U.S. Battery Storage Market

Regulatory and Market Environments

PRESENTED TO

Philadelphia Area Municipal Analyst Society

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THE Brattle GROUP

Agenda

- Electricity Industry Trends
- Multiple Layers of Value for Battery Storage
- Battery Storage Investment Activity

Electricity Industry Trends

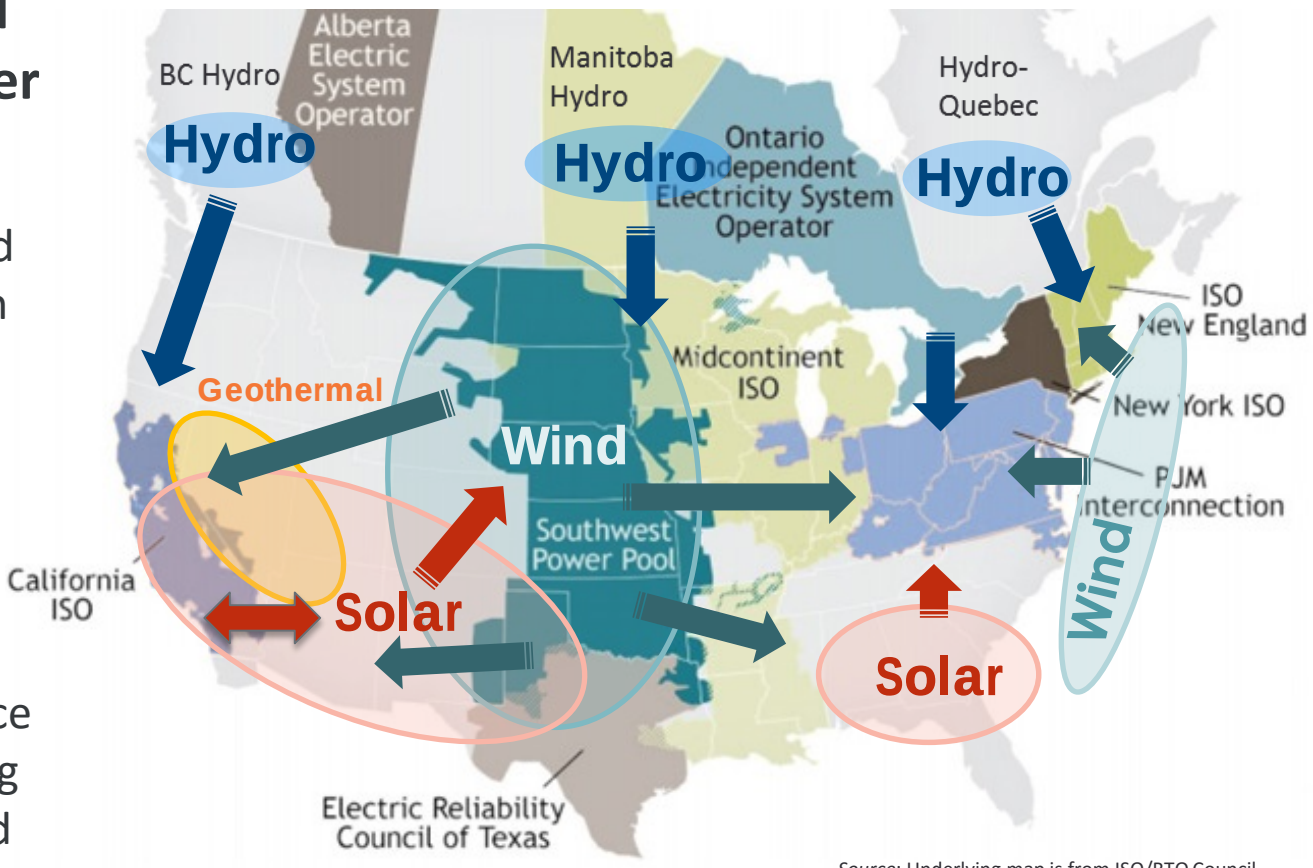
- **Reduced growth in traditional electricity consumption**
- Increased customer **preferences for conservation and clean energy**
- **Technological advances** that allow customers and electric utilities to better monitor and control electricity usage
- Significant **cost reduction in solar and wind generation** and innovative project financing, yielding low cost clean resources
- **Low natural gas prices** place significant downward pressure on coal and nuclear plants
- **Increased stringency in local environmental regulations** of air emissions, water usage, waste disposal, and land use for all power plants
- **Increasing electrification** of transportation and heating
- **Battery storage** cost reduction and deployment across supply chain

These are significant changes that utilities, grid operators, and regulators are trying to manage.

