Energy Storage – Evolution and Revolution on the Electric Grid

Lon Huber
March, 2017
Strategen provides insight to global corporations, utilities and public sector leaders, helping them to develop impactful and financially sustainable clean energy strategies.

A Sampling of Our Clients

- Minnesota Department of Commerce
- Mass. Dept. of Environmental Protection
- Xcel Energy
- Sandia National Laboratories
- Bosch
- NFPA
- Hudson Clean Energy
- Chevron Energy Solutions
- Portland General Electric
- GAF
- CalCEF
- Rockport Capital
- PSE
- Walmart
- 3M
Storage analytics and cost/benefit
Energy storage is a very broad asset class

**Electro-Chemical**
- Flow battery / Lithium Ion

**Mechanical**
- Flywheel

**Thermal**
- Ice / Molten Salt

**Bulk Mechanical**
- CAES

**Bulk Gravitational**
- Pumped Hydro

**Transportation and Chemical**
- Electric and Hydrogen Vehicles
Size and Duration by Technology

Source: Australian Renewable Energy Agency (7/2015): Energy Storage Study Funding and Knowledge Sharing Priorities
Topics

What is energy storage?

Value and services

Key trends and drivers

Moving forward
Broad electric power system applicability
Energy storage is flexible

- Energy storage can be deployed quickly, relocate and scaled up or down as required. (Shift, scale-able, shift-able)

- This makes it a critical tool to navigate the rapid change that is occurring

**Aliso Canyon: from RFP to online in 7 months**

- May 27, 2016
  - SCE issues Aliso ACES RFO and DBT RFP

- Jul. 18, 2016
  - SDG&E files application for 150 MWhs of storage

- Aug. 15, 2016
  - SCE files application for 108 MWhs of storage

- Aug. 18, 2016
  - CPUC approves SDG&E applications

- Sept. 15, 2016
  - CPUC approves SCE Round 1 applications

  - Projects brought online

**Total:**
94.5 MW / 342 MWh
Resiliency: Dominican Republic

- 20 MW of storage in Santa Domingo, Dominican Republic provides efficient frequency regulation to the grid
- Provided key services during September’s Hurricanes Irma and Maria, when about 50% of the island’s power plants were forced offline

SOURCE: AES

CASE STUDY: HTTP://CDN2.HUBSPOT.NET/HUBF5/2810531/COLLATERAL/AES%20ES%20CASE%20STUDY%20STORM%20RESILIENCE.PDF
Operational use cases for storage systems (There are many)

<table>
<thead>
<tr>
<th>Grid Location</th>
<th>Minimum duration of output energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Short (&lt; 2 min)</td>
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<tr>
<td></td>
<td>- Provide Spin/ Non Spin</td>
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<td></td>
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<td></td>
<td>Medium (2 min – 1 hour)</td>
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<td></td>
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<td></td>
<td>- Provide Capacity</td>
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<td>- “Firm” Renewable Capacity</td>
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<tr>
<td>Distribution</td>
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<td></td>
<td>- Shift Energy</td>
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<td>- Avoid dump energy and/or minimum load issues</td>
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<td></td>
<td>- Provide Black Start</td>
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<tr>
<td></td>
<td>- Provide In-Basin Generation</td>
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<tr>
<td>End User</td>
<td></td>
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<tr>
<td></td>
<td>- Avoid Congestion Fees</td>
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<td></td>
<td>- Defer System Upgrades</td>
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<tr>
<td></td>
<td>- Improve System Reliability</td>
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<td></td>
<td>- Mitigate Outages</td>
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<tr>
<td></td>
<td>- Integrate Intermittent Distributed Generation</td>
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<tr>
<td></td>
<td>- Self-consumption</td>
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<td>- Provide Uninterruptible Power Supply</td>
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<td>- Demand Charge/ TOU</td>
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</tbody>
</table>

Source: Modified from SCE 2011 chart
Approach to evaluating storage opportunities

1. Identify primary need
2. Explore combinations of stackable benefits; discard incompatible value streams
3. Optimize value streams and understand tradeoffs
## Main Use Case: Distribution deferral

### Grid Location

<table>
<thead>
<tr>
<th>End User</th>
<th>Dynamic Response</th>
<th>Generation</th>
<th>Transmission</th>
<th>Distribution</th>
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</thead>
<tbody>
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### Minimum duration of output energy

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<td></td>
<td>Defer System Upgrades</td>
<td></td>
</tr>
</tbody>
</table>

