UTILITY-SCALE ENERGY STORAGE TO SUPPORT HIGHER PENETRATION OF VARIABLE RENEWABLE ENERGY

Astana, November, 1 2019
Agenda

- Financial Perspectives
- Methodologies – Value Stacking, Levelized Cost, Models
- Example
- BESS Siting
- -- Break –
- Policy Considerations
• Financial Perspectives
# Cost of Utility-Scale ES Projects, based on 3Q 2019 estimates

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>$/kWh</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li-ion Battery</td>
<td>$175</td>
<td>53%</td>
</tr>
<tr>
<td>Balance of System+Transformer</td>
<td>$39</td>
<td>11%</td>
</tr>
<tr>
<td>Power Convertor</td>
<td>$13</td>
<td>4%</td>
</tr>
<tr>
<td>EMS</td>
<td>$14</td>
<td>5%</td>
</tr>
<tr>
<td>System Integrator</td>
<td>$21</td>
<td>6%</td>
</tr>
<tr>
<td>EPC</td>
<td>$39</td>
<td>12%</td>
</tr>
<tr>
<td>Developer</td>
<td>$30</td>
<td>9%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$331</strong></td>
<td></td>
</tr>
</tbody>
</table>

Utility-scale = Size of at least 20 MW/80 MWh and higher  

Source: BNEF 2019
New Implementation of ES and Four New Financial Models

New Implementation of ES = Solar PV + ~50% Capacity ES with 2 to 4 hours of energy

1. Solar + Storage, time-variant tariff PPA
   - Example, tariff for summer evening is 6 times in off-peak hours
   - NV Energy:
     - $138–161/MWh for peak, which is 5% of blocks
     - $21–25/MWh for off-peak
     - Levelized $36.8–42.8/MWh

2. Solar PPA + Storage capacity payment
   - Solar is paid tariff for energy ($35/MWh)
   - Storage is paid tariff for capacity ($6000/MW-month)
   - This allows for storage to be used for flexible operation

3. RE Dispatchable PPA
   - Based on capability and performance of the combined plant
   - Tariff tied to energy delivered

4. Blended PPA
   - Separate tariff for solar ($30/MWh) and storage ($15/MWh)

Source: BNEF 2019
# Business Structures for Energy Storage Market Transactions

## Table 2.1: Energy Storage Ownership Models

<table>
<thead>
<tr>
<th>Wholesale</th>
<th>Substation</th>
<th>End-Use Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility-owned</td>
<td>Utility-owned</td>
<td>Customer-owned</td>
</tr>
<tr>
<td>IPP-owned</td>
<td>- Grid asset</td>
<td>ESCO (with aggregator)-owned</td>
</tr>
<tr>
<td>Supplier-/Vendor-owned</td>
<td>- Smart-grid asset</td>
<td>IPP-owned</td>
</tr>
<tr>
<td></td>
<td>IPP-owned</td>
<td>Utility (LSE)-owned</td>
</tr>
<tr>
<td></td>
<td>ESCO-owned</td>
<td>Part of utility program</td>
</tr>
<tr>
<td></td>
<td>IPP/LSE contract for grid</td>
<td></td>
</tr>
<tr>
<td></td>
<td>support services</td>
<td></td>
</tr>
</tbody>
</table>

ESCO = energy service company, IPP = independent power producer, LSE = load-serving entity.
Source: Korea Battery Industry Association 2017 “Energy storage system technology and business model”.