Diversifying Low-Cost Clean Energy Resources

Resource and demand diversification can offer significant benefits:

- Reduces investment and balancing cost with high levels of intermittent resources
- Relies on build out of transmission to interconnect them
- Increases the importance of interregional planning processes going forward



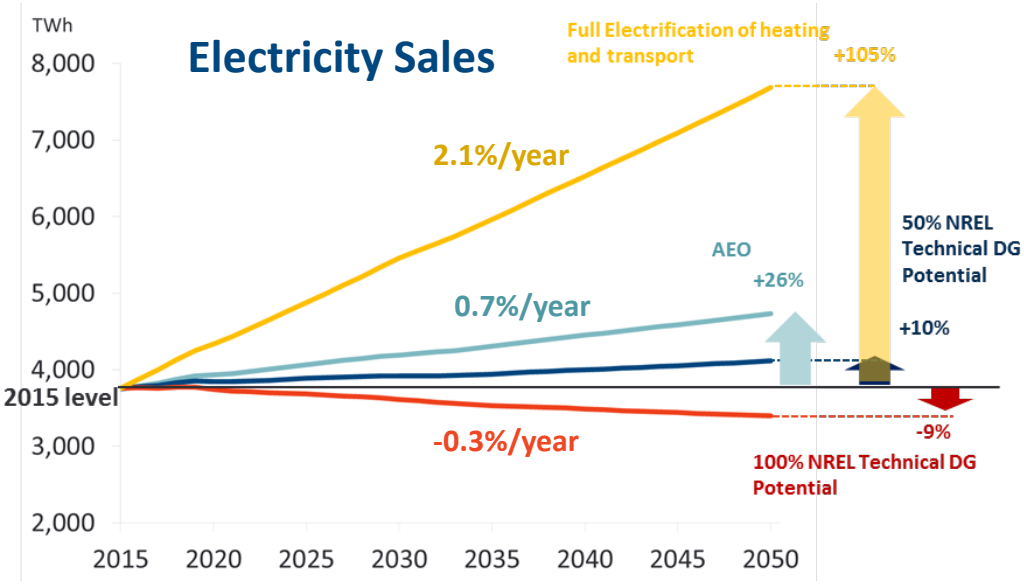
Source: Underlying map is from ISO/RTO Council

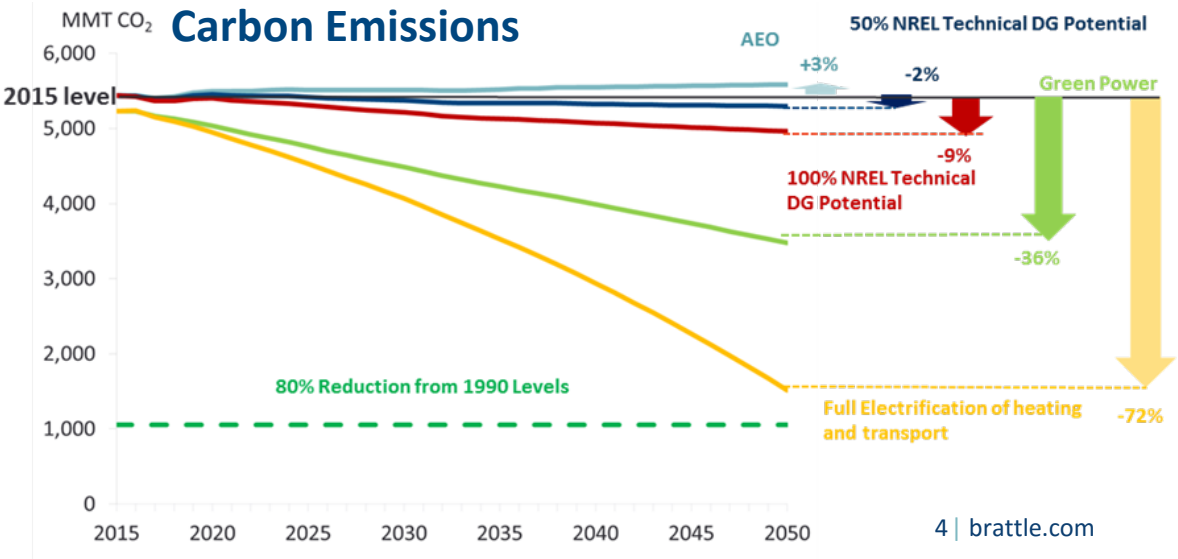
Ability to access multiple clean energy resources and match their generation profiles to load profiles will be a key factor in defining the role for storage

Electrification of Transportation and Heating

With 100% electrification:

- Sales could **double by 2050**, even with significant distributed PV penetration
- Economy-wide GHG emissions reductions could be achieved if coupled with clean generation
- **Utilities could grow in size and relevance, and play a central role in decarbonizing the US economy**
- Highly utilized modes of transportation (Uber, AVs) will **accelerate adoption of EVs**