### Source
Modified from SCE 2011 chart
Value stack example #1: Distribution deferral

Costs and Benefits of a Hypothetical Storage Project

- **Net Present Value (000s)**
  - $1,400
  - $1,200
  - $1,000
  - $800
  - $600
  - $400
  - $200
  - $0

- **Cost**
  - Equity
  - Debt
  - OpEx
  - Dist. Deferral, $460
  - Taxes

- **Benefit**
  - Use Case 1 (Dist. Deferral)

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**Graph Details**

- **Demand**
- **Power System Limit**
- **Net Demand After Storage**

- **Energy storage discharges to reduce peak**
- **Energy storage charges at underutilized time**

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4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 0:00

**Time**

---

**Net Present Value**

---
Value stack example #2: Frequency regulation

- **Grid Location**
  - Generation
  - Transmission
  - Distribution
  - End User

- **Dynamic Response**
  - Improve Short-Driven Performance
  - Provide System Inertia
  - Maintain Power Quality

- **Minimum duration of output energy**
  - Short (< 2 min)
    - Provide Spin/ Non Spin
    - Provide Ramping
    - Provide Frequency Regulation Services
  - Medium (2 min – 1 hour)
    - Smooth Intermittent Resource Output
    - Improve System Reliability
    - Defer System Upgrades
  - Long (1 hour+)
    - Provide Capacity
    - "Firm" Renewable Capacity
    - Shift Energy
    - Avoid dump energy and/or minimum load issues
    - Provide Black Start
    - Provide In-Basin Generation

- **Energy Shifting**
  - Avoid Congestion Fees
  - Defer System Upgrades
  - Mitigate Outages
  - Integrate Intermittent Distributed Generation
  - Self-consumption
  - Provide Uninterruptible Power Supply
  - Demand Charge/ TOU

*Source: Modified from SCE 2011 chart*
Value stack example #2: Frequency regulation

![Graph showing costs and benefits of a hypothetical storage project for frequency regulation.](Image)

- **Costs and Benefits of a Hypothetical Storage Project**
  - **Net Present Value (000s)**:
    - $0 to $1,400
  - **Power (MW)**:
    - Supply
    - Demand
  - **Time (seconds)**:
  - **Excess Supply** (need regulation down)
  - **Supply Shortfall** (need regulation up)

- **Use Case 1 (Dist. Deferral)**:
  - **Cost**: $460
  - **Benefit**: $0

- **Use Case 2 (Freq. Reg.)**:
  - **Cost**: $336
  - **Benefit**: $0

- **Equity**
- **Debt**
- **OpEx**
- **Taxes**
Value stacking: Dist. deferral + frequency regulation
**US installed capacity by application**

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation</td>
<td>Market products for wholesale market participation</td>
</tr>
<tr>
<td>Renewable Integration</td>
<td>Storage sited with renewable projects</td>
</tr>
<tr>
<td>Resiliency</td>
<td>Microgrids and Black Start applications</td>
</tr>
<tr>
<td>Capacity</td>
<td>Local Capacity and Resource Adequacy</td>
</tr>
<tr>
<td>T&amp;D</td>
<td>Transmission and Distribution Upgrade Deferral</td>
</tr>
</tbody>
</table>

**Energy Storage Applications by State**

Note: Pumped Hydro technology excluded. Some storage capacity may be double-counted if the system performs multiple applications

Source: DOE Energy Storage Database Accessed Jan 11, 2018
The power system is underutilized

Source: PG&E Demand Response Programs: An Overview Presentation
Why peak demand is important

- Analysis finds that for every $1 spent on reducing peak demand, at least $2.62 can be saved by ratepayers in Illinois and $3.26 by ratepayers in Massachusetts.

- Cutting top 100 hours of peak demand could save New York State up to $1.7 billion per year
  - 15% of total production assets run less than 7 days per year or less than 2% of that time

According to EIA:
Average peaker plant runs about 2-7% of the year
Over 70 GW of new peaker plants will be built in the U.S. before 2026

MA DOER slide: Commissioner Judson presentation at Restructuring Roundtable, May 2016
Source: https://info.aee.net/peak-demand-reduction-report
Topics

What is energy storage?

Value and services

Key trends and drivers

Moving forward
Chapter 1
Frequency regulation

- Frequency regulation (FR) storage projects are low energy applications therefore lower cost for batteries
- Important but shallow market as renewable generation increases
- FR was largest front-of-meter storage application in USA until 2016
  - 265 MW of fast-response storage in PJM
  - Typically 30 minute to an hour capacity
  - Volatile market pricing

Source: Energy Storage North America 2017
solarprofessional.com
Chapter 2
Niche transmission & distribution infrastructure deferral

Energy storage for T&D deferral is expected to grow from 332 MW in 2017 to 14,325 MW in 2026.

