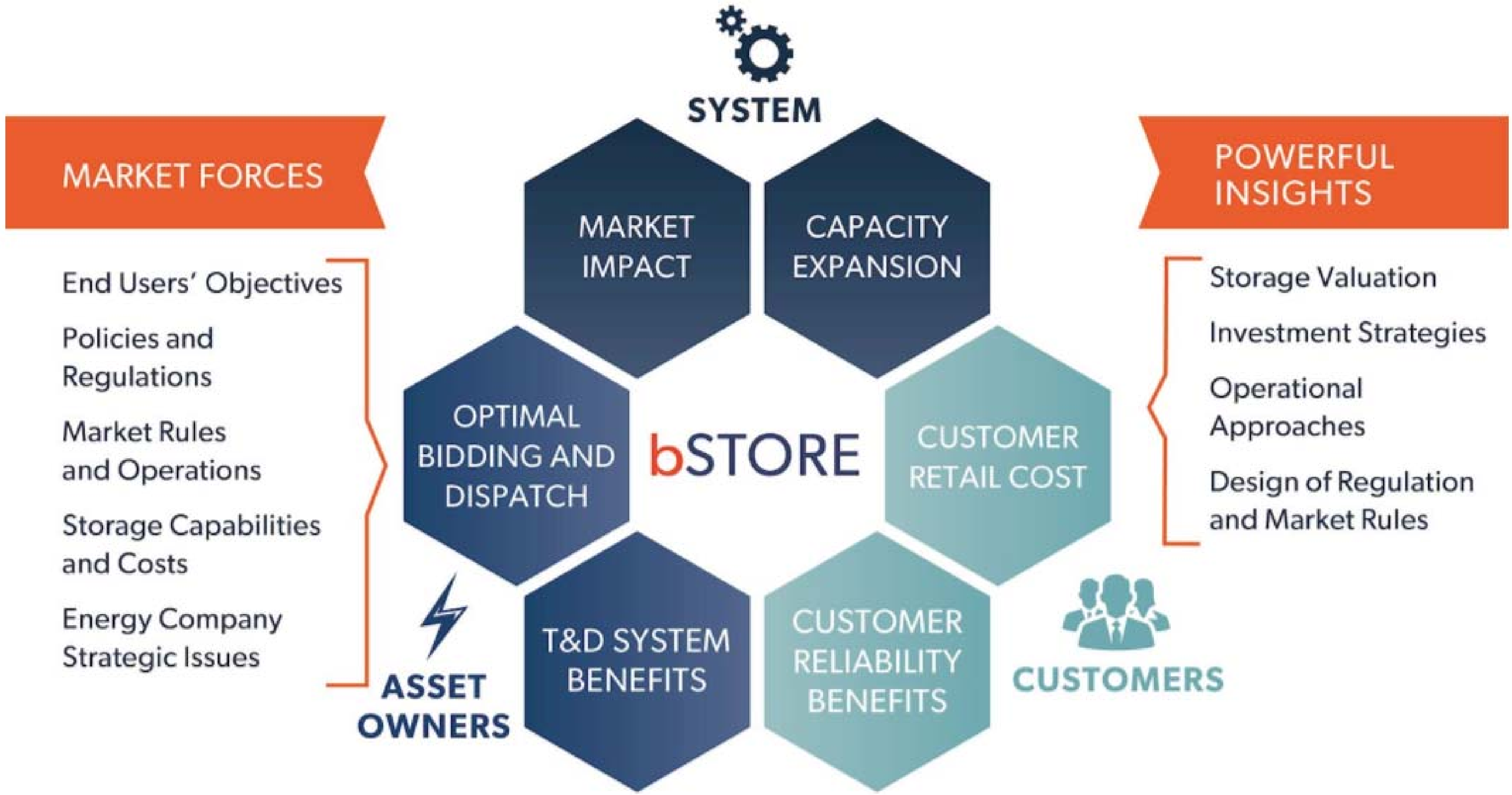
CRISP

(Corporate Risk Integrated Strategy Platform)