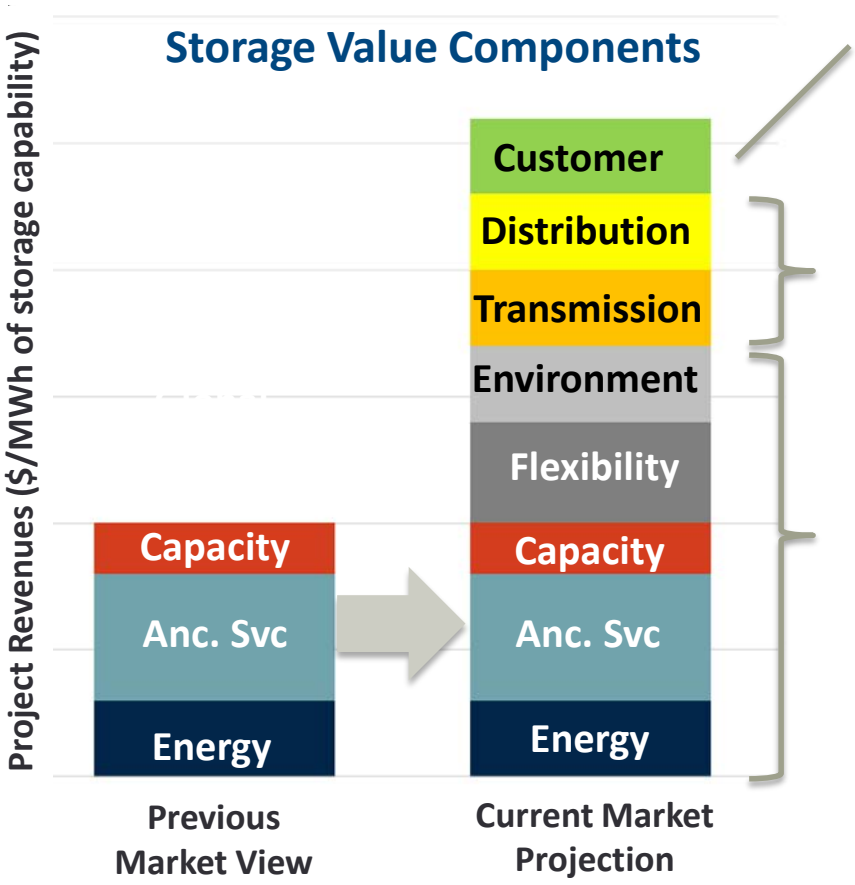
Battery Storage Capital Cost Estimates

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

Battery Storage Value Streams

Project developers and investors are seeking opportunities to match the battery storage capabilities with highest value projects



Customer

- Increased reliability
- Increased engagement in power supply

Infrastructure

- Avoided investments in distribution and transmission infrastructure

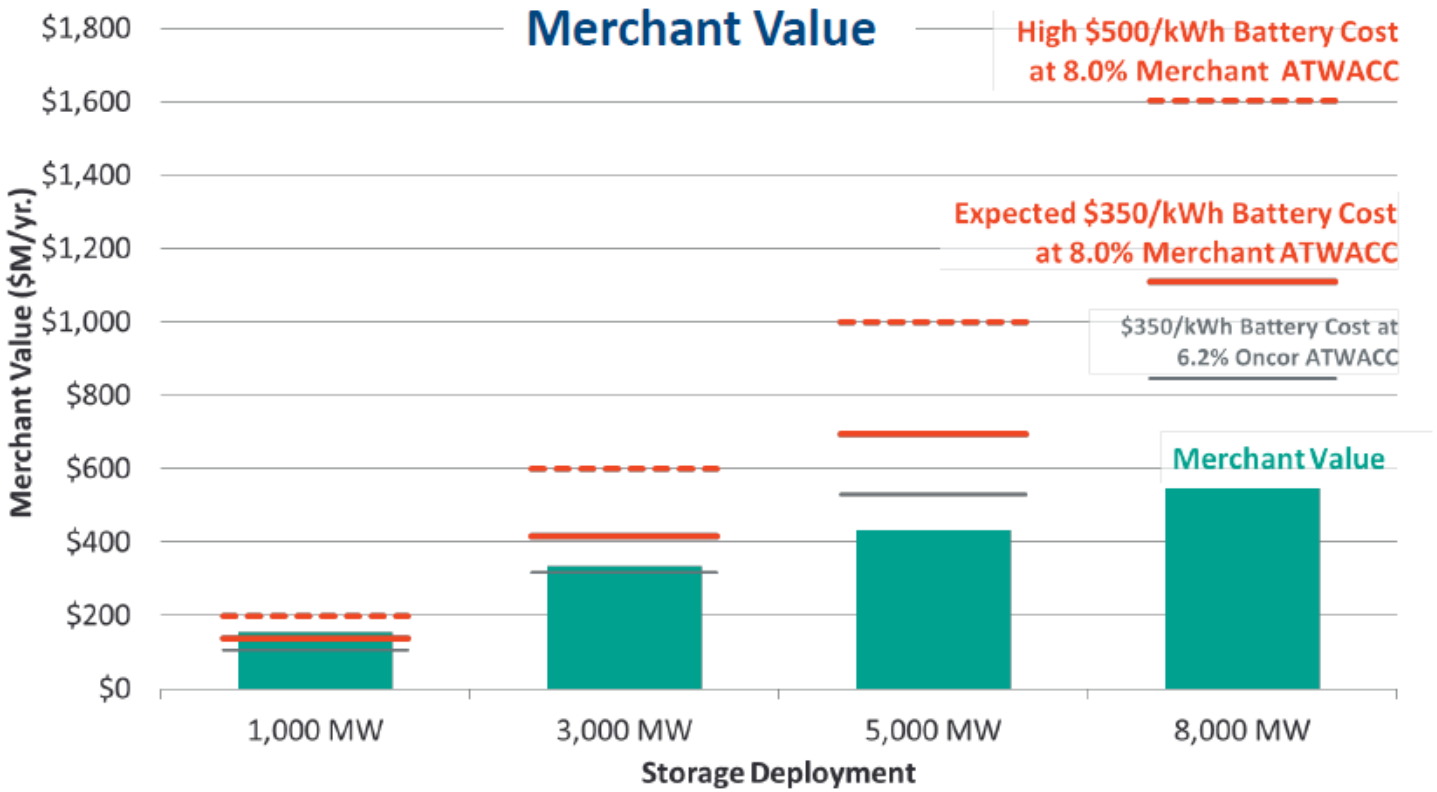
Wholesale Markets

- 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

Texas Study (Oncor)