Use case attributes:
- High T&D upgrade costs
- High peak-to-energy ratio
- Modest projected load growth
- Uncertainty regarding the timing or likelihood of major load additions
- T&D construction limitations (siting, line access local community opposition to new power lines and infrastructure.)
- An energy storage system used for T&D deferral will be able to provide additional benefits (renewable integration, etc.)

Australia Example: Grid utility support system, 20 energy storage systems to support remote networks

Source: energy-storage.news, businesswire.com, ergon.com
Chapter 3
Battery peaker – local capacity

*SCE purchased 5X CPUC requirement (50MW)*

- **Aliso - 94.5 MW / 342 Mwh**
  - Peaker Plants Constructed In 7-months
  - Highlighted Fast Deployment Of Energy Storage
- **Led To 100MW In 100 Days’ Deployment In Australia**
- **Primarily a Storage-only Application**

### SCE Energy Storage LCR Procurement

<table>
<thead>
<tr>
<th>Seller</th>
<th>Resource Type</th>
<th>Total Contracts</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adv. Microgrid Solutions</td>
<td>BTM Battery</td>
<td>4</td>
<td>50.0</td>
</tr>
<tr>
<td>AES</td>
<td>FTM Battery</td>
<td>1</td>
<td>100.0</td>
</tr>
<tr>
<td>Ice Energy</td>
<td>BTM Thermal</td>
<td>16</td>
<td>25.6</td>
</tr>
<tr>
<td>NRG</td>
<td>FTM Battery</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Stem</td>
<td>BTM Battery</td>
<td>5</td>
<td>85.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27</strong></td>
<td><strong>261.1</strong></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 3.5
C&I and Co-op Demand Charge Mitigation

- Great River Energy Co-op in Minnesota issued RFP for 10 MW PV and 10 MW/20 MWh Storage system in 2018

- Primary use case for storage is to dispatch over 2-4 hours peak period for demand reduction

- Storage to be charged 100% by co-located PV

Source: greatriverenergy.com, advmicrogrid.com,
Chapter 4
Dispatchable solar – PV + storage peaker

Australia: Cooktown Solar and Storage
- 33MW solar plus 1.4MW/5.4MWh Lithium based battery storage
- Fringe grid in Australia and will test the boundaries of operation of utility scale solar battery storage in these conditions.
- The Project is now in operation.
- Funding dependent on dispatchable/storage aspect to assist with supplying solar during evening peak
- Altogether, Lyon Group planning 1.7GW of PV and 1GW of battery storage by 2020

Source: http://www.lyoninfrastructure.com/cooktown.html

Arizona: Tucson Electric Power 100 MW solar plus storage plant
- 30 MW of four-hour duration batteries
- 20 year PPA
- ~3 cents/kWh solar – ~4.5 cents/kWh with battery
- Will be largest solar-plus-utility-scale-battery system in the US

Source: http://insights.globalspec.com/article/4139/solar-storage-peaker-plant-for-kauai
Chapter 4.5
DER alternatives

- Customer sited DER and embedded solutions will be leveraged more in the future to avoid utility infrastructure.
- New markets and compensation models will be required to encourage, guide and extract this value.
- New grid operation approaches will be required to compliment new markets

New York: Brooklyn Queens Demand Management program
- 41 MW customer sited solutions
- 11 MW utility sited solutions

California: SCE & PG&E Energy Storage Solicitation for Local Capacity
- Several behind and in-front of meter energy storage resources procured

Australia: AGL virtual power plant.
- 1000 aggregated BTM storage systems, 5MW/7MWh total for customer, distribution and wholesale benefits

Source: conedbqdm auction.com, arena.gov.au
Chapter 5
RE + longer duration storage

KIUC: The Lawai Project
- 28 MW solar farm
- 100 MWh 5 Hour Li-Ion Battery
- Expected 3.7 million gallon reduction in fossil fuel consumption per year.
- 25-year PPA, 11 cents/kWh
- Near the wholesale energy price!
- Supply power at peak evening times

Australia: Australia’s largest solar farm.
- Solar Q proposes to build 350MW solar PV + storage with a second phase to expand to 800MW
- 800MW would provide ~ 15% of the state's south-east electricity needs from PV and 4,000 MWh of batteries
- Storage is critical aspect to serve evening load

Source: theverge.com, abc.net.au, hawaienergypolicy.hawaii.edu
Topics

- What is energy storage?
- Value and services
- Key trends and drivers
- Moving forward
Making it a reality

Chapters won’t happen by themselves

- Market Rules
- Market Study, Valuation & Targets
- All Source Procurements and Resource Plans
- Renewable Energy Strategy
- Non-wires Alternatives
- Resiliency
- Rate Design
- EV Infrastructure

Source: EPRI
Conceptual path forward Li-Ion batteries (Costs are proportional to energy/time)

Source: SCE 2011

Source: ABB
The importance of demand

- Modest sales of EV/hybrids can have significant impact on global cell production
- Currently, significant underutilization in global cell production

The Rise of Electric Cars

By 2022 electric vehicles will cost the same as their internal-combustion counterparts. That's the point of liftoff for sales.

