International experience and best practices in Energy Storage

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Deployment of electricity storage technologies is picking up pace

175 GW of electricity storage capacity installed worldwide

Pumped hydro energy storage systems are the leading ESTES with 95% of the installed capacity worldwide, followed by Thermal energy storage at 1.8%

Battery ESS at 1.6% and flywheels with 0.5% of installed capacity come next

Liquid air and hydrogen energy storage systems are upcoming technologies
More than 1400 energy storage projects are under way

Mercom Capital Group estimates about $820 million dedicated to energy storage project financing during 2016; $30 million in 2015

Three large grid-scale projects in Southern California to integrate renewable energy generating resources; One storage farm can offer up to 30 megawatts of capacity for up to four-hour stretches

Most common reason for deploying storage is to reduce peak consumption

95% of the energy storage projects (by number, not capacity) installed in 2015 used lithium-ion technology

Lithium-ion batteries are currently ahead of the commercial competition
Falling costs of Lithium Ion battery packs

Source: BNEF

Lithium-ion products dominate applications requiring 75 kilowatts to 100 megawatts of capacity, from 15 minutes to eight hours of duration.
Lithium ion batteries have high energy density amongst commercially available technologies, but newer technologies promise a more optimised output at a lower cost and longer life.

Electricity from renewables is getting cheaper and diesel is getting costlier and also being shunned as a polluting fuel.

Battery storage deployments for buses are already viable.

Tesla has 300 MW worth of battery-powered storage systems across 18 countries. AES and Siemens have a combined 463 MW of such projects across 13 countries.

Tesla has a gigafactory and plans to build three more.
KEY DEPLOYMENT AREAS FOR ESTES
BEST PRACTICES - ENVIRONMENTAL CONSIDERATIONS

Pumped storage hydro -
- impact on local population, ground water levels
- impact on river flows, displacement of people and farm animals
- loss of cultivable land, impact on flora and fauna
- compact PHS being planned

Lithium - very volatile element, making lithium-ion batteries prone to thermal runaway if in the event of over-discharge, short circuits, mechanical impacts and from use in locations with high ambient temperature

Water used for extinguishing charged electrochemical devices can pick up high concentrations of toxic materials

Thus, there are doubts about suitability of lithium-ion applications close to significant populations or near critical grid infrastructure

Samsung Galaxy phone was a small but scary example of battery risks
Flow batteries contain vanadium and bromine.

Vanadium can be toxic in large quantities. Vanadium electrolyte replacement needs wearing of special suits by trained technicians. Therefore, potentially risky accidents during transportation.

Bromine is also hazardous in both gas and liquid form.

Alternative flow batteries being developed with zinc-iron electrolyte - non-toxic, non-flammable and non-explosive.
Major effort under way internationally to create Modular Energy Storage Architecture

Open, non-proprietary set of specifications and standards

To be developed by an industry consortium of electric utilities and technology suppliers

Standardization expected to accelerate interoperability, scalability, safety, quality, availability, and affordability in energy storage components and systems.

**Standardisation will yield tremendous benefits to market development**
Common standards would help to:

- Accelerate interoperability and scalability
- Reduce project-specific engineering costs
- Enable technology suppliers to focus on their core competency, facilitating quality, safety, and cost-effectiveness
- Reduce training costs and improve safety for field staff through standardized procedures for safety and efficiency

Will enable multi-vendor, component-based energy storage systems
EFFICIENCY AND LIFE-CYCLE COMPARISONS

DLC - Double layer capacitor
# Current Levels of Technology Suitability

<table>
<thead>
<tr>
<th>Energy Storage Technology</th>
<th>ESS</th>
<th>EV</th>
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<tbody>
<tr>
<td>Li-ion</td>
<td>★★★</td>
<td>★☆☆</td>
</tr>
<tr>
<td>Ultracapacitor</td>
<td>★☆☆</td>
<td>★★★</td>
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<tr>
<td>Fuel cells</td>
<td>★</td>
<td>★☆☆</td>
</tr>
<tr>
<td>Lithium air</td>
<td>★</td>
<td>★☆☆</td>
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<tr>
<td>Lead-acid</td>
<td>★★★</td>
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<tr>
<td>NiMH</td>
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<tr>
<td>Lithium sulphur</td>
<td>★★★</td>
<td>★☆☆</td>
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<tr>
<td>Sodium sulphur</td>
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<tr>
<td>Metal air</td>
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<tr>
<td>Flow batteries</td>
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<tr>
<td>Flywheel</td>
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<tr>
<td>Molten salt</td>
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<td>X</td>
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<td>Hydropower</td>
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<tr>
<td>SMES</td>
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<tr>
<td>CAES</td>
<td>★★★</td>
<td>X</td>
</tr>
</tbody>
</table>

Source: Daleware  
Note:  
- ★★★ = Excellent  
- ★☆☆ = Good  
- ★ = Usable  
- X = Not usable

ESS – Energy Storage System  
EV – Electric Vehicle
Analysis in Europe for large-scale balancing of wind power shows flow cells more economic than lithium-ion for periods more than an hour.

However, averaging of generation / consumption cycles could give skewed results.

Specific characteristics of the system requirements may get masked.

Variations may need to be recorded at one-minute (or lesser) intervals rather than hourly or daily patterns and analysed to assess suitability of the right storage system.
OBSERVED IMPACT OF AGGREGATION

Source: Energynautics, Germany
Does this really make sense for the given location and its needs?

How long will the technology last?

How much space do we have?

How safe is the chemistry?
Each technology has unique characteristics, appropriate application field and storage scale. For a user, key technical & commercial criteria for:

- Energy and power density
- Self-discharge
- Response time
- Cost and economics of scale
- Life time
- Storage capacity
- Monitoring and control equipment
- Efficiency
- Operating constraints

Essential to select most suitable technology for each application.
EMERGING TECHNOLOGY TRENDS

- Sonnen, a German company focuses on residential applications; its storage products use lithium-iron phosphate, which can handle more discharges and recharges than lithium-ion technology.

- Eos Energy Storage, with focus on water-based zinc-cathode chemistry.

- A Stanford University chemistry professor is testing batteries that combine aluminum, graphite and urea which are abundantly found materials. In lab tests, it has been found to charge quickly and over thousands of cycles. It’s been used for vehicle batteries.

- Thermal storage technologies include an air-conditioning technology called IceBank where chillers make ice during the night, when energy costs are traditionally lower, and then use it to cool the air being blown into a building during the daytime. This is being used by more than 4,000 businesses in the U.S. including Bank of America, Marriott, and Walmart and schools.
EMERGING BUSINESS TRENDS

The U.S. National Renewable Energy Laboratory (NREL) has said in a recent report that by 2020, the business case for PV coupled with energy storage in California could be more favourable than stand-alone PV.

Some Solar O&M service providers are considering getting into the storage business and at the same time, some batteries companies are mulling entry into the Solar O&M business.

Batteries can stabilise output, reduce grid deviation penalties and also improve PPA prices.
Electric vehicles

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POSITIVES

- Policy incentives
- Attracting large investments
- Can use RE selectively
- Can help grid balancing

Source: ET
Electric vehicles could shift the whole paradigm for energy storage

CHALLENGES
- Uniform charging infrastructure
- Dynamic electricity pricing to assist the grid
- Safety issues – batteries, overhead charging
- Strong resistance from auto industry
- Regulatory issues

Infrastructure concerns: Will the world have charging infrastructure that is dependable, low-cost, time-efficient?

Wooing buyers: Will consumers accept EVs and overcome range anxiety (worry that battery may run out of power)?

Source: ET
THANK YOU