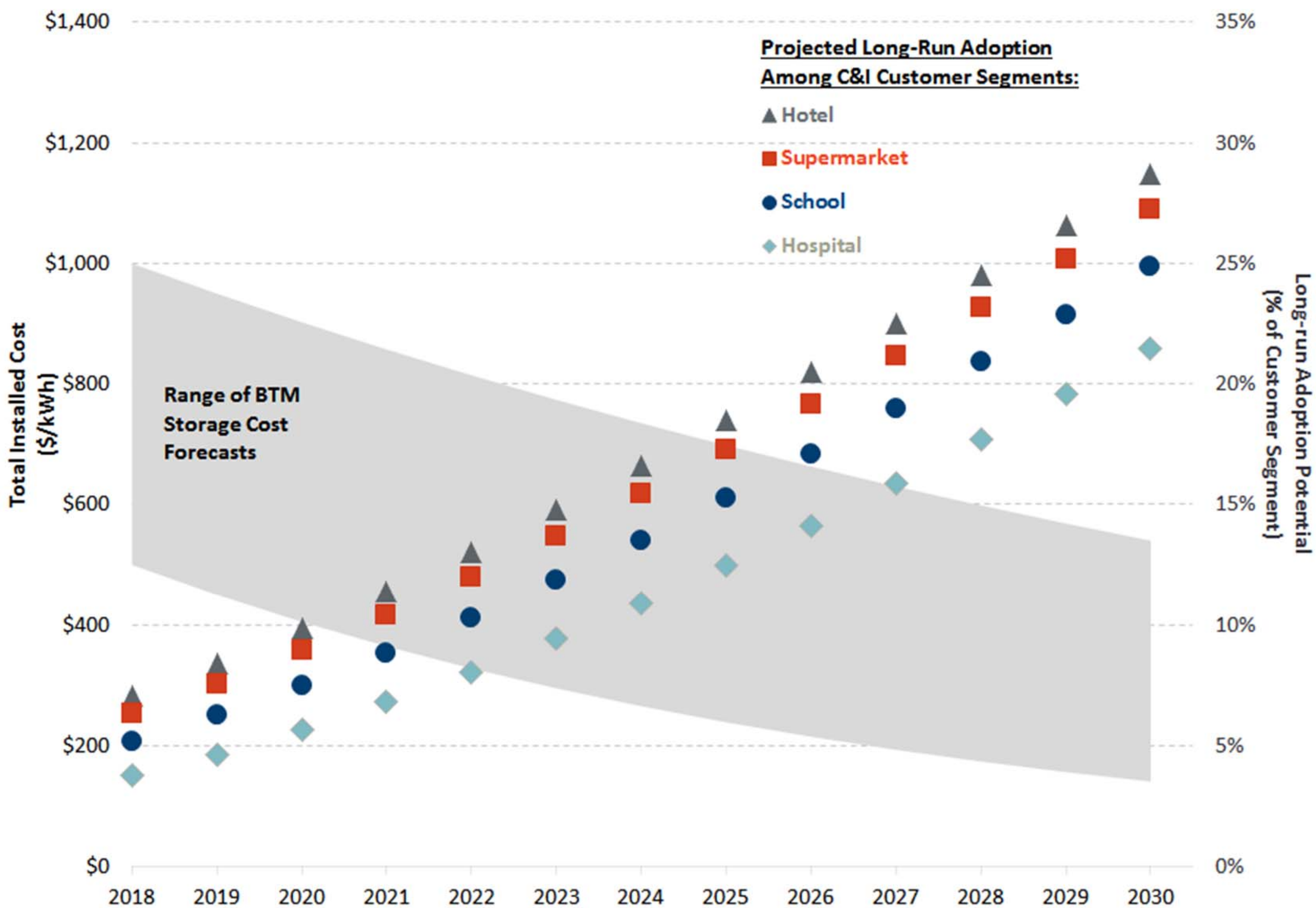


Appendix A:
Additional Materials

Brattle developed the bSTORE model to explore emerging storage-related issues



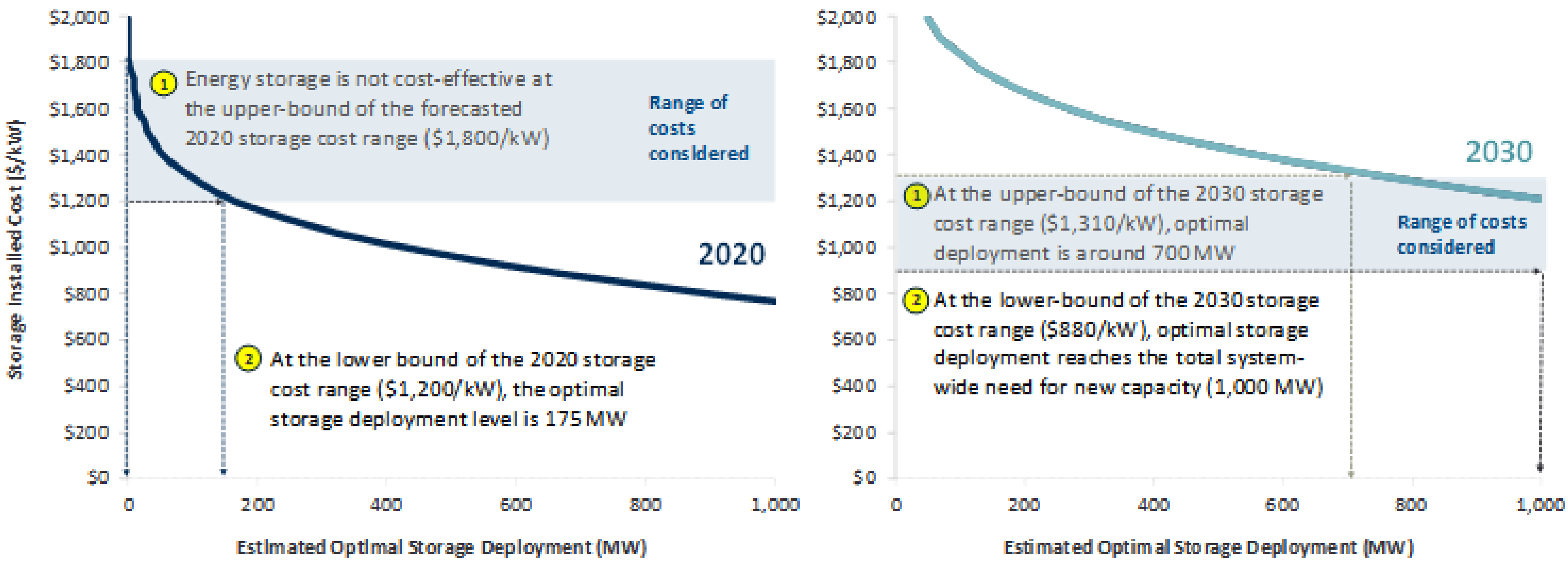
Long-run adoption of BTM storage could reach 20% for key customer segments



Notes: The Brattle Group analysis. Assumes 100% bonus depreciation. Battery cost estimates are stated prior to any tax benefits of depreciation. Adoption rates are long-run estimates that would take