The BESS Market Today

- BESS Technology Overview
  - Main Type, Cost Trends

- Energy Storage Services
  - Regional, Utility and Customer

- BESS Economic Value
  - Where does BESS value come from?

- BESS and ZNE Today
  - How BESS is implemented

- Policy and Tariff Support
Battery Energy Storage Systems (BESS)

An Overview

- Technology
- Cost Trends
### Lithium-ion (Li-ion and LIB)

- Highly developed – more bankable
- High energy density, portable
- 30 min to 3-hour applications
- 75-85% round trip efficiency
- Degrade over time, require replacement/disposal strategy
- No moving parts, high reliability
- Discharge rate, duty cycle and climate impact efficiency

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**BESS Overview**

95% of the US grid BESS market is Lithium-Ion
BESS Overview

4% of the US grid BESS market are Flow Batteries

+ Flow (reduction-oxidation)
  • Lower energy density
  • 4-hour+ applications
  • 65-75% round trip efficiency
  • Do not degrade significantly, long service and cycle life
  • Pumps reduce reliability
BESS Overview

**BESS Cost Trends (LIB)**

**Cheaper Batteries**
Lithium-ion battery prices just keep falling. They’re down 24% from 2016 levels.

$1,200 U.S. dollars a kilowatt-hour

<table>
<thead>
<tr>
<th>Year</th>
<th>Price (US$ per kWh)</th>
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<tbody>
<tr>
<td>2010</td>
<td>800</td>
</tr>
<tr>
<td>2011</td>
<td>700</td>
</tr>
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<td>2012</td>
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<td>2013</td>
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<td>2015</td>
<td>350</td>
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<td>2016</td>
<td>300</td>
</tr>
<tr>
<td>2017</td>
<td>250</td>
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Note: Figures are volume-weighted averages
Source: Bloomberg New Energy Finance survey of more than 50 companies
BESS Overview

- $207/kWh 2017
- $144/kWh 2022
- 8-10%/year through 2022

Year-Over-Year Decline in Battery Price and BOS Cost, 2013 – 2022e

Source: GTM
BESS Services
by Market Sector

- ISO/RTO
- Utility (front of meter)
- Customer (behind the meter)
BESS Services

BESS Services by Market Sector

Source: NREL
Regional ISO/RTO Services – CAISO Example

• What is CAISO?
  • California Independent System Operator
  • Manages electricity flow across transmission lines in 80% of CA and part of Nevada
  • Coordinates energy resources and operates a wholesale power market
  • Forecasts electrical demand and dispatches lowest cost generation

• ISO/RTO BESS Services
  • Frequency Regulation
  • Ramping/Spinning Reserves
  • Voltage/Reactive Power Support
  • Energy Arbitrage/Renewables Firming
  • Black Start
BESS Services

ISO/RTO
Capacity and Services

Source: EIA
Utility Services (in front of the meter)

- Resource Adequacy
- Renewables Firming
- Transmission Congestion Relief
- Transmission Deferral
- Distribution Deferral

Example

Resource Adequacy/Peaker Plant Replacement

- 567 MW Li-ion BESS project in Bay Area
- Proposal to CPUC to replace 3 gas-fired peaker plants
- CPUC has not approved yet, but likely to

<table>
<thead>
<tr>
<th>Counterparty (Project Name)</th>
<th>Storage Technology</th>
<th>Connection Point</th>
<th>Term (years)</th>
<th>Discharge Duration (Hours)</th>
<th>Size (MW)</th>
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<tbody>
<tr>
<td>Dynegy Marketing and Trade, LLC (Vistra Moss Landing Energy Storage)</td>
<td>Lithium Ion Batteries</td>
<td>Transmission</td>
<td>20</td>
<td>4</td>
<td>300</td>
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<tr>
<td>Hummingbird Energy Storage, LLC (Hummingbird Energy Storage)</td>
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<td>Transmission</td>
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<td>4</td>
<td>75</td>
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<td>Micronoc Inc. (mNOC AERS Energy Storage)</td>
<td>Lithium Ion Batteries</td>
<td>Customer (Behind the Retail Meter)</td>
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<td>4</td>
<td>10</td>
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<tr>
<td>Tesla, Inc. (Moss Landing Energy Storage)</td>
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<td>Transmission</td>
<td>20</td>
<td>4</td>
<td>182.5</td>
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</table>

