DNV KEMA Energy & Sustainability Overview

- DNV KEMA Energy & Sustainability offers innovative solutions to customers across the energy value chain, ensuring reliable, efficient and sustainable energy supply, now and in the future.
- 3000+ energy experts across all continents
- KEMA and DNV combined: a heritage of nearly 150 years
- Headquartered in Arnhem, the Netherlands
- Offices and agents in over 30 countries around the globe
- **World-Renowned Engineering, Consulting, and Testing**
How is storage used for Renewable Integration?

- The issue is really focused on variable renewable integration – wind and solar – where the output can be unpredictable.

- Please note output patterns are not consistent across the Globe...what we encounter in the western part of the United States does automatically map to Europe or Southwest Asia.
  - Weather patterns for particular area is really the driver for wind & solar.

- Still, some lessons can be learned from case studies we have seen.

- Agenda for Today
  - Impact of Wind
  - Impact of Solar
  - Benefits – Where we are seeing applications today
  - Technologies
    - Bulk Storage
    - Utility Scale
Challenges to Integrating Renewables – Penetration Rates

- Chart shows renewable portfolio standards across the U.S.

- Consensus is that as penetration rates of variable generation surpasses 20-25%, problems are created for system operators as the try to balance generation with load.

Source: dsireusa.org
Example: July Renewables 2020HI – Challenges

- Issue 1: Wind often blows in “off peak” hours when there is no load to accept it

- Issue 2: Chart shows challenges of solar and wind MW production during 24 hours in July
  - Some swings in diagram represent up to 3,500 MW

- Challenge is simply where will this come from?

source: DNV KEMA
For Distribution: Are the Issues Similar?

- Problems seemed to be focused on solar and protection due to the variability – similar problems to solve but for different reasons.

- Storage is often discussed as a potential option to be used with solar technologies.

- What are these applications?
  - Solar Grid Integration
  - Energy time shifting
  - Capacity firming
Solar Generation Grid Integration

- Benefit: Smooth intermittent output due to cloud cover and maintain morning/afternoon ramp rate limits
- Control: Low-pass smoothing filter in conjunction with storage charge bias
- Location: Generation location, downstream of impacted circuit
- Discharge Duration: 15-60 minutes
- Cycle Duty: Multiple cycles per day during intermittent operating days
- Benefit Impact? Grid Operator, Utility
Renewable Capacity Firming

- Benefit: Storage fills in “gaps” in intermittent renewable output to allow for use as an almost constant power source.
- Control: Modulate storage for net constant output for scheduled time periods (hour ahead, day ahead) based on forecast level of intermittency.
- Location: Interconnection between grid and renewable source.
- Discharge Duration: 2 – 4 hours on low or moderate variable days.
- Cycle Duty: Multiple cycles per day.
Renewable Energy Time-Shift

- **Benefit:** Increase value of energy by shifting output from off to on-peak time.
- **Control:** Adaptive scheduling control with on/off peak time frames and generation forecast.
- **Location:** Renewable generation source, aggregation point near load.
- **Discharge Duration:** 2-5 hours, depending on local load peak.
- **Cycle Duty:** One cycle per day.
- **Benefit Impact:** Typically Customer Side.
So the Solutions is simple?

- Many issues that make addition of storage difficult to implement

- Question with any added component to a system – How to pay?
  - Will a customer want to adopt this
    - If it has an economic benefit, of course they will
  - Will a utility want to see storage adopted?
    - If it can protect the grid, of course they will

- Options and Hurdles being faced today
  - Will policies allow Applications are a mix of Power and Energy – can technologies available provide all services needed?
  - developers to get compensated for adding a technology that is protecting the system?
    → Answer: There is work that still needs to be done

- Where is this solution working today
  - Island applications where the price of electricity is high enough to absorb the additional component (Hawaii, Puerto Rico)
Today’s Storage Technology Options

The Technologies Range from Power (< 1 hour) to Energy Applications (multiple hours)

- **Compressed Air Energy Storage** – will be utilized for “centralized” applications
- **Above Ground CAES** – Gen II, projected as 5MW, above ground
- **Sodium Sulfur (NaS) battery** – Long duration, Transmission back-up
- **Vanadium Redox Battery** – Long duration, flow battery, used for back-up applications
- **Advanced Lead Acid Batteries** – 1 to 4 hours, used for renewable integration
- **Sodium Nickel Chloride Battery** – Targeting vehicles and small backup (Telecom)
- **Li-ion – High Energy** – Used for CES, renewable integration, maybe regulation
- **Li-ion – High Power** – used for frequency regulation, renewable integration
- **Flywheels** – 15 minute, many cycles, used for frequency regulation
What are the Technology Options For Renewable Integration?