Source: [https://www.adb.org/sites/default/files/publication/479891/handbook-battery-energy-storage-system.pdf](https://www.adb.org/sites/default/files/publication/479891/handbook-battery-energy-storage-system.pdf)
Economic Viability is Complicated...Multiple Variables

Table 2.2: Key Factors Affecting the Viability of Battery Energy Storage System Projects

<table>
<thead>
<tr>
<th>Factor</th>
<th>Impact on Project Viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of storage</td>
<td>Battery costs, while falling, are still the most significant driver of project viability. Costs depend on the MW/MWh ratio of the battery. The terminal value at the end of the project's economic life also has a bearing, with a higher terminal value improving project economics.</td>
</tr>
<tr>
<td>Network reinforcement cost</td>
<td>Higher conventional network reinforcement costs increase the value of deploying storage as an alternative, improving project economics (and vice versa) for DNOs directly and for third-party projects with a contract for peak shaving with a DNO.</td>
</tr>
<tr>
<td>Commercial services</td>
<td>Increased access to and higher value from the provision of commercial services (for example, ancillary service markets, the wholesale market, the capacity market) increase project revenue streams, improving project economics (and vice versa). It is generally accepted that value streams will need to be stacked to increase the economic viability of BESS projects (see Figure 10).</td>
</tr>
<tr>
<td>Policy developments</td>
<td>Removing barriers to storage or creating a more favorable environment for investment enhances the realizable value of a project, improving project economics (and vice versa).</td>
</tr>
</tbody>
</table>

BESS = battery energy storage system, DNO = distribution network operator, MW = megawatt, MWh = megawatt-hour.

Source: Korea Battery Industry Association 2017 “Energy storage system technology and business model”.

Source: https://www.adb.org/sites/default/files/publication/479891/handbook-battery-energy-storage-system.pdf
High Level Approach for Monetary Assessment of Energy Storage

Source: DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA, Akhil et al, Sandia National Laboratories
Methodologies
- Value Stacking, Levelized Cost, Models
Value Stacking – Necessary to Maximize Returns on Investment

• As more Variable Renewable Energy on the grid, more need for flexibility and more need for storage – creates value
• Batteries are often still too expensive to justify their cost from providing just a single service
• For example, Batteries (and their owners/operators) can add value by providing multiple ancillary services, such as:
  – Regulation Reserves: short-term variability
  – Fast Frequency Response: Compensate for inertial losses
• Another example: Hornsdale Power Reserve, 100 MW/129 MWh Li-ion battery in South Australia (Tesla PowerWall)
  – Energy Arbitrage (can bid up to 30 MW and 119 MWh capacity when wind energy creates cheap marginal power)
  – Frequency Market (remainder, i.e., 70 MW, as fast-acting grid stabilizer when coal plant tripped off-line)
Energy Services Required for Reliable & Cost Effective Power Delivery

Front-of-Meter (Utility) Services

- Bulk energy services
  - Electric energy time shift (arbitrage)
- Ancillary services
  - Regulation
- Transmission infrastructure services
  - Transmission upgrade deferral
- Distribution infrastructure services
  - Distribution upgrade deferral

Behind-Meter (End User) Services

- Customer energy management services
  - Power quality
  - Power reliability
  - Retail electric energy time shift
  - Demand charge management
  - Increased self-consumption of solar PV

Off-grid
- Solar home systems
  - Electric 2/3 wheelers, buses, cars and commercial vehicles

Transport sector
- Mini-grids: System stability services
- Mini-grids: Facilitating high share of VRE

Boxes in red: Energy storage services directly supporting the integration of variable renewable energy

Utility Energy Storage – What Services are Making $$$?