Total Capacity (MWs) 567.5
BESS Services

**Customer Services (behind the meter)**

- TOU Bill Management
- Peak Shaving/Demand Charge Reduction
- Renewables Firming
- Backup Power/Resilience

This is where the vast majority of ZNE energy storage is deployed: Customer sited, behind the meter.
**BESS Services**

**Customer Services Example: CA Public School District**

- **Peak Shaving/Demand Charge Reduction**
  - Took almost a year to stabilize system function
  - Vendor connected one system to wrong meter, requiring major rework of interconnection

- **TOU Bill Management (energy arbitrage)**
  - Not available because system was installed with solar PV using Federal ITC
  - Batteries can only be charged from solar PV

- **Backup Power/Resilience**
  - Would like to augment portable backup generators
  - Can’t be used for this because of SGIP requirements for discharge cycles, uneconomic to set aside significant portion of battery capacity as reserve
BESS Economic Value

Customer Sited Systems

- Value Streams and Stacking
- Financing
- Utility Tariffs
BESS Economic Value

For Customers (behind the meter), value stream stacking is limited

Value Streams and Stacking

- Regulatory, tariff, equipment, network barriers for Customers

- Primarily demand cost reduction

- Can sometimes utilize energy arbitrage
  - Limited by ITC financing with solar

- Other value streams limited
  - Regulation and tariffs years away and unpredictable
BESS Economic Value

Proposed PG&E A-6 Tariff and TOU Periods
**Tariff Change Example: PG&E Option S**

*New “Storage Friendly” tariff*

*Pilot program to address lack of tariff support for storage*

- Applies to E19 and E20 rate customers only (medium/large commercial)
- Based on **Option R** solar friendly tariff
- Hourly demand charges (instead of peak monthly)
- No demand charges during middle of day
- Capped at 150 MW of storage

*Will have strong impact on energy management*
BESS Economic Value

Solar and Storage Incentives phasing out over time

+ 30% ITC extended until the end of 2019
  • 3-year stepdown after 2019
+ SGIP Incentives for energy storage (PG&E)
  • Step 2 – Large Storage (Step 3, all others)
  • Step 4 – Small Residential

+ Storage deployment barriers
  • SGIP Penalties (retroactive?)
  • Metering requirements ($15-25k)
  • No DC coupled systems
  • Lack of tariff support
BESS and ZNE Today

How BESS is Implemented

- An IT Energy Solution
- What does it look like?
- How do you know it works?
BESS and ZNE Today

What a real Storage project looks like

An IT Solution
- It’s all about the software
- Data inputs:
  - Site usage
  - Generation (Solar PV, fuel cells)
  - Active tariff
  - Time of day
  - BESS parameters
    - Capacity, charge, temp,
    - Inport/export limits
  - Historical trends

Source: Geli
BESS and ZNE Today

What a real Storage project looks like

Vendor configurations

- Software-only
  - STEM
  - Geli
- Integrators (most BESS vendors)
  - Renewable Energy Systems Group
  - AES Energy Storage
  - NEC Energy Solutions
  - Engie/Green Charge Networks
- Vertical (hardware + software in-house)
  - Tesla
  - Wartsila/Greensmith
BESS and ZNE Today

What a real Storage project looks like

Footprint

- Residential
  - Wall Mounted

- Commercial
  - Up to 500kW/1000kWh = 1 parking space
BESS and ZNE Today

What a real Storage project looks like
Commercial BESS Project Financing

- Most ZNE BESS projects financed within overall project financing
  - Results in hard design by project contractors
  - Often not the most efficient PV/storage designs
- Can be financed separate through Design-Build competitive procurement
  - RFQ/P with performance specification
  - Contract doc set or term sheet
  - Performance guarantees must take into account PV contribution
- Financing Arrangements
  - Cash
  - Bonds (Muni tax-exempt or GO)
  - Lease/debt (typically a Capital lease)
    - Shared savings, No-loss
  - PPA (when paired with solar PV)
So, how do you know it works...?