- **Bulk Storage Technologies**
  - Addresses the problem from a centralized approach with very large systems
  - Typically greater than 300 MW
  - Addresses issue more from a grid support, ancillary service perspective or project that targets a group of renewable projects
  - Compensation from regulation services provided

- **Utility-scale Solutions**
  - Addresses the problem from a decentralized “solution at the source” approach
  - Typically kW to aggregated 50MW applications
  - Compensation challenges – usually applied to meet interconnection guidelines
  - Attempts being made to bundle the solution to perform multiple applications
Bulk Storage Options

- Pumped Hydro is terrific if available. However, most potential sites have been built out
  - New construction suffers from long permitting and commissioning processes (up to 10 years)
  - Highly regional/geographic

- Compressed Air Energy Storage
  - Hurdles to construction are similar to pumped hydro but more exaggerated because of overall conceptual design and cost
Bulk Storage Options (Continued)

- Concentrating solar thermal is beginning to make advancements today
  - Systems are still relatively expensive on a capital cost basis

- But when storage is added to plants that are already constructed
  - Incremental cost are small
New concepts - What is Power to Gas?

- Using the natural gas infrastructure to support the conversion of power into gas

- Why Discuss?
  - As renewable penetration increases on electricity grid, there is going to be a need for low cost, bulk storage to help integrate the technologies
  - This generation needs to be flexible and not increase emissions
  - Historically, efficiency issues were problematic for the concept, but developments in electrolysis technologies and injecting into the pipeline system (utilizing existing infrastructure) has increased interest in concept
Utility Scale Applications

- Advanced storage applications are being used at the site of the project to meet the immediate “interconnections issues” of ramping.

- The devices can then be used to perform other applications.

- Case where ramping needs are being coupled ancillary services to help pay for the application.

Courtesy: AES Energy Storage
What Technologies are being for these needs?

- **Advanced Lead Acid Batteries**
  - Advantages: Low capital cost, higher power and lower internal resistance, lower maintenance, proven technology
  - Companies: Xtreme Power, East Penn, Exide, Axion
  - Deployments: Kahuku Wind Farm

- **Lithium-ion Batteries**
  - Advantages: High energy and power density, high efficiency for “power” cells, good cycle life
  - Companies: A123, Altairnano, SAFT, EnerDel, International Battery, Greensmith
  - Deployments: AES 12 MW Frequency Regulation Chile Installation, AES 20 MW Westover Installation

- **Sodium Batteries**
  - Advantages: High energy and power density, good cycle life, long discharge times (6 hours)
  - Companies: NGK Insulators, FZ Sonick (FIAMM), GE
  - Deployments: Many sites in Japan, Multiple AEP sites (most recent Presidio, TX 4 MW), XCEL Energy 1 MW
Storage Trends

TECHNOLOGIES

• Flow Batteries
  – Advantages: Potential for extended discharge cycles since energy relates to volume of electrolyte tanks.
  – Companies: ZBB Energy, Premium Power, Redflow, Prudent (vanadium)

• Flywheels
  – Advantages: High power density, long lifetimes, low maintenance.
  – Companies: Beacon Power, Active Power, Boeing
  – Deployments: Beacon 20 MW Frequency Regulation, Stephentown, NY

• Compressed Air Energy Storage
  – Advantages: Potential for bulk energy storage at lowest cost.
  – Companies: Energy Storage Power Corporation, SustainX
  – Deployments: 110 MW unit in McIntosh, Alabama in 1991
## Storage Projects $\geq 2$ MW

(Courtesy of Electricity Storage Association)