Table 1: Applications of Utility-Scale Energy Storage

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Duration of Service Provision</th>
<th>Typically Valued in U.S. Electricity Markets?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arbitrage</td>
<td>Purchasing low-cost off-peak energy and selling it during periods of high prices.</td>
<td>Hours</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm Capacity</td>
<td>Provide reliable capacity to meet peak system demand.</td>
<td>4+ hours</td>
<td>Yes, via scarcity pricing and capacity markets, or through resource adequacy payments.</td>
</tr>
<tr>
<td>Operating Reserves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Primary Frequency Response</td>
<td>Very fast response to unpredictable variations in demand and generation.</td>
<td>Seconds</td>
<td>Yes, but only in a limited number of markets.</td>
</tr>
<tr>
<td>• Regulation</td>
<td>Fast response to random, unpredictable variations in demand and generation.</td>
<td>15 minutes to 1 hour</td>
<td>Yes</td>
</tr>
<tr>
<td>• Contingency Spinning</td>
<td>Fast response to a contingency such as a generator failure.</td>
<td>30 minutes to 2 hours</td>
<td>Yes</td>
</tr>
<tr>
<td>• Replacement/Supplemental</td>
<td>Units brought online to replace spinning units.</td>
<td>Hours</td>
<td>Yes, but values are very low.</td>
</tr>
<tr>
<td>• Ramping/Load Following</td>
<td>Follow longer-term (hourly) changes in electricity demand.</td>
<td>30 minutes to hours</td>
<td>Yes, but only in a limited number of markets.</td>
</tr>
<tr>
<td>Transmission and Distribution Replacement and Deferral</td>
<td>Reduce loading on T&amp;D system during peak times.</td>
<td>Hours</td>
<td>Only partially, via congestion prices.</td>
</tr>
<tr>
<td>Black Start</td>
<td>Units brought online to start system after a system-wide failure (blackout).</td>
<td>Hours</td>
<td>No, typically compensated through cost-of-service mechanisms.</td>
</tr>
</tbody>
</table>

Most storage systems in the United States provide operating reserves and ancillary services. Despite this current focus, the total U.S. market for these services is limited, and utility-scale storage may begin providing more firm and peak capacity in the near future.

![Graph: U.S. Utility-scale battery storage capacity by service. Data source: U.S. Energy Information Administration, Form EIA-860, Annual Electric Generator Report](image)

Greening the Grid, Grid Integration Toolkit; [www.nrel.gov/usaid-partnership](http://www.nrel.gov/usaid-partnership)
Different Storage Technologies for Different Use Cases

Figure 7: Global energy storage power capacity shares by main-use case and technology group, mid-2017

Lazard’s Levelized Cost of Storage (LCOS)

• Analyze cost effectiveness, revenue potential, and underlying value of different energy storage technologies and applications – “apples to apples” comparison

• Create Energy Storage Model for each type of technology and typical project, solving for $/MWh equal to assumed cost of equity/levered IRR → ”Margin”

• While battery costs continue to decline, high lithium-ion demand and commodity prices for cobalt may slow price drops

• Short-Duration storage applications (4 hours or less) are still the most cost-effective applications

• Improvement in project economics are generally attributed to decreasing costs, not increasing revenues

• Along with ancillary services at wholesale level, demand response and demand charge mitigation at the commercial and industrial level are most promising, though site-specific

• Project economics are site-specific, i.e., individual markets, geographies, available resources, make each situation unique

Lazard’s LCOS Results

- Wholesale 20 years, 100 MW, 400 MWh capacity, Annual MWh: 140,000; Project MWh: 2,800,000
- Wholesale Value Streams include Energy Arbitrage, Frequency Regulation, Resource Adequacy, Spinning & Non-Spinning Reserves
  - Lithium-ion: $204 - $298/MWh
  - Vanadium Flow: $257 - $390/MWh
  - ZnBr Flow: $267 – $300/MWh

- Transmission & Distribution: 20 years, 10 MW, 60 MWh capacity, Annual MWh: 15,000; Project MWh: 300,000
- T&D Value Streams @ utility level include providing extra capacity to meet expected load growth and defer T or D investment
  - Lithium-ion: $263 - $471/MWh
  - Vanadium Flow: $293 – $467/MWh
  - ZnBr Flow: $406 - $464/MWh