Merchant Value in Wholesale Market

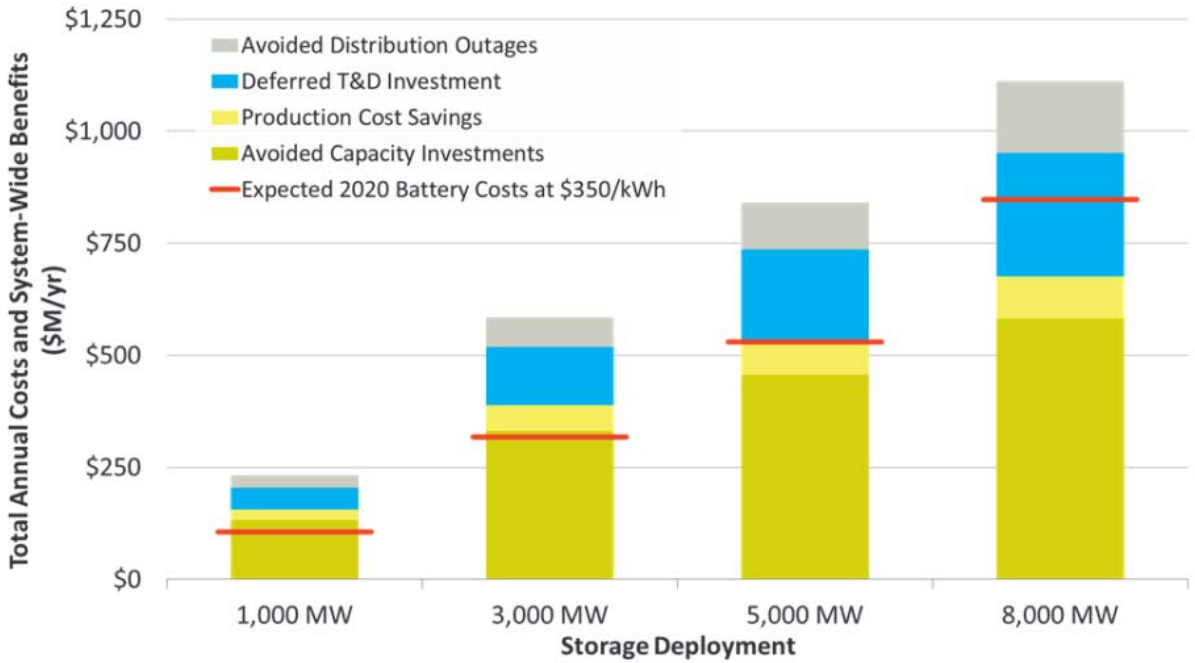
- Merchant value greatest at low levels of deployment
- At larger scales, the wholesale market value of storage is too limited to support merchant investment even at lower end cost projections
- Particularly true if investment risks were to exceed assumed 8% ATWACC

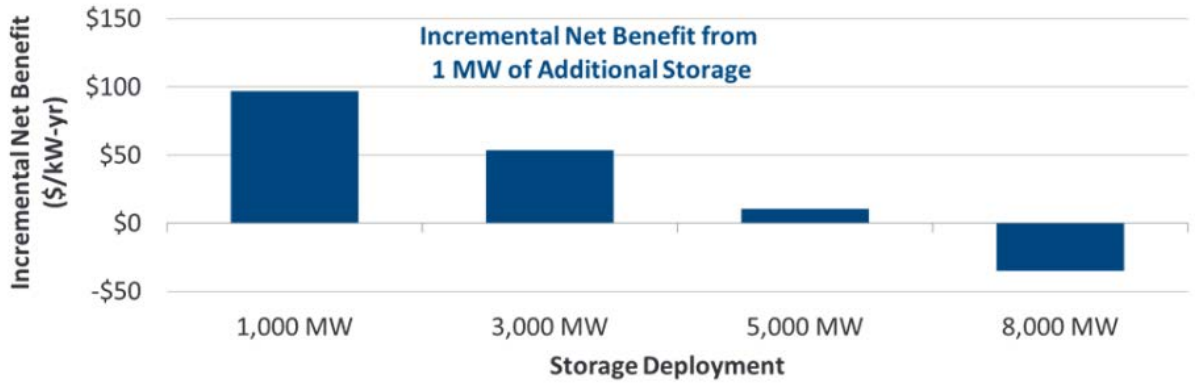


Source: Chang, et al., The Value of Distributed Electricity Storage in Texas: Proposed Policy for Enabling Grid-Integrated Storage Investments, Prepared for Oncor, March 2015.