several years to be realized; they are not achieved instantaneously in the year shown. Adoption estimates are based on the midpoint of the range of total installed battery costs shown. Results are shown for a 2-hour battery sized to 5% of the customer's peak load. Assumes customers are offered the storage-oriented rate shown in this presentation.

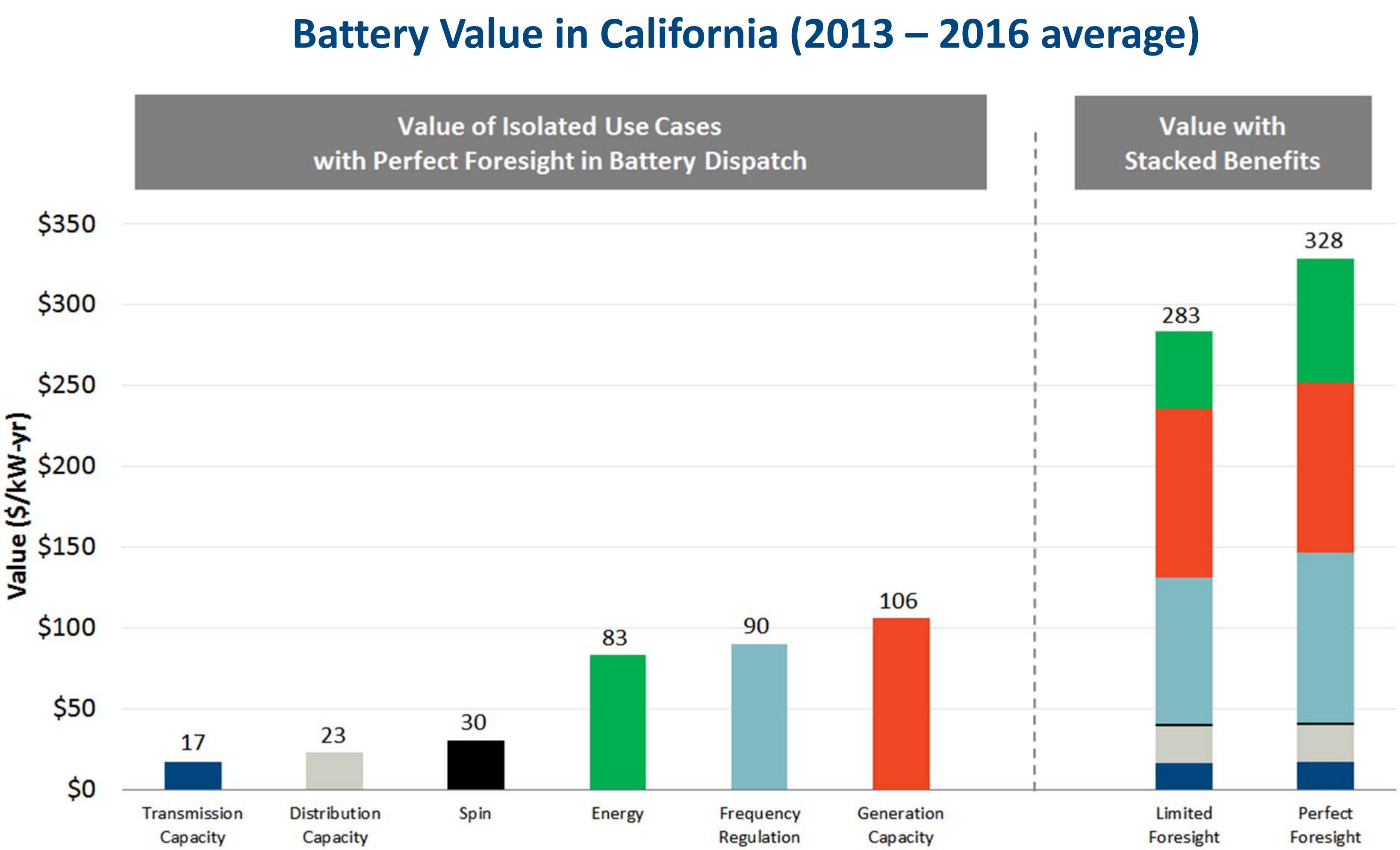
The economic potential for storage is highly dependent on future storage technology costs