### Analytical Modeling Tools to Evaluate Storage Cost Effectiveness

<table>
<thead>
<tr>
<th>Category</th>
<th>Resource Portfolio Planning</th>
<th>Production Simulation</th>
<th>Load Flow/ Stability</th>
<th>Dynamics Simulation</th>
<th>Electricity Storage Technology Screening</th>
<th>Electricity Storage Cost-Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Long-term resource and capacity planning needs</td>
<td>Future-year trans. Grid simulation</td>
<td>Near-term T&amp;D grid resource stability/engineering needs</td>
<td>Short-term variability and load-balancing</td>
<td>Screening storage technology and service combinations</td>
<td>Assessing storage project cost-effectiveness</td>
</tr>
<tr>
<td>Goals</td>
<td>Minimize cost and risk of resource portfolio, maximize social welfare</td>
<td>Least-cost unit commitment and economic dispatch with reliability/transmission constraints to manage minutes to hours variability and uncertainty</td>
<td>Least-cost planning to meet reliability and tolerance thresholds</td>
<td>Manage seconds to minutes variability and uncertainty</td>
<td>Identify promising technology/services combinations</td>
<td>Maximize expected NPV of storage investment</td>
</tr>
<tr>
<td>Examples</td>
<td>NESSIE, RETScreen, NEMS, EGEAS EMCAS</td>
<td>PLEXOS, UPLAN, GridView, PROMOD, Ventyx, GE-MAPS PROBE PSO</td>
<td>Trans: PSG/E, PGLF, HOMER, Dist:CYMDist, OpenDSS, GridLab-D VSAT TSAT POM</td>
<td>Kermit FESTIV PSO</td>
<td>EG-Select ESVT ESCT</td>
<td>ESVT (EPRI) ESCT (Navigant)</td>
</tr>
<tr>
<td>Core Strengths</td>
<td>Evaluate range of future, regional scenarios and resource portfolios</td>
<td>One-year system dispatch with zonal/modal model of regional grid, including market price effects</td>
<td>High resolution power flow, Volt/Var and fault analysis for specific grid configurations</td>
<td>Short-time-scale dispatch for frequency regulation</td>
<td>Scoping analysis of a wide range of technologies and services</td>
<td>Life-cycle financial and cost-benefit analysis from owner/operator and societal perspectives</td>
</tr>
</tbody>
</table>

### Summary Cost Metrics

1. **Installed Cost ($/kW)**
2. **Levelized Cost of Capacity ($/kW-yr)**
3. **Levelized Cost of Energy (LCOE, $/MWh)**
4. **Net Present Value of Lifecycle Costs ($/kW installed)**
5. **Net Present Value of Lifecycle Costs ($/kWh installed)**

### Typical Metrics

**Source:** DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA, Akhil et al, Sandia National Laboratories

**URL:** [https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2015/151002.pdf](https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2015/151002.pdf)