Texas Study (Oncor)

System-Wide Annual Benefits



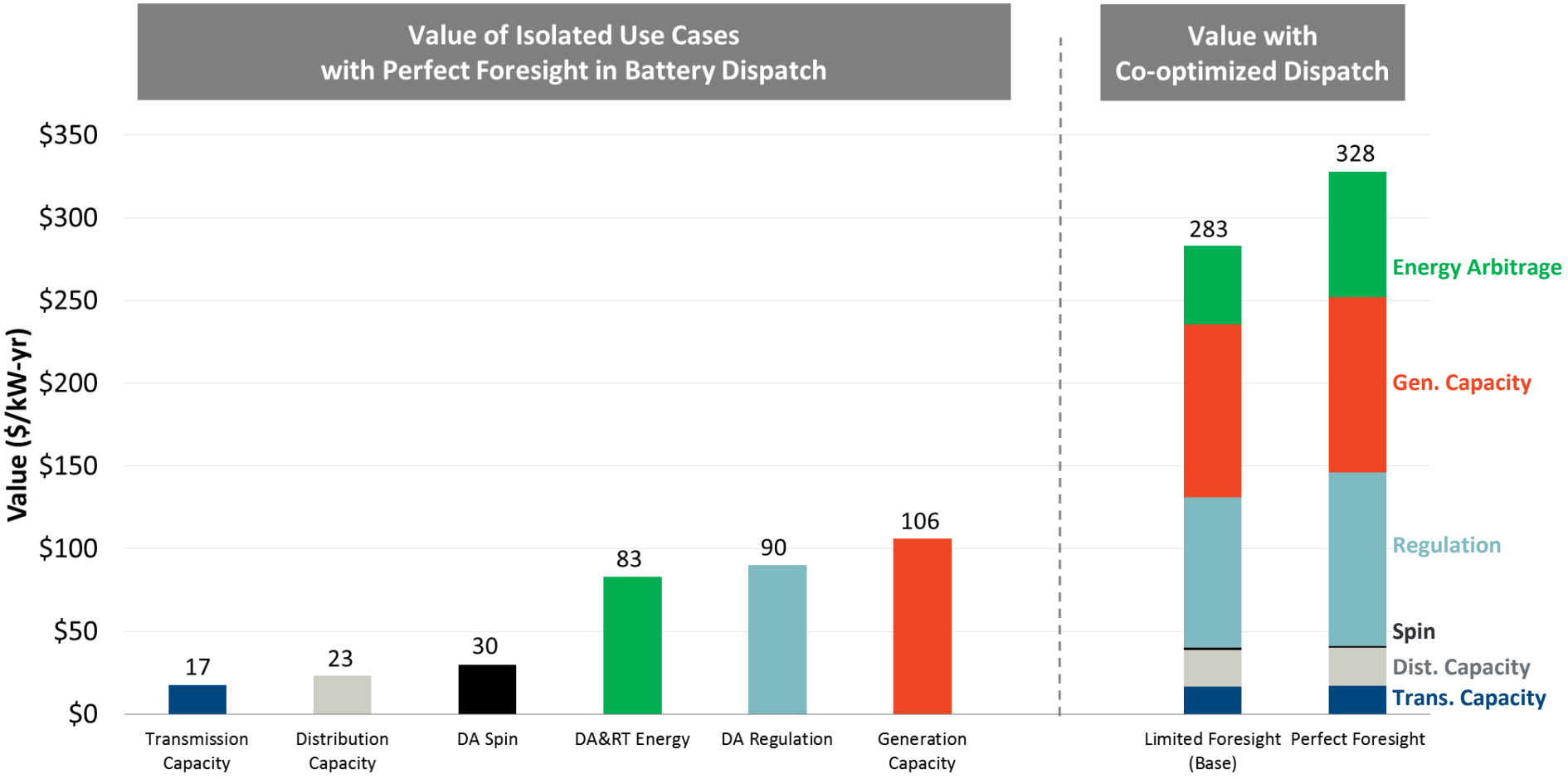


- 30 – 40% of benefits related to reliability and T&D savings
- Value maximized when located closest to load
- Must be integrated into T&D planning to capture benefits
- Challenge is to create regulatory framework to capture value streams, including wholesale, infrastructure, customer

Sources and Notes: The Expected 2020 Battery Costs are based on Oncor's 6.3% ATWACC, with 15- and 30-year assumed lifetime for the battery and balance of plant respectively. Chang, et al., The Value of Distributed Electricity Storage in Texas: Proposed Policy for Enabling Grid-Integrated Storage Investments, Prepared for Oncor, March 2015.

California Study (Eos Storage)

Battery Value Estimates



There is significantly more system benefit if the battery can be utilized to capture multiple value streams rather than just individual use cases

Source: Hledik, et al., Stacked Benefits: Comprehensively Valuing Battery Storage in California, Prepared for Eos Storage, September 2017.