Nevada Optimal Storage Deployment Curves, 2020 and 2030



Notes: Costs are shown in nominal dollars. Values are based on an assumed energy storage configuration of 10 MW / 40 MWh. See The Brattle Group, "The Economic Potential for Energy Storage in Nevada," October 2018.

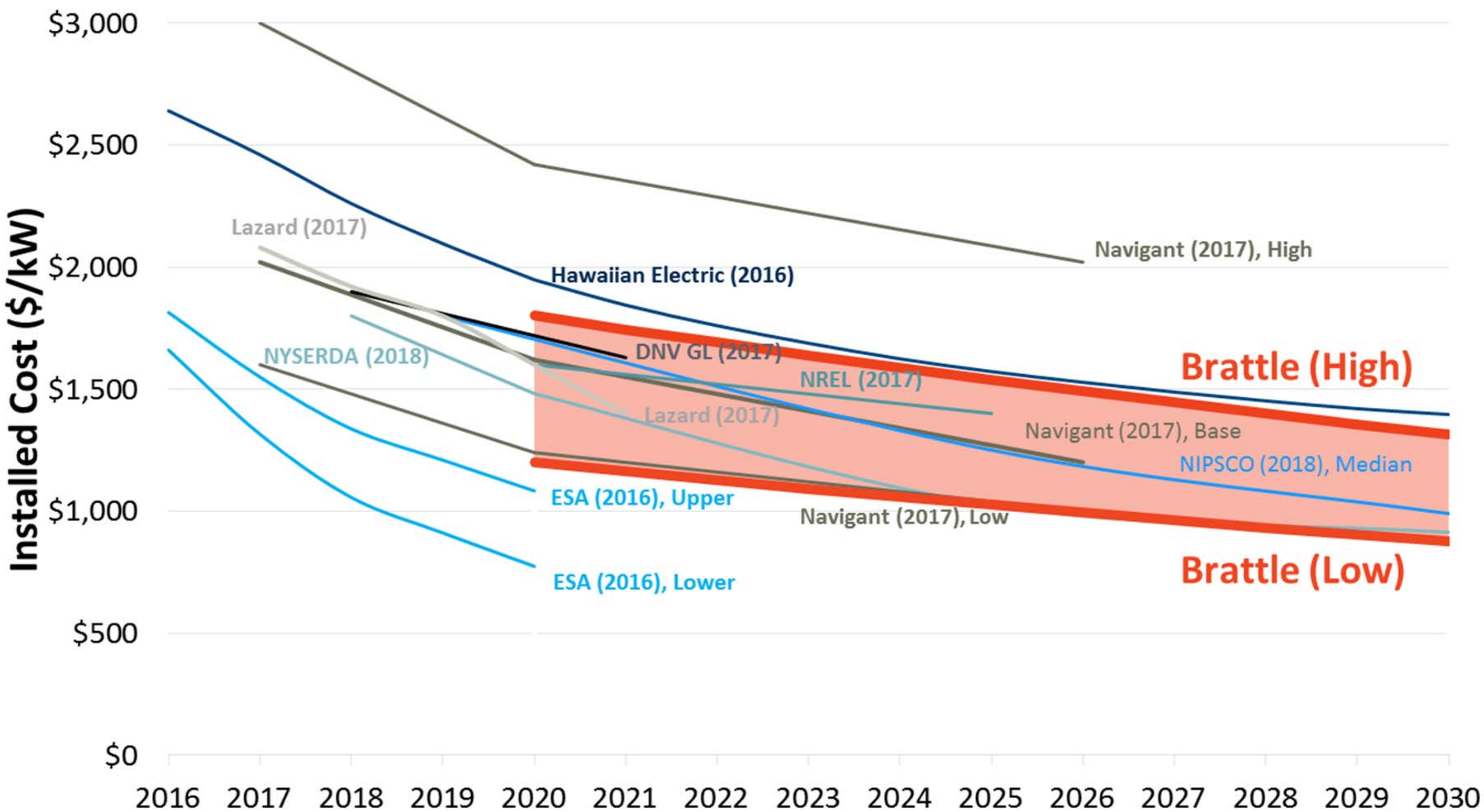
"Value stacking" significantly increases the total benefits of energy storage