#### Example Life Cycle Calculator – Typical Metrics

<table>
<thead>
<tr>
<th>COST AND PERFORMANCE DATA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Size</strong></td>
<td></td>
</tr>
<tr>
<td>Charge/Discharge Capacity (kW)</td>
<td>kW</td>
</tr>
<tr>
<td>Hours of storage at rated capacity</td>
<td>hours</td>
</tr>
<tr>
<td>Depth of Discharge per cycle</td>
<td>%</td>
</tr>
<tr>
<td>Useable Energy Storage Capacity (kWh)</td>
<td>kWh</td>
</tr>
<tr>
<td>Installed Energy Storage Capacity</td>
<td>kWh</td>
</tr>
<tr>
<td><strong>Useful Life</strong></td>
<td></td>
</tr>
<tr>
<td>End-of-Life Residual Energy Storage</td>
<td>%</td>
</tr>
<tr>
<td>Degradation Factor (%/yr)</td>
<td>%</td>
</tr>
<tr>
<td>System Life</td>
<td>Years</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td></td>
</tr>
<tr>
<td>AC/AC Efficiency OR</td>
<td>%</td>
</tr>
<tr>
<td>Energy Charge Ratio</td>
<td>kW in/kWh out</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
</tr>
<tr>
<td>Cycles per Year</td>
<td>#</td>
</tr>
<tr>
<td><strong>Installed Cost</strong></td>
<td></td>
</tr>
<tr>
<td>DC Battery Cost per kWh of usable storage</td>
<td>$/kWh</td>
</tr>
<tr>
<td>Total DC Battery Cost</td>
<td>$</td>
</tr>
<tr>
<td>$/kW Installed (incl PCS)</td>
<td>$/kW</td>
</tr>
<tr>
<td>Total $/kW Cost</td>
<td>$</td>
</tr>
<tr>
<td>Total</td>
<td>$</td>
</tr>
<tr>
<td>Cost per kW</td>
<td>$/kW</td>
</tr>
<tr>
<td>System Cost - Regional Multiplier</td>
<td>Ratio</td>
</tr>
<tr>
<td>System Cost - Regional Cost</td>
<td>$/kW</td>
</tr>
<tr>
<td>$/kW - Using kWh</td>
<td>$/kWh</td>
</tr>
<tr>
<td><strong>Fixed O&amp;M</strong></td>
<td></td>
</tr>
<tr>
<td>Fixed O&amp;M Cost</td>
<td>$/kW-Yr</td>
</tr>
<tr>
<td><strong>Variable O&amp;M</strong></td>
<td></td>
</tr>
<tr>
<td>Variable Costs</td>
<td>$/kWh produced</td>
</tr>
<tr>
<td><strong>Charging Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Avg. Charging Cost</td>
<td>$/MWh</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>$/MMBtu</td>
</tr>
<tr>
<td>Fuel Cost Escalation</td>
<td>%</td>
</tr>
<tr>
<td><strong>CO2 Emission Rate by Fuel</strong></td>
<td>lb/MBtu</td>
</tr>
<tr>
<td><strong>CO2 Allowance Price</strong></td>
<td>$/ton</td>
</tr>
<tr>
<td><strong>Heat rate</strong></td>
<td>Btu/kWh</td>
</tr>
<tr>
<td><strong>Annual Heat Rate Degradation</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>Fixed O&amp;M Cost - Escalator (%/yr)</strong></td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>Variable O&amp;M Cost - Escalator (%/yr)</strong></td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>Finance</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Ownership</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Percent Financed with Equity</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>Debt Interest Rate</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>After-Tax WACC</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>Cost of Equity</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>Target average Debt Service Coverage Ratio</strong></td>
<td>ratio</td>
</tr>
<tr>
<td><strong>Debt Term</strong></td>
<td>Years</td>
</tr>
</tbody>
</table>
IRENA Cost of Service Tool

• Spreadsheet model allowing user input for:
  – Technology Type
  – Inverter/PCS size
  – Application
  – Costs, upfront & yearly
  – Financial parameters
• Projects from 2016 → 2030
• Does not calculate Value Stacking
• Demonstrate – Provide Example

Source: https://www.irena.org/DocumentDownloads/Publications/IRENA_Electricity_Storage_Costs_2017.pdf © IRENA
Cost Considerations in Project Development

Figure 2.5: Benchmark Capital Costs for a 1 MW/1 MWh Utility-Sale Energy Storage System Project (real 2017 $/kWh)

EPC = engineering, procurement, and construction; ESS = energy storage system; MW = megawatt; MWh = megawatt-hour; PCS = power conversion system.

Source: Bloomberg New Energy Finance (BNEF)

Source: https://www.adb.org/sites/default/files/publication/479891/handbook-battery-energy-storage-system.pdf
• Example
So How Does It Work?