Main Drivers of Battery Storage Investments

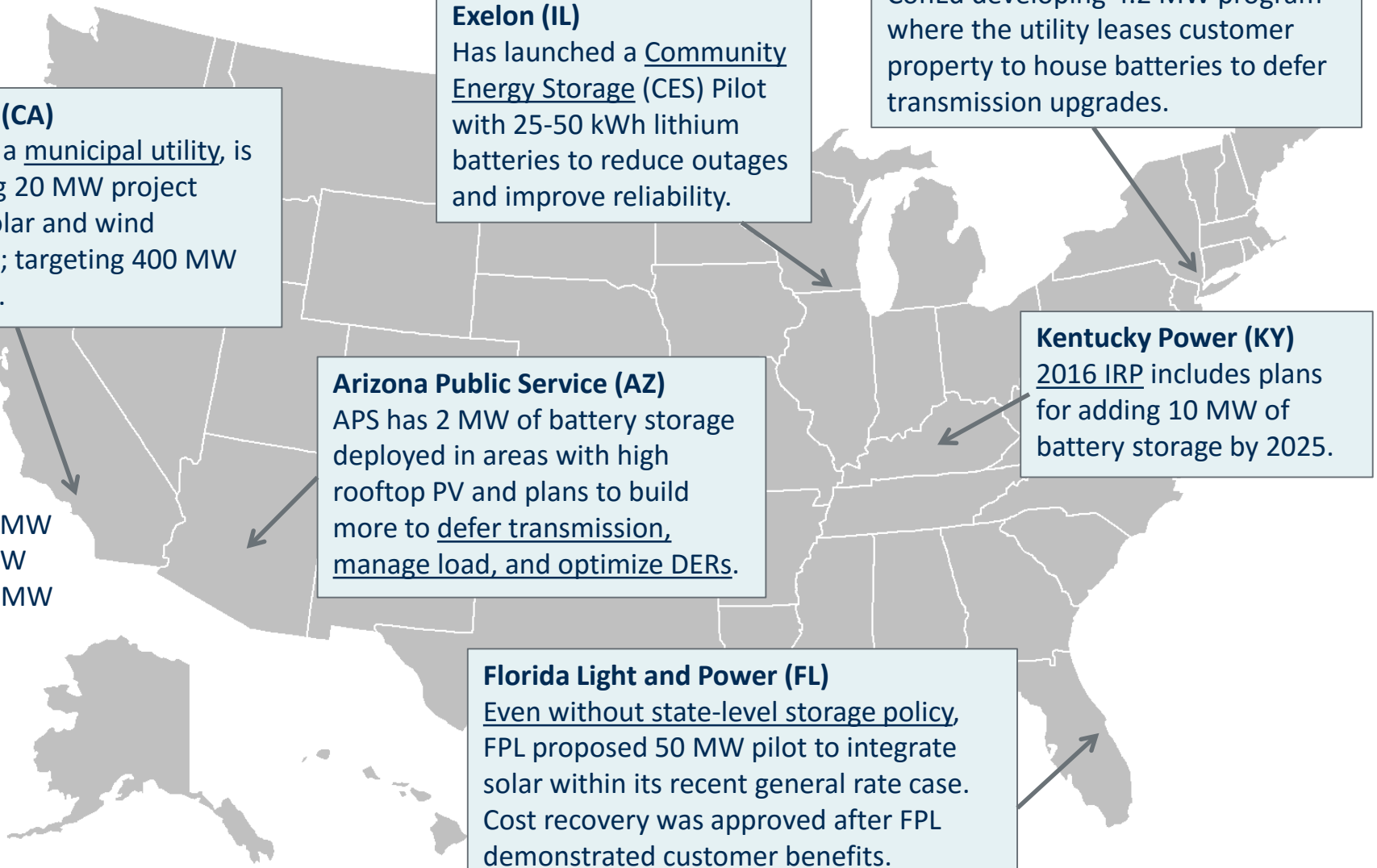
Legislative or Regulatory Emphases:

- State goals, mandates and incentives
- Utility and RTO pilot programs
- Inclusion in integrated resource plans
- State-level working groups or storage studies
- Commission-ordered utility procurement
- Commission proceedings on regulatory framework and participation

Improved Market Value:

- Expanded participation in wholesale markets by FERC and PUCT
- Fast-response ancillary service products that pay for performance
- Increased demand for regulation with greater renewable integration
- Greater intraday price disparities
- Ability to capture multiple value streams (esp. avoided T&D)
- Inclusion in solar or microgrid projects

Utility Project Examples



ConEd (NY)
In response to the REV proceeding, ConEd developing 4.2 MW program where the utility leases customer property to house batteries to defer transmission upgrades.

Exelon (IL)
Has launched a Community Energy Storage (CES) Pilot with 25-50 kWh lithium batteries to reduce outages and improve reliability.

LADWP (CA)
LADWP, a municipal utility, is planning 20 MW project along solar and wind corridor; targeting 400 MW by 2025.

Kentucky Power (KY)
2016 IRP includes plans for adding 10 MW of battery storage by 2025.

Arizona Public Service (AZ)
APS has 2 MW of battery storage deployed in areas with high rooftop PV and plans to build more to defer transmission, manage load, and optimize DERs.

PG&E: 250 MW
SCE: 300 MW
SDG&E: 80 MW

Florida Light and Power (FL)
Even without state-level storage policy, FPL proposed 50 MW pilot to integrate solar within its recent general rate case. Cost recovery was approved after FPL demonstrated customer benefits.