Notes: See The Brattle Group, "Stacked Benefits: Comprehensively Valuing Battery Storage in California," September 2017.

Battery costs are expected to continue to decline significantly

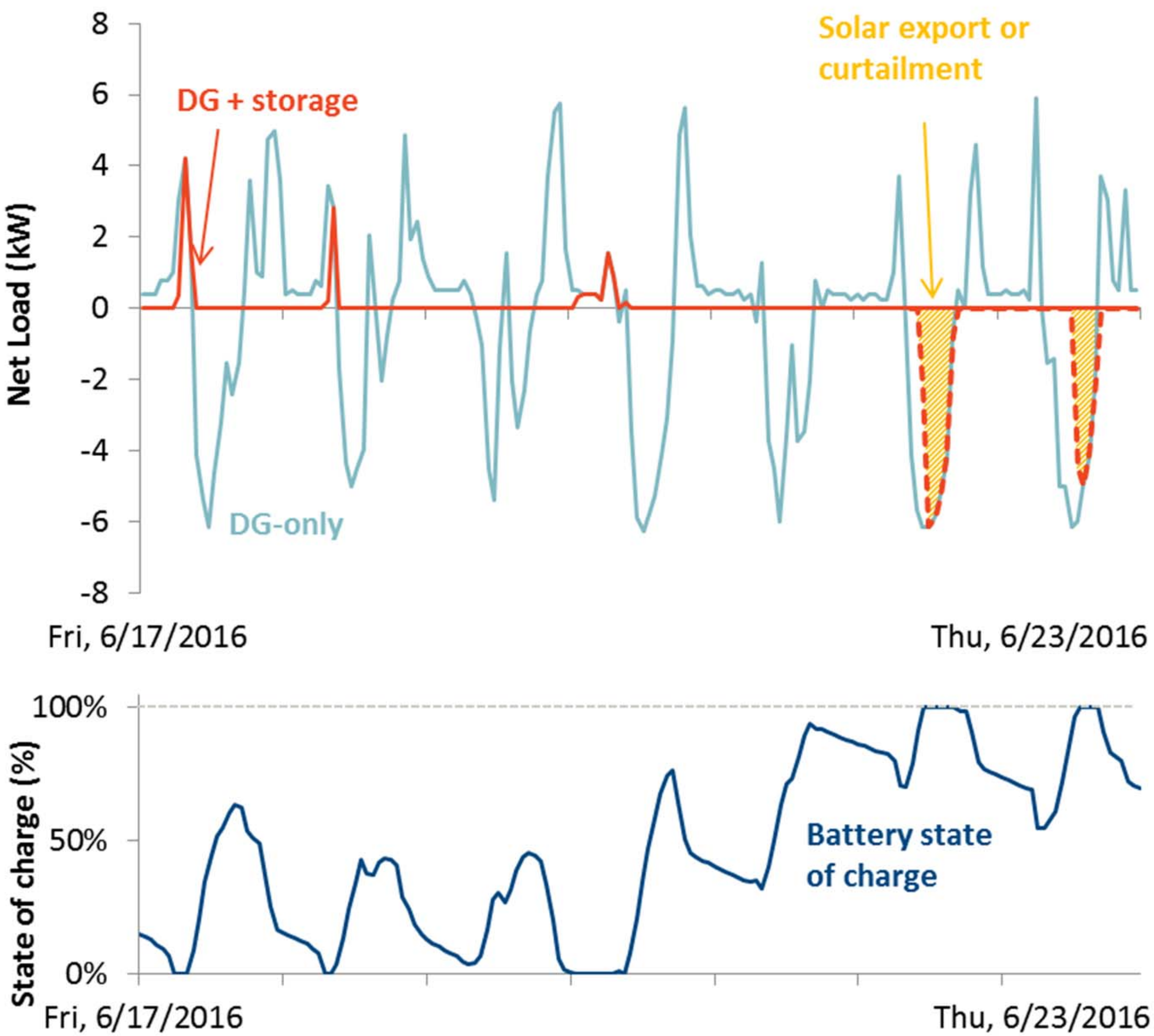
Installed Cost Projections for 4-hour Lithium-Ion Battery Storage Facilities



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. See The Brattle Group, "The Economic Potential for Energy Storage in Nevada," October 2018.