- Focus on PJM – Regional Transmission Operator (RTO)
- Wholesale electricity in 13 US States and District of Columbia (Wash, DC)
- 369,089 square mile area
- 84,000 miles of transmission lines
- 65 million people
- Reliability & Least cost via financial incentives, planning, competition

Source: https://www.ferc.gov/market-assessments/mkt-electric/pjm.asp
Components of Wholesale Electricity Cost in PJM Territory

- **Energy Market:** Divided into Day-Ahead & Real-Time – match consumers & suppliers with time, place, price; ~ 63% of total wholesale cost

- **Capacity Market:** Reliability Pricing Model; 3-year forecast, bid annually; need to meet peak demand & emergencies – ensures investment in new resources & innovation; ~ 20% of wholesale cost

- **Ancillary Services:** Regulation Resources & Reserves; < 1% of wholesale cost
  - Regulation – ensures reliability to correct short-term fluctuations affecting stability
  - Reserves – generation resources to come quickly on-line or end-users to quickly reduce demand; also help balance in emergencies

Source: [http://pjm.com/](http://pjm.com/)
PJM Snapshot, Part 1

Area Control Error

Locational Marginal Prices
PJM Snapshot, Part 2

Ancillary Services Pricing

Wind Energy
• BESS Siting
Different Potential Locations of Storage – Each with Different Value and Costs

Source: https://www.irena.org/DocumentDownloads/Publications/IRENA_Electricity_Storage_Costs_2017.pdf © IRENA
BESS Siting to Provide Most Value

- Option 1: @ Load Centers – Transmission & Distribution is Primary Consideration
  - Relieves congestion, defers T&D investment, reduces T&D losses
  - Easier to site than thermal generation; Scalable (some now, more later)
- Option 2: @ Remote, VRE Resources
  - Transmission required to bring energy to market; Storage can reduce transmission costs, improve capacity factor; consider value stacking for storage
- Option 3: Integrated with VRE Generation
  - Can assist with ramp rate control
  - Save $ on shared components, e.g., inverters & BMS
  - Often easier for off-takers, e.g., utilities purchasing from IPP
- Application Value can change based on siting; Each situation requires site-specific analysis

Co-locating Solar PV & Storage Reduces Costs

VRE & Battery Services are Sometimes Inversely Related

With increased PV penetration, the capacity value of PV decreases while the capacity value of storage increases.

Policy Considerations
National, Regional, and State Policies – Each Has Role to Play

**FERC**
- Regulates wholesale electricity market operations.
- Sets rules for ISO and Regional Transmission Organization (RTO) operations/procurement rules.
- Influences participation of energy storage and demand response in transmission grid operation and sale of ancillary services in wholesale markets.

**ISO**
- Manages electric transmission in a geographic region, ensures access for all.
- Buys ancillary services to balance supply and demand on its transmission system.
- Establishes rules for procurement of resources (e.g., ancillary services, spinning reserves) to help maintain transmission grid stability.

**PUC**
- Regulates utilities’ energy and capacity acquisition, management and operations.
- Sets retail electric rates, assesses cost-recovery and prudency of resource acquisition and operations. Can affect use, acquisition and mode of payment for energy storage at distribution level.

National Level Policy: Tariffs that Promote Energy Storage

• **FERC Order 841**: Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent Sys

• Federal Energy Regulatory Commission, February 2018

• FERC Order 841 is a final rule from the United States Department of Energy’s Federal Energy Regulatory Commission that directs RTOs and ISOs to develop tariffs to integrate electric storage into all electric (capacity, energy, and ancillary service) markets. This rule is expected to usher in the wider use of electric storage and in turn result in higher integration of intermittent and variable onto the grid. The rule applies to all storage capable of both charging from and discharging to the grid, regardless of whether it was a behind-the-meter, distribution, or transmission level system. In May 2019, citing their jurisdictional authority, FERC commissioners declined to allow states to opt out of this rule.