<table>
<thead>
<tr>
<th>SPONSOR</th>
<th>PROJECT &amp; STATE</th>
<th>MW/MWh</th>
<th>APPLICATION</th>
<th>SUPPLIER &amp; TECHNOLOGY</th>
<th>TARGET DATE</th>
<th>CO-FUNDING</th>
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<tbody>
<tr>
<td>Primus Power</td>
<td>Modesto Irrigation, CA</td>
<td>25/75</td>
<td>WS, LS, AS</td>
<td>Primus Power, RFB</td>
<td>2012</td>
<td>ARRA grant</td>
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<td>First Wind</td>
<td>Kaheawa Wind Power II, HI</td>
<td>10/20</td>
<td>WS</td>
<td>Xtreme Power, ALA</td>
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<td>Duke Energy</td>
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<td>Xtreme Power, ALA</td>
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<td>SCE</td>
<td>Tehachapi Wind ES Project, CA</td>
<td>8/32</td>
<td>WS, E</td>
<td>A123, LI</td>
<td>2012</td>
<td>ARRA grant</td>
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<td>East Penn Mfg.</td>
<td>Ancillary Services, PA</td>
<td>3/1-4</td>
<td>AS</td>
<td>Ecoult, ALA</td>
<td>2012</td>
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<td>Kodiak Electric</td>
<td>Pillar Mountain, AK</td>
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<td>Xtreme Power, ALA</td>
<td>2012</td>
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<td>A123</td>
<td>Alternative Technology Regulation, MA</td>
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<td>AR</td>
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<td>Private</td>
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<td>Premium Power</td>
<td>Peak Demand Reduction, CA</td>
<td>3.5/3</td>
<td>D</td>
<td>Premium Power, Flow</td>
<td>2011</td>
<td>ARRA grant</td>
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<td>Beacon Power</td>
<td>Stephentown, NY</td>
<td>20/5</td>
<td>AR</td>
<td>Beacon Power, FW</td>
<td>2011</td>
<td>DOE loan</td>
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<tr>
<td>AES Energy Storage</td>
<td>Laurel Mountain, WV</td>
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<td>WS</td>
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<td>Private</td>
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<tr>
<td>First Wind</td>
<td>Kahuku Wind Project, HI</td>
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<td>WS</td>
<td>Xtreme Power, ALA</td>
<td>2011</td>
<td>DOE loan</td>
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<td>AES Energy Storage</td>
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<td>AEP</td>
<td>Presidio/TX</td>
<td>4/25</td>
<td>T&amp;D</td>
<td>NGK, NAS</td>
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<td>Rate base</td>
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<td>AEP</td>
<td>Bluffton, OH</td>
<td>2/14</td>
<td>T&amp;D</td>
<td>NGK, NAS</td>
<td>2007</td>
<td>DOE loan</td>
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<td>AEP</td>
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</tbody>
</table>

ALA = Advanced Lead Acid   RFB= Redox Flow Battery   LI = Lithium Ion   NAS = Sodium Sulfur   FW = Flywheel   D = Demand   WS = Wind Support   LS = Load Shifting   AS = Ancillary Services   AR = Area Regulation   E = Experimental   T&D = Deferral
## Policy Initiatives Shaping the U.S. Storage Market

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Description</th>
<th>Market Impact / Timeframe</th>
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<tr>
<td>ISO/RTO Ancillary Service Markets Open to Storage</td>
<td>Five open-bid ancillary services markets are now (or shortly will be) directly accessible to energy storage: PJM, NYISO, ISO-NE, MISO and CAISO</td>
<td>In place • Creates large-scale markets for storage-based regulation</td>
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<tr>
<td>FERC Final Rule (RM11-7-000; Final Order No. 755)</td>
<td>Clarifies frequency regulation compensation for fast-response storage in organized markets (Oct. 2011)</td>
<td>Near-term • Increased revenues for storage-based regulation due to value of fast response</td>
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<tr>
<td>ERCOT Ancillary Services for Storage</td>
<td>ERCOT is considering new rules for storage participation in the ancillary services markets. (In process as of 2011)</td>
<td>Mid-term • Expands market for regulation; pending</td>
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<tr>
<td>California State Law (AB 2514)</td>
<td>Sets energy storage procurement targets in the State of California (Enacted 2010)</td>
<td>Mid-term • Increased awareness of storage capability and benefit</td>
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<tr>
<td>U.S. STORAGE Act of 2011 (S.1845)</td>
<td>Legislation would provide tax incentives for grid storage as well as on-site and residential applications. (Introduced Nov. 2011)</td>
<td>Long-term • Would accelerate growth of national market by defraying initial investment</td>
</tr>
<tr>
<td>Renewable Portfolio Standards (29 states)</td>
<td>State-driven RPS mandates and goals to increase renewable generation. Targets from 10% - 40%</td>
<td>Current to Long-term • Greater need to mitigate intermittency</td>
</tr>
<tr>
<td>FERC Order 1000</td>
<td>States that energy storage should also be evaluated as a potential solution for applicable T&amp;D issues</td>
<td>Current to Long-term • Opens door to storage solutions for T&amp;D</td>
</tr>
<tr>
<td>FERC Declaratory Order; Western Grid Development LLC Approved Jan. 2012</td>
<td>FERC determined that the batteries will operate as wholesale transmission facilities and granted Western Grid the advanced transmission incentives subject to California ISO transmission planning</td>
<td>Current to Long-term • Opens door to rate base storage for T&amp;D; basis point and other incentives may apply for advanced technology</td>
</tr>
</tbody>
</table>
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