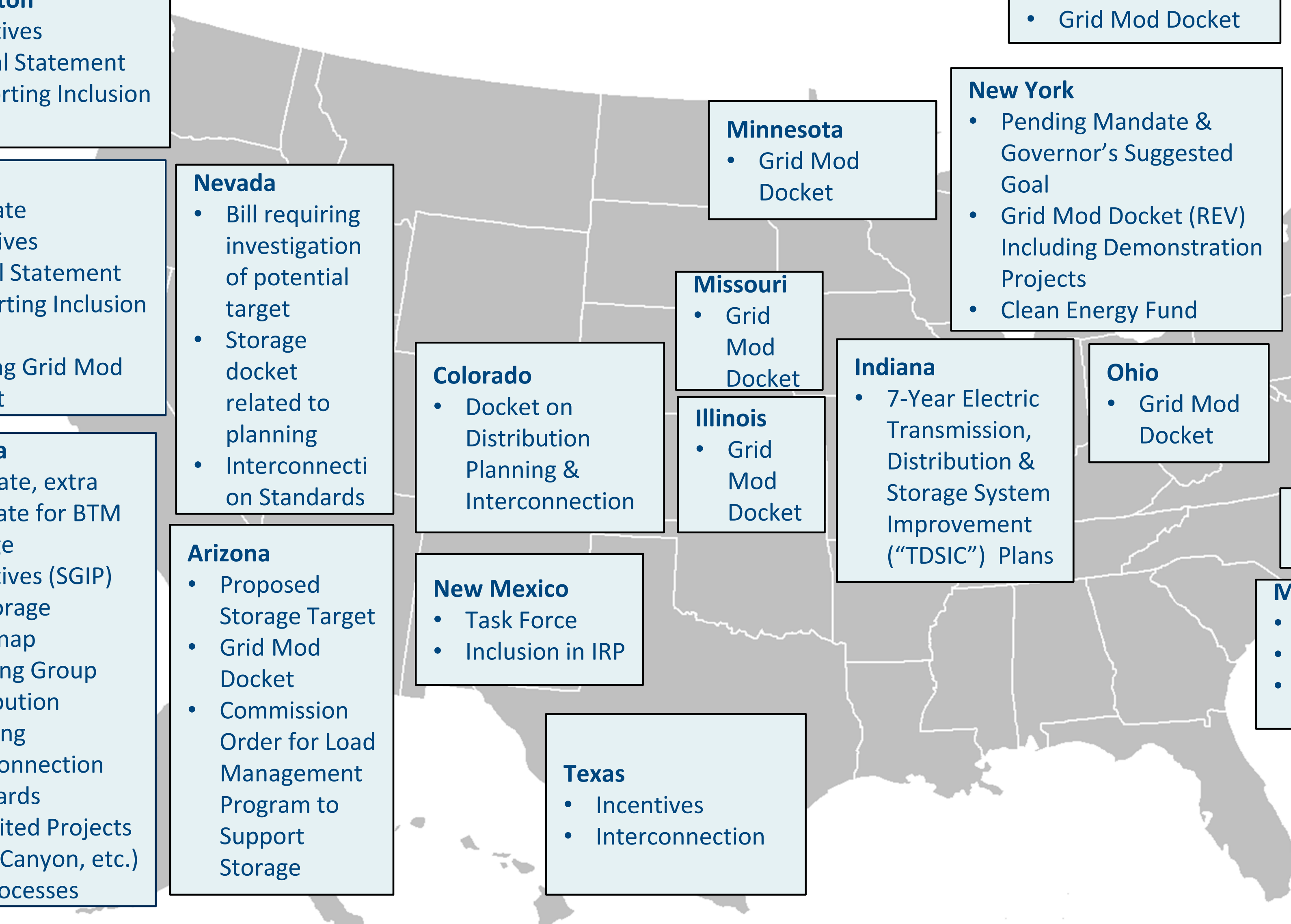
BTM storage does not automatically solve the problems otherwise introduced by rooftop solar with NEM and flat rates