[https://greeningthegrid.org/Grid-Integration-Toolkit/Topics-And-Resources/energy-storage](https://greeningthegrid.org/Grid-Integration-Toolkit/Topics-And-Resources/energy-storage)
Regional Business Structure & Policy Leverage

Additional Revenues Include:
- Retail incentives ($350/kWh, $130 Million)
- Bulk incentives ($85-110/kWh, $150 million)
- Emissions regulations
- More incentives for Behind the Meter
State Level Policy to Promote Energy Storage

• **AB-2514 Energy storage systems**
• Public Utilities Commission of the State of California, September 2010
• California established a target of 1.325 GW of energy storage by 2020 for its various investor-owned utilities. Key details included:
  • Specific biennial procurements requirements for each utility. As at June 2018, California’s three main investor-owned utilities - Pacific Gas & Electric, Southern California Edison and San Diego Gas & Electric were 40%, 70% and 95% towards their respective goals of a combined 1.325 GW of battery energy storage.
  • Value-stacking of energy storage allowed. That is, energy storage could be used in multiple applications in capacity, ancillary and peak shaving services.
  • Utilities’ ownership of storage could not exceed 50%.
  • Large scale pumped hydro storage could not be used to meet requirement.

Source: https://greeningthegrid.org/Grid-Integration-Toolkit/Topics-And-Resources/energy-storage
California Public Utilities Commission Rule-making for Utilities Purchasing BESS Services

- BESS projects can only provide services at nominal voltages or greater

- Reliability services highest priority; storage cannot contract for additional services that would interfere with reliability services

- BESS must comply with performance and availability requirements; non-compliance penalties communicated in advance

- BESS must inform Utility of any services it currently provides or intends to provide

- No Double Compensation (Different from Value Stacking)

State Level Policy Initiatives

- **Massachusetts** passed H.4857 in July of 2018, setting a goal of 1,000 MWh of energy storage by the end of 2025.

- **New York** Public Service Commission announced in January 2018 a goal of 1,500 MW of energy storage by 2025 and 3,000 MW by 2030. Under this directive, New York Green Bank has agreed to invest $200 million towards energy storage technologies.

- **California's** three largest IOU’s have been mandated to develop a combined energy storage capacity of 1,325 MW by the end of 2024. An extra 500 MW was added to the mandate in 2016.

- In **Oregon**, law HB 2193 mandates that 5 MWh of energy storage must be working in the grid by 2020.

- **New Jersey** passed A3723 in 2018 that sets New Jersey’s energy storage target at 2,000 MW by 2030.

- **Arizona** has proposed a target of 3,000 MW of energy storage by 2030.

Source: Fact Sheet: Energy Storage (2019), Environmental and Energy Study Institute
https://www.eesi.org/papers/view/energy-storage-2019
Additional Policy Tools to Promote Energy Storage

• Incorporate consideration of storage into grid integration studies to determine the cost-effectiveness of storage relative to other flexibility options at a variety of variable RE penetrations
• Conduct integrated resource planning to identify locations for feasible and effective implementation of storage measures
• Develop modeling tools that can fully characterize the costs and benefits of storage technologies
• Support early-stage research and development into emerging energy storage technologies
• Streamline implementation of new energy storage regulations to reduce administrative delays that limit storage deployment
• Address revenue compensation mechanisms and market shortcomings for the services offered by energy storage resources. These can include:
  • Explicitly allowing storage systems to provide system services;
  • Ensuring that the unique technical characteristics of storage (fast response time, ability to act as both a load and supply source) are properly compensated;
  • Removing barriers to value-stacking.

Source: https://greeningthegrid.org/Grid-Integration-Toolkit/Topics-And-Resources/energy-storage
Support for Storage Around the World

• Germany subsidizes solar power generation–related ESSs with 30% ESS installation subsidy.

• German government support has increased, from €25 million in 2013 to €30 million between 2016 and 2018, for a total of about €150 million over 6 years.

• Japan provided 31 billion yen in subsidies until 2015 to develop “industrial ecosystem” for ESSs with goal of capturing 50% of global market by 2020.

• US is pushing power-market operators in each state to develop ESS-related business models.

• Republic of Korea supporting ESS market penetration by applying weighted value to new and renewable energy–related ESSs such as Photovoltaic 5.0 until 2019.