- The vendor/software tells you
  - How do you know the vendor/software is right?
  - Energy Storage is not like PV

- Currently, there is no independent auditing function
BESS Policy and Tariff Support

Top Down and Bottom Up

- Federal
- State (CA)
- CPUC/Utility
BESS Policy and Tariff Support

Current Affairs

+ Federal
  - FERC – 2/2018 rule opening wholesale energy markets to storage
  - IRS - Investment Tax Credit (ITC) for Solar
    - 30% through 2019
    - Can be used with battery storage

Source: NREL
BESS Policy and Tariff Support

Current Affairs

+ CA Legislature and State:
  - SGIP Program
  - 50+ 2018 bills that affect solar and storage
  - Title 24 update ZNE

+ CAISO
  - Storage as a Transmission Asset
    - Straw proposal August, 2018

+ CPUC/Utility
  - PG&E Option S
  - DER and Storage Committees
BESS with Solar PV ZNE Case Study

CA Public School
PG&E Territory
# PG&E Case Study: 5-Site School

<table>
<thead>
<tr>
<th>Metric</th>
<th>Site A</th>
<th>Site B</th>
<th>Site C</th>
<th>Site D</th>
<th>Site E</th>
<th>Cumulative Project Cash Flow (Loss)</th>
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<tr>
<td><strong>Do Nothing - Business As Usual</strong></td>
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<td>25-year Nominal Elect. Energy Cost</td>
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<td>$17,077,000</td>
<td>$47,589,000</td>
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<td>25-year NPV, 3% Discount Rate</td>
<td>$647,000</td>
<td>$911,000</td>
<td>$793,000</td>
<td>$1,134,000</td>
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<td>25-year Nominal Return</td>
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<td>$1,442,000</td>
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<tr>
<td><strong>BESS</strong></td>
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<tr>
<td>25-year NPV, 3% Discount Rate</td>
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<td>$314,000</td>
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<td>$621,000</td>
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<td><strong>Project Total</strong></td>
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<td>25-year NPV, 3% Discount Rate</td>
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<tr>
<td>CO2 Offset 25-year Total (Tonnes)</td>
<td>5,550</td>
<td>9,340</td>
<td>8,730</td>
<td>11,440</td>
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<td>Equivalent Cars</td>
<td>40</td>
<td>70</td>
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<td>80</td>
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<td>Equivalent Trees Planted</td>
<td>44,420</td>
<td>74,730</td>
<td>69,820</td>
<td>91,530</td>
<td>38,810</td>
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## PG&E Case Study: 5-Site School

<table>
<thead>
<tr>
<th>Site</th>
<th>Energy Provider (kWh)</th>
<th>New PV System Size (kW DC)</th>
<th>New PV System Type</th>
<th>BESS System Size (kW/kWh)</th>
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<tbody>
<tr>
<td>Site A</td>
<td>PG&amp;E</td>
<td>537.6</td>
<td>Carport</td>
<td>-</td>
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<tr>
<td>Site B</td>
<td>MCE (CCA)</td>
<td>947.2</td>
<td>Carport</td>
<td>-</td>
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<tr>
<td>Site C</td>
<td>Constellation (DA)</td>
<td>877.7</td>
<td>Carport</td>
<td>250/500</td>
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<tr>
<td>Site D</td>
<td>Constellation (DA)</td>
<td>1,154.4</td>
<td>Carport</td>
<td>250/500</td>
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<tr>
<td>Site E</td>
<td>Constellation (DA)</td>
<td>483.2</td>
<td>Carport</td>
<td>-</td>
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<td><strong>Totals</strong></td>
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<td>Carport</td>
<td><strong>500/1000</strong></td>
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PG&E Case Study: P-50, P-90 and Sensitivity

25-Year Nominal Returns
- P-50 = $6.8 MM
- P-90 = $5.2 MM