Investor Project Examples

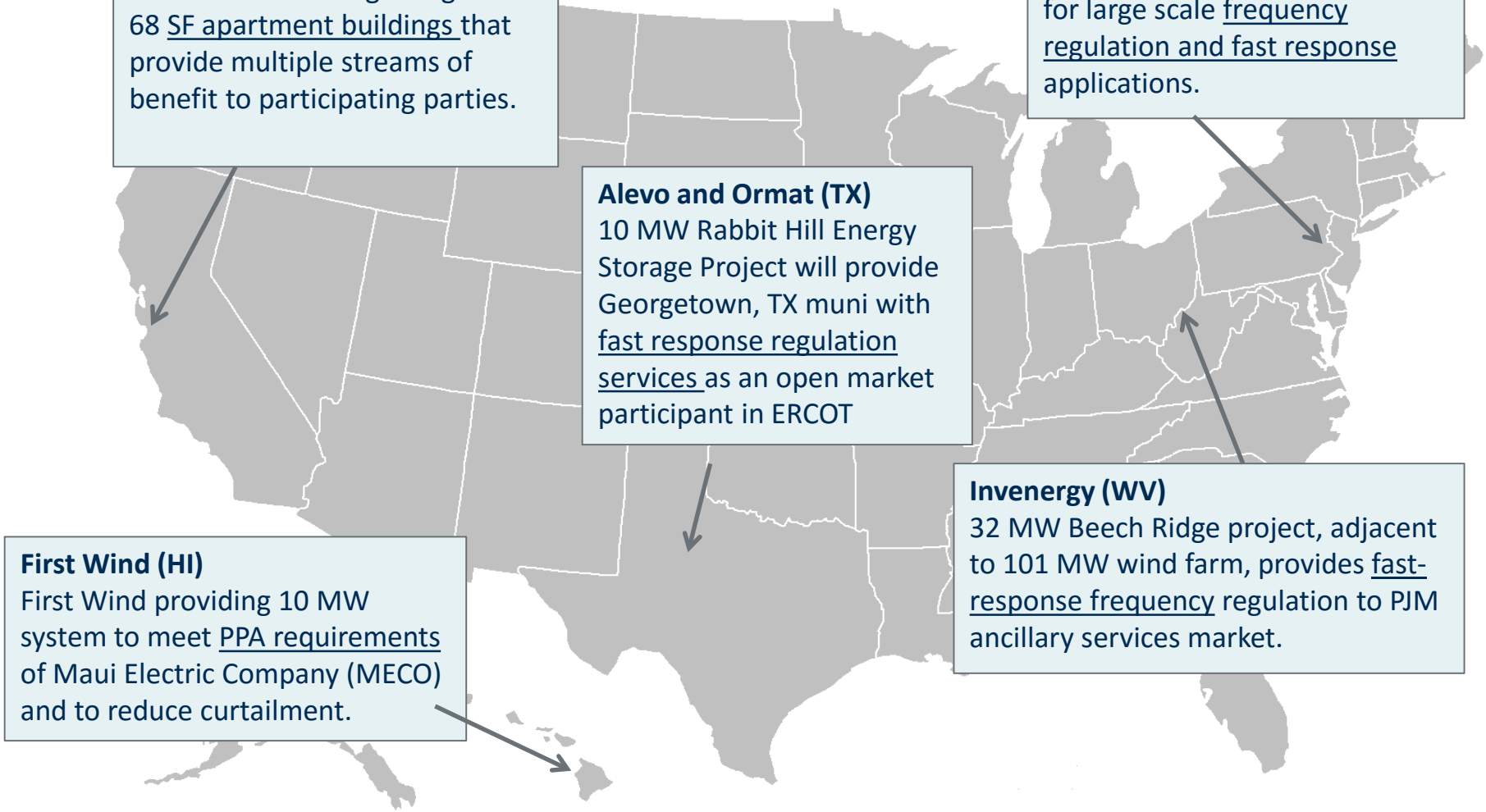
PowerTree Services (CA)
PowerTree installing chargers in 68 SF apartment buildings that provide multiple streams of benefit to participating parties.

Altairnano (NJ)
Energy Storage Holdings, LLC, has a 3 year lease on a 1.8 MW lbattery system designed for large scale frequency regulation and fast response applications.