• Australia has very favorable market conditions for ESS development (high RE penetration) but struggling with keeping up with policy
More Policy Rec’s

• Frequency Regulation (Where the $ is…so far):
  – Update grid code to allow for delivery of frequency regulation by various generation, load, and storage configurations
  – Create market instruments that capitalize on the fast response time of batteries, e.g., enhanced frequency response (EFR), which requires faster ramp rates and response times to reflect the enhanced capabilities of BESS in frequency regulation
  – In Germany, bidding criteria has been relaxed to increase participation of BESS and other asset types in existing ancillary service markets
  – Enable smaller participants such as BESS operators and “prosumers” (producers–consumers) to offer ancillary services by reducing the minimum bid size (MW) and volume of available energy (MWh). In Germany, secondary reserve procurement has changed from weekly to daily delivery
With Lots of Batteries…Comes Lots of Waste

**Table B1:** Lithium-ion battery electricity storage system recycling pathways

<table>
<thead>
<tr>
<th>MECHANICAL</th>
<th>PIROMETALURGICAL</th>
<th>HYDROMETALURGICAL</th>
<th>THERMAL PRE-TREATMENT + HYDROMETALURGICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dismantling to cell or pack level</td>
<td>High temperature processing aimed at recovery or refinement of metals at elevated temperature</td>
<td>Treatment of aqueous solutions to separate components</td>
<td>Low-temperature thermal treatment aimed at removing organic compounds and graphite (carbon oxidation)</td>
</tr>
<tr>
<td>Crushing (hammer mill)</td>
<td>Works under a separation principle producing two phases</td>
<td>Black mass is treated by leaching, cementation, purification, solvent extraction or precipitation methods to extract valuable components</td>
<td>Allows phase transformation into water soluble lithium carbonate</td>
</tr>
<tr>
<td>Classifying</td>
<td>Slag phase where Li, Mn, Al are lost</td>
<td>Electric are furnace and shaft furnace are used</td>
<td>Has low energy requirements</td>
</tr>
<tr>
<td>Scrap fractions generated</td>
<td>Recovers Co, Ni, Cu, Fe in a metal phase (allow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black mass with valuable metals (cobalt, nickel, manganese, lithium, etc. are recovered)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Notes: Li = lithium; Mn = manganese; Al = aluminum; Co = cobalt; Ni = nickel; Cu = copper; Fe = iron.

RE History Lesson … Apply to Growth of Storage

- Feed-in Tariffs
- Investment & Production Tax Credits
- Integrated Planning, Rulemaking

Source: The Edge: Wood Mackenzie Weekly Insights, 25 April 2019
Hybrid Resources (e.g., VRE & Storage) currently under-valued, and changing faster than the markets and regulators can adapt. NEW RULES are needed.

Energy Storage Systems will soon be lower cost than gas peaker plants in many locations and adding important flexibility to the grid.

When 40-50% RE penetration, energy storage is necessary.

Still lacking long duration storage; US Dept of Energy recently released $30 million for long duration (10 – 100 hours), focused on thermal storage, geomechanical pumped storage, and sulfur-manganese flow battery.

De-carbonization goals will further accelerate need and opportunity.

BESS is most effective as part of Grid Modernization, Demand Response, Good Planning, vibrant markets.

https://sepapower.org/resource/2019-utility-energy-storage-market-snapshot/
Policy Summary for ES

• Set target for ES, possibly tied to target for VRE

• Clearly specify through regulations or grid code, how ES can participate
  – Qualifications criteria for participating in the grid

• Make ES specific rules:
  – Include State of Charge as a parameter in dispatch
  – Prevent conflicting dispatch
  – Metering and accounting

• Make ES eligible to provide all services, and set tariffs that reflect the services provided by ES:
  – Ancillary Services: Frequency, voltage regulation
  – Flexibility: Load following
  – Capacity: Operating reserve
  – Deferral of Upgrade: Transmission
  – Arbitrage: Peak shaving

• If required provide an incentive in the short-term to encourage investment in ES
Thank You