Sources: Data compiled by Bloomberg New Energy Finance, Marklines

Source: CEMAC report to DOE
China targeting/investing in energy storage

- China are expecting Li-ion to play significant role in clean energy future
- China’s 13th 5 year plan guarantees payouts if manufacturers meet targets
- Directing and encouraging internal manufacturing to increase production and capture market

China is leading the charge
Lithium-ion megafactories in China to grow capacity 6X by 2020

Global lithium-ion battery production capacity will increase by 521% between 2016 and 2020.

<table>
<thead>
<tr>
<th></th>
<th>Capacity in 2016</th>
<th>Capacity in 2020</th>
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<tbody>
<tr>
<td></td>
<td>GWh</td>
<td>GWh</td>
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<tr>
<td>2016</td>
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<td>2020</td>
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</table>

Source: www.visualcapitalist.com
Price of US Wind Power at ‘All-Time Low’ of 2.5 Cents per Kilowatt-Hour

New Record Set for World's Cheapest Solar, Now Undercutting Coal

by Anna Hirtenstein
May 3, 2016, 9:20 AM PDT

2.99 U.S. cents per kilowatt-hour is 15% lower than old record

NV Energy buys utility-scale solar at record cents/kW

The Mexican government this month announced the average price achieved in its third long-term auction of 2017 was $20.57 per megawatt-hour, which it said is “one of the lowest prices achieved internationally.”
What is at stake?

A: 55% renewables, business as usual case:
- Solar PV dominates new procurement
- No additional bulk storage
- Continuation of today’s operation policies

B: 55% renewables, GHG target case:
- Balanced portfolio
- Additional bulk storage
- Economically rational imports and exports
- Renewables allowed to provide essential reliability services and flexibility

Difference in Cases: B minus A
- CA Cost savings: $1.1 B/yr
- CA Carbon saved: 5 MMT/year
- Rest of WECC carbon saved: 2.5 MMT/yr

Renewable curtailment & negative prices

[Graph showing California Independent System Operator net generation, March 11, 2017, with data on distributed solar, utility-scale solar imports, other renewables, thermal, nuclear, and hydroelectric energy.

Graph on real-time average hourly price with a highlighted area indicating negative prices.

Bar graph showing Curtailed MWh YTD with data on System, Local, ExDispatch, Economic, and other categories.

The RPS 2.0

Are your state policies ready?

Coming in less than 5 years!

Xcel Attracts ‘Unprecedented’ Low Prices for Solar and Wind Paired With Storage

Bid attracts median PV-plus-battery price of $36 per megawatt-hour. Median wind-plus-storage bids came in even lower, at $21 per megawatt-hour.

JASON DEIGN | JANUARY 08, 2018

Renewable plus storage bids in Xcel Colorado solicitation could set low-price benchmark
Thank you!

Lon Huber
Vice President
Strategen Consulting, LLC

- Email: lhuber@strategen.com
- Phone: 928-380-5540

6th Energy Storage North America (ESNA) Conference + Expo: November 6-8, Pasadena, CA

Largest grid-connected energy storage conference in North America, covering all applications including EV charging (www.esnaexpo.com)

Clean Peak Paper:
Appendix
Adding solar to storage unlocks tax benefits

- Storage is eligible for ITC if charged from solar
  - Level of benefit dependent on ability to charge from solar-paired system
  - Battery must be ≥75% charged from solar to receive ITC
  - Retrofits eligible for ITC, if 100% RE charged
- Tax reform includes changes to depreciation/MACRS, and ITC – stay tuned for new IRS rules

Source: NREL
Global drivers of EVs

- By 2030 all new cars in the Netherlands must be emission free
- India announced that it would end sales of gas and diesel cars by 2030.
- Norway agreed to end sales of gas and diesel cars by 2025.
- France announced it would end sales of gas and diesel cars by 2040.
- Britain announced it would end sales of gas and diesel cars by 2040.
- The Scottish government announced it would phase out gas and diesel cars by 2032.

Others soon to announce

Source: www.vox.com