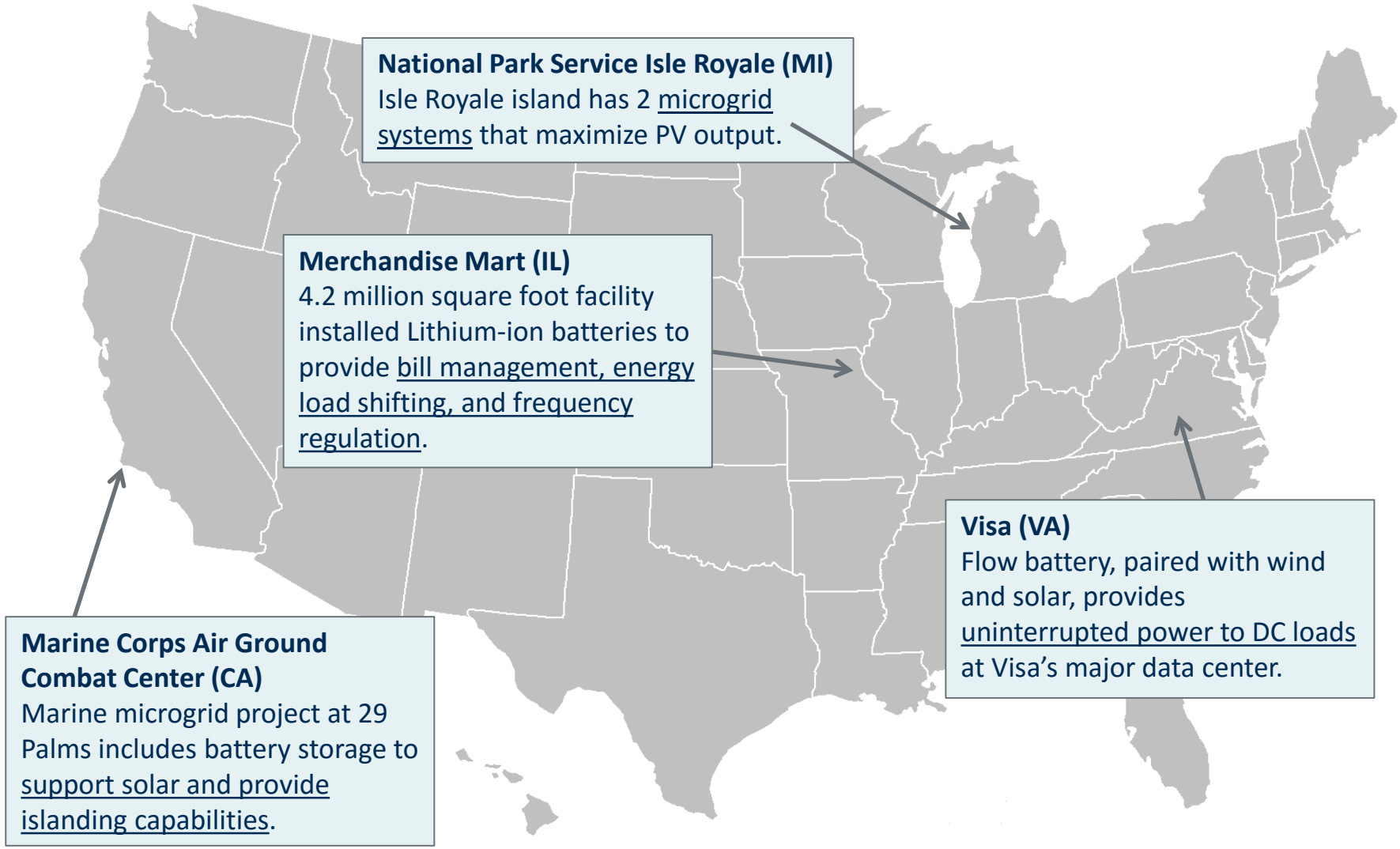
Alevo and Ormat (TX)
10 MW Rabbit Hill Energy Storage Project will provide Georgetown, TX muni with fast response regulation services as an open market participant in ERCOT

Invenergy (WV)
32 MW Beech Ridge project, adjacent to 101 MW wind farm, provides fast-response frequency regulation to PJM ancillary services market.

First Wind (HI)
First Wind providing 10 MW system to meet PPA requirements of Maui Electric Company (MECO) and to reduce curtailment.



Customer Project Examples



National Park Service Isle Royale (MI)
Isle Royale island has 2 microgrid systems that maximize PV output.

Merchandise Mart (IL)
4.2 million square foot facility installed Lithium-ion batteries to provide bill management, energy load shifting, and frequency regulation.

Visa (VA)
Flow battery, paired with wind and solar, provides uninterrupted power to DC loads at Visa's major data center.

Marine Corps Air Ground Combat Center (CA)
Marine microgrid project at 29 Palms includes battery storage to support solar and provide islanding capabilities.

Brattle bSTORE Modeling Suite

Storage simulation and decision-support platform to assess the potential value of storage projects

- Six modules that each provide insights into a different aspect of storage valuation
- Modules can be run separately or in conjunction with one another
- Built on top of multi-time frame economic dispatch optimization engine

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
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- Demand Forecasting Methodology
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
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Each States Sets Own Agenda

Many States have set program goals and pilot projects: Examples

New York

- **Procurement Targets**: SB 5190/A 6571 Energy Storage Program 2030: Cuomo proposed 1,500 MW procurement
- **Incentives:** Clean Energy Fund includes $200M for storage
- **Grid Modernization:** New York Reforming the Energy Vision (REV) driving storage development through:
  - **Requirements for Distribution Planning/Goals:** Development of Utility Distributed System Implementation Plans (DSIPs) include directives for distribution hosting capacity, interconnection portals, non-wires alternatives and energy storage; established goal for 2 projects by 2018.
  - **Storage Study/Net Metering:** The Value of Distributed Energy (VDER) study includes net metering successor with compensation for storage paired with renewables. Transition to Value Stack compensation underway.
  - **Pilot programs** and will tie Performance Based Ratemaking mechanisms (Earnings Impact Mechanisms or EIMS) to goals such as storage.

Pending: *"New York Grid Modernization Act" (A.B.7480) would establish a Smart Grid Advisory Council, and efforts would include promoting DERs*

Texas

- **New Technology Implementation Grant (NTIG),** part of the Texas Emissions Reduction Plan provides funding for solar plus storage in counties with air quality issues. $9 million has been awarded through 2015-2017
- **High Renewable penetration from wind and solar (expected)**
- **Utilities:**
  - **TX Utility-Scale Battery:** A 4 MW sodium-sulfur (NAS) energy storage system technology in Presidio, Texas developed to provide backup power to the town was the first utility scale battery in Texas.
  - **Ownership:** AEP proposed two distribution scale storage projects (1 MW and 500 kW batteries) to avoid more expensive transmission and distribution solutions.
  - **Ownership:** Utilities are not permitted to own generation assets but the Commission is currently considering approval of the projects.
- **Grid Modernization:** AEP has a modernization plan that includes Vehicle to Home Connectivity Research as well as a 900 MW solar and wind goal.
- **Net Metering:** No state defined net metering but some utilities are addressing singularly – may actually be more favorable for storage at customer-site