Individual Customer Net Load and Battery State of Charge



- Figure illustrates net load for an individual DG customer with and without storage
- Battery capacity is assumed to be large enough to store all energy that would otherwise be exported on any individual day of the year
- However, low load during nighttime hours prevents battery from fully discharging between days
- This eventually leads to conditions where the battery is charged fully to capacity, and excess DG output would need to be exported to the grid or otherwise curtailed to avoid exporting
- Additionally, days with high load continue to produce spikes in demand, leading to a low overall customer load factor
- For further methodological detail, see Brattle presentation filed on August 10, 2018 by Idaho Power in Idaho PUC Case No. IPC-E-17-13

Many active state regulatory proceedings will affect storage deployment



New Hampshire
- Grid Mod Docket

Vermont
- Grid Mod Docket

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

Washington
- Incentives
- Formal Statement Supporting Inclusion in IRP

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

Nevada
- Bill requiring investigation of potential target
- Storage docket related to planning
- Interconnection Standards

Minnesota
- Grid Mod Docket

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

Missouri
- Grid Mod Docket

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

Colorado
- Docket on Distribution Planning & Interconnection

Illinois
- Grid Mod Docket

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

Ohio
- Grid Mod Docket

California
- Mandate, extra mandate for BTM storage
- Incentives (SGIP)
- CA Storage Roadmap
- Working Group
- Distribution Planning
- Interconnection Standards
- Expedited Projects (Aliso Canyon, etc.)
- IRP Processes

