Energy Storage - Evolution and Revolution on the Electric Grid

Prepared For:

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GTM, MAKE & Wood Mackenzie form the premier market intelligence provider on the decarbonization and decentralization of energy.

We guide companies leading the electricity transformation.

Power Market Fundamentals
- Long-term Supply & Demand Outlooks
- 20-year Wholesale & Retail Price Outlooks

Regional Market Dynamics
- Policy and Regulation Analysis
- Thermal & Renewable Databases and Demand Outlooks

Technology Value Chain Evolutions
- Wind, Solar, Storage, and Grid Edge Competitive Landscapes
- Technology Cost and Performance Outlooks
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Tomorrow’s Decarbonized and Decentralized Power Market

The Power Market of the Past
A top-down, flow from supply to demand

- Dispatchable Generation
  - Transmission
  - Distribution
  - End Customers

Tomorrow’s Decarbonized and Decentralized Power Market
A flatter system with outside market responses and actors at every node reshaping power market planning and operations

- Dispatchable Generation
  - Intermittent Generation
  - Energy Storage
- Transmission
  - Advanced Metering Infrastructure
  - Distributed Generation
- Distribution
  - Electric Vehicles
  - Demand Side Management
  - Connected Devices
- End Customers
U.S. Q4 2017 Deployments in Megawatt-Hours Down 57% From Previous Year

U.S. Quarterly Energy Storage Deployments by Segment (MWh)

Source: GTM Research/ESA U.S. Energy Storage Monitor

Record breaking quarters: Q4 2016 and Q1 2017 – Aliso Canyon Systems come on-line
Where Is Energy Storage Deployed So Far? (Megawatt-Hours)

California Accounts for 48% Through 4Q 2017

Residential
- California: 34%
- Arizona: 5%
- Hawaii: 24%
- All Others: 37%

Non-Residential
- California: 86%
- New York: 4%
- Hawaii: 2%
- All Others: 8%

Utility
- California: 40%
- Texas: 29%
- Hawaii: 6%
- All Others: 25%

Source: GTM Research/ESA U.S. Energy Storage Monitor
Lithium-Ion Technology Continues the Trend of More Than 94% Share

Quarterly Energy Storage Deployment Share by Technology (MW %)

Energy Storage Deployments by Technology (MW)

- Lithium Ion
- Lead Acid
- Sodium Chemistries
- Flow - Vanadium
- Flow - Zinc
- Other

* "Other" includes flywheel and unidentified energy storage technologies.

Source: GTM Research / ESA U.S. Energy Storage Monitor
2. Energy Storage Technology and Cost Trends
Commercialized Energy Storage Technologies: Cost ($/kWh) Versus Cumulative U.S. Installed Capacity (MW)

- **Lithium Ion**: Cycle life of more than 100,000; mature in power quality and UPS applications and frequency regulation, suited for <30-minutes duration projects.
- **Lead Acid**: Oldest battery technology with cycle life of 1,000 at high depth of discharge; particularly suited to the off-grid market and 4-hour discharge duration or longer.
- **Sodium Chemistries**: Cycle life of 2,500 to 4,500, suited for peak shaving; NaS suited for 6-hour while Na-Ni suited for 2- to 6-hour discharge applications.
- **Flywheel**: Cycle life ranges from 300-15,000 depending on depth of discharge, mature technology with over 600 MW of utility-scale systems deployed, suited for power and energy applications from 12-minutes to 4-hour discharge on both sides of the meter.

Source: GTM Research / ESA U.S. Energy Storage Monitor

Ravi Manghani, GTM Research: Energy Storage - Evolution and Revolution on the Electric Grid
Early Stage Storage Technologies – No Clear Winner, Flow Batteries Have Better Prospects

Demonstration/Pilot Phase Energy Storage Technologies: Cumulative U.S. Installed Capacity (MW)

For technologies still in early commercial/demonstration phase, costs are illustrative

- High power, low energy, cycle life of 1 million, suited for 2-minutes or less power applications like frequency regulations, voltage stabilization, renewables smoothing and battery support
- Cycle life still under test, suited for 2- to 12-hour discharge applications like microgrids and off-grid projects
- Cycle life of 3,000, suited to applications needing 4- to 20-hour discharge like microgrids and off-grid applications
- Cycle life of 6,000, pricing ranges from $160- $200/kWh, demonstration phase, suited for applications of 4 hour discharge like peak load shaving and power centric applications

Cycle life varies from 10,000 - 12,000, cost spreads from $425-$750/kWh, few projects deployed, VRB batteries furthest along while Zn-Br batteries still nascent, suited for power and energy-centric applications of 4- to 12-hour discharge at rated power

Source: GTM Research / ESA U.S. Energy Storage Monitor
Annual Declines in Battery Price and Balance-of-System Costs Will Drop Below 10% After 2020

Year-Over-Year Decline in Lithium-Ion Battery Price and BOS Cost, 2013 – 2022E (%)

Phase 1: Battery price reductions were the primary driver for system price declines
-10%  -11%

Phase 2: Extreme reductions in BOS costs drove down system prices by more than 25%
-14%  -14%  -8%  -8%  -8%

Phase 3: Continued reductions in battery prices and BOS costs are driven by production ramp-up, growing competition and improvements in system design and engineering
-22%  -22%  -24%  -24%  -27%  -32%

Phase 4: As the storage market matures, both battery prices and BOS costs will continue to decline but the rate will be lower post-2020, with improvements arising from experience.

Source: GTM Research
3. Federal and State Policy Barriers Coming Down
On February 15th, FERC released draft final rules adopting participation and eligibility requirements for energy storage in ISOs and RTOs. The participation model for electric storage resources must:

- Ensure that a resource using the participation model for electric storage resources in an RTO and ISO market is **eligible to provide all capacity, energy, and ancillary services** that it is technically capable of providing.
- Ensure that a resource using the participation model for electric storage resources can be **dispatched and can set the wholesale market clearing price as both a wholesale seller and wholesale buyer** consistent with rules that govern the conditions under which a resource can set the wholesale price.
- Account for the **physical and operational characteristics** of electric storage resources through bidding parameters or other means.
- Establish a minimum size requirement for participation in the RTO and ISO markets that does not exceed **100 kW**. Also requires that the sale of electric energy from the RTO or ISO market to an electric storage resource that the resource then resells back to those markets must be at the **wholesale locational marginal price**.
There are several utility resource proceedings all over the country that explicitly include storage in their resource plans. There’s about 5.1 GW of opportunity in existing utility IRPs. These IRPs offer a view of storage as a flexible resource on the grid, and complementary, not necessarily a direct threat to CT plants.
Notable State Policies Roundup – Levelling the Playing Field

**Washington**
- WA UTC energy storage policy statement

**Oregon**
- Minimum 5 MWh per utility storage mandate

**California**
- 1,385 MW storage mandate
- SGIP incentive
- ESDER initiative to integrate storage on CAISO
- Local capacity procurements, storage RFOs for peaker replacement

**Colorado**
- SB18-009 allows customers to install BTM storage

**Massachusetts**
- 200 MWh energy storage target
- $20 million ACES program
- SMART energy storage adder

**New York**
- Gov. Cuomo - 1,500 MW goal
- NY REV demo projects
- Con Edison demand management programs

**Maryland**
- First state with BTM energy storage tax credit

**Texas**
- Texas PUC initiated rulemaking docket to address energy storage on distribution grid

**Arizona**
- Clean peak standard proposal
- 3 GW energy storage goal proposal

**Hawaii**
- First state with innovative solar-plus-storage projects
- Customer solar self-supply tariff
Thank You!

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