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

New Mexico
- Task Force
- Inclusion in IRP

DC
- Grid Mod Docket

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

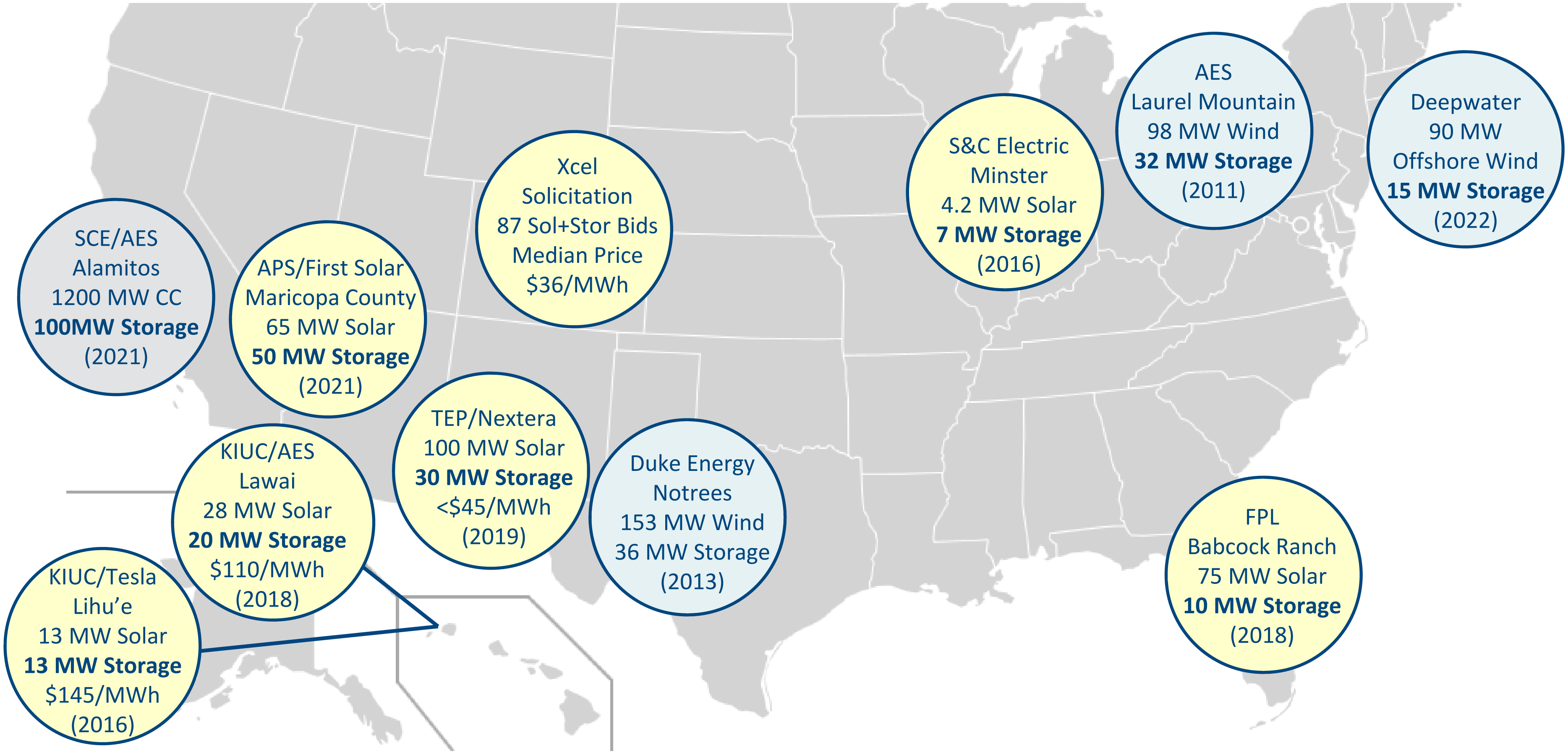
Texas
- Incentives
- Interconnection

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.

Utility-scale hybrid storage deployments are increasing

Significant activity in hybrid deployment of utility-scale 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**



Appendix B: Methodological Details

Data sources

Customer load profile: DOE's OpenEI database, for Chicago area

- https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states

PV Output: NREL's PVWatts calculator, using Chicago data

- https://pvwatts.nrel.gov/

Rate assumptions

Flat rate (with NEM)

- 7 c/kWh volumetric charge
- All solar PV output compensated at 7 c/kWh rate
- $15/month fixed charge

Flat rate (without NEM)

- 7c/kWh volumetric charge
- Net exports of solar PV compensated at average wholesale cost of 5 c/kWh
- $15/month fixed charge

Storage-Oriented Rate

- See slide 7
- $5/kW supply charge
- $7/kW demand charge
- Energy price pass-through
- $15/month fixed charge
- Revenue neutral to flat rate for average residential customer

Battery utilization

Solar+storage configuration

- Rooftop solar PV maximum output of 4.5 kW
- Battery capacity of 10 kW / 20 kWh, with 90% roundtrip efficiency
- Battery sized roughly with enough energy storage capacity to store maximum net solar PV exports for any single day across the year
- 2-hour battery duration roughly optimizes tradeoff between battery cost and demand charge avoidance capability

Battery charge/discharge methodology

- Flat rate without NEM: Battery charges with excess generation from the PV unit, and discharges to reduce customer purchases from the grid whenever customer net load is positive
- Storage-oriented rate: Battery dispatch is optimized to maximize customer bill savings across the supply charge, demand charge, and hourly energy prices

Illustrative utility cost profile

Energy costs

- Represented by hourly wholesale energy market prices (PJM 2016)
- Assumed same as hourly prices in storage-oriented retail rate

Supply costs

- Determined by utility load during top peak hours for ISO and utility
- Costs assumed same as supply charge in storage-oriented retail rate

Distribution costs

- Assumed to be partially correlated to individual customer max billing demand
- A reduction in customer max billing demand that produces a $10 reduction in the distribution portion of the bill is assumed to produce $7.50 in long-run avoided distribution costs
- This illustrative assumption is heavily dependent on the design of the rate and its alignment with the underlying cost structure of an individual utility

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Mr. Hledik specializes in the economics of policies and technologies that are focused on the energy consumer. He assists clients confronting complex issues related to the recent slowdown in electricity sales growth and the evolution of utility customers from passive consumers to active managers of their energy needs.

Mr. Hledik has supported utilities, policymakers, law firms, technology firms, research organizations, and wholesale market operators in matters related to retail rate design, energy efficiency, demand response, distributed generation, and smart grid investments. He has worked with more than 50 clients across 30 states and 7 countries.

A frequent presenter on the benefits of smarter energy management, Mr. Hledik has spoken at events throughout the United States, as well as in Belgium, Brazil, Canada, Germany, Korea, Poland, Saudi Arabia, the United Kingdom, and Vietnam. He regularly publishes on complex retail electricity issues.

Mr. Hledik received his M.S. in Management Science and Engineering from Stanford University, with a concentration in Energy Economics and Policy. He received his B.S. in Applied Science from the University of Pennsylvania, with minors in Economics and Mathematics. Prior to joining The Brattle Group, Mr. Hledik was a research assistant with Stanford University's Energy Modeling Forum and a research analyst at Charles River Associates.

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Our storage expertise

Asset Valuation & Planning

- 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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Additional Brattle storage resources

"The Economic Potential for Energy Storage in Nevada," Ryan Hledik, Judy Chang, Roger Lueken, Johannes Pfeifenberger, John Imon Pedtke, Jeremy Vollen, October 1, 2018

"Storage-Oriented Rate Design: Stacked Benefits or the Next Death Spiral?" Ryan Hledik, Jake Zahniser-Word, Jesse Cohen, *The Electricity Journal*, forthcoming.

"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

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