ADVANCED ENERGY STORAGE

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ADVANCED ENERGY STORAGE TECHNOLOGIES

• Advanced Energy Storage – Definition and Overview
• Examples of Various Technologies
• Technology Marketplace Development / Policy Overview
ADVANCED ENERGY STORAGE (AES)

• Advanced Energy Storage technologies convert electricity into energy, store it and then convert back into usable electricity at a later time.
  • One example of this would be capturing “free” electricity created by a photovoltaic system, storing it in a battery and then discharging it at a later time when a property’s demand for electricity is greater/more costly.
WHY ADVANCED ENERGY STORAGE?

“Electricity is perhaps the only commodity in today’s economy that is both essential on an as-demanded 24/7 bases, and to date, has not been stored in inventory.” CESA.com

- Electricity that can be generated is fixed over short period of time, although demand for electricity fluctuates constantly. Managing this flow of energy to meet grid demands is essential and very challenging.

  For Utility Scale sized projects (> 5 MW) Advanced Energy Storage technologies play an integral role in storing electrical energy so it can be available to meet consumer demand at peak times.

- Need for storage will continue to increase due to:
  - Development of large amounts of renewable energy sources - AES plays an important role in smoothing out intermittent generation technology energy spikes that are introduced into the utility grid network during high renewable energy production days. Occurs with wind and solar on high/low wind and sun days.
  - Management of an antiquated Utility Grid Network - AES technologies allow grid operators to more effectively manage the flow of energy resources decreasing the need for additional “dirty” power plants.
  - Higher Energy (Demand) Costs – AES technologies allow consumers to better manage their energy in real time by Load Shifting. Load shifting occurs when electricity is stored during “off-peak” hours while electric tariff costs are low and discharging stored energy during peak hours when costs are high.

*www.cesa.com*
Energy Storage—a Cheaper and Cleaner Alternative to Natural Gas-Fired Peaker Plants

Energy Storage Technologies Today Can Deliver On-Peak Electricity at a Lower Cost than Gas-Fired Peakers

Gas-Fired Turbine Peaker Plant

<table>
<thead>
<tr>
<th>Costs</th>
<th>Assumptions</th>
<th>LCOG ($/MWh)</th>
<th>LCOG ($/kW-y)</th>
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<tbody>
<tr>
<td>Fixed O&amp;M</td>
<td>$24/kW/yr</td>
<td>$69</td>
<td>$29</td>
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<td>Corp. Taxes</td>
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<tr>
<td>Insurance</td>
<td>0.6% of CAPEX</td>
<td>$23</td>
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<tr>
<td>Property Tax</td>
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<td>$12</td>
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<td>Natural Gas Fuel</td>
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<td>Variable O&amp;M</td>
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<tr>
<td><strong>Subtotal</strong></td>
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<td>$227</td>
<td>$93</td>
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Energy Storage Peaker Substitution

<table>
<thead>
<tr>
<th>Costs</th>
<th>Assumptions</th>
<th>LCOG ($/MWh)</th>
<th>LCOG ($/kW-y)</th>
</tr>
</thead>
<tbody>
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<td>Corp. Taxes</td>
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<td>Insurance</td>
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<tr>
<td>Property Tax</td>
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<tr>
<td>Off-Peak Grid Charging</td>
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<tr>
<td>Variable O&amp;M</td>
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</tr>
<tr>
<td><strong>Subtotal</strong></td>
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<td>$121</td>
<td>$50</td>
</tr>
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</table>

**Levelized Cost of Generation for Energy Storage is Less Than a Simple Cycle Gas-Fired Peaker**
• Energy storage can help address a number of other challenges such as:
  • Green House Gas (GHG) and CO2 emissions reduction (Assembly Bill 32)
  • Back up power for critical loads
  • Utility Transmission and Distribution constraints
  • Enabling the efficient deployment of Electric Vehicle (EV) Charging Stations to meet increasing demand
ADVANCED ENERGY STORAGE TECHNOLOGIES
AES Technologies

- Chemical
  - Biofuels
  - Hydrated salts
  - Hydrogen
  - Liquid nitrogen
  - Power to gas
  - Vanadium Pentoxide

- Biological
  - Glycogen
  - Starch

- Electrochemical
  - Flow battery
  - Rechargeable battery

- Electrical
  - Supercapacitor
  - Superconductor magnetic energy storage (SMES)

- Mechanical
  - Compressed air energy storage (CAES)
  - Fireless locomotive
  - Flywheel
  - Hydraulic accumulator
  - Hydroelectric energy storage

- Thermal
  - Eutectic System
  - Ice Storage
  - Molten Salt
  - Seasonal thermal energy storage
  - Solar pond
  - Steam accumulator
  - Thermal energy storage.
FLOW BATTERY

• A flow battery is an easily rechargeable system that stores its electrolyte as a liquid in external tanks. (Fuel cell)

• Unlike typical batteries that are packaged as fixed cells, a flow battery allows the battery’s power to be decoupled.

• Harvard researchers are talking about their breakthrough with a flow battery made out of natural molecules – the same ones found in rhubarb.

*www.seas.harvard.edu/organic-mega-flow-battery-for-renewable-energy*
RECHARGEABLE BATTERIES

• A rechargeable battery is a type of electrical battery that is comprised of one or more electrochemical cells.

• Rechargeable batteries work by fully restoring its energy capacity when an electric current is applied to them.
SUPERCAPACITORS

- They are being developed for cars to recover and reuse the energy that would normally be wasted when the brakes slow down a vehicle.
- Unlike batteries, supercapacitors can charge quickly and discharge the energy just as fast.
- The Gwangju Institute of Science and Technology in Korea developed a graphene-supercapacitor that stores almost as much energy as a lithium-ion battery.
- Supercapacitors can fully charge in 16 seconds and have repeated this 10,000 times without a significant reduction in performance.

COMPRESSED AIR ENERGY STORAGE

• CAES captures and stores compressed air in geologic structures underground when off-peak power is available.

• The stored high-pressure air is returned to the surface and used to produce power when additional energy generation is needed, such as during peak demand periods.

• Currently only two plants available – Huntorf, Germany & McIntosh, Alabama.

*www.caes.pnnl.gov/*
PUMPED HYDROELECTRIC STORAGE

- In a PHS system, water from a reservoir is pumped to an upper reservoir. During period of peak demand, power is generated by releasing the stored water through turbines in the same manner as a conventional hydropower station.
- Currently there are 40 pumped-storage projects operating in the U.S., which provide more than 20GW.

*http://www.consumersenergy.com/content.aspx?id=6985
MARKETPLACE DEVELOPMENT / POLICY OVERVIEW
Current Estimated Worldwide Installed Advanced Energy Storage Capacity (2128 MW as of 2010)

- Batteries: 451 MW
- Compressed Air: 440 MW
- Molten Salt: 142 MW
- Thermal: 1,002 MW
- Flywheels and Other: 95 MW
CHALLENGES FOR MARKETPLACE DEVELOPMENT

• Legislative and Regulatory policy struggles to keep pace with advances in AES and the lack of a clear policy direction.

• AES technologies are better established in industries such as consumer electronics and transportation, but are less commercially available for distributed generation purposes.

• The electric power industry is highly regulated. Although this is not inherently a challenge it does take time to realize changes in policy in a rapidly evolving marketplace due to mandatory public comment periods and California Public Utility Commission oversight.

• Current market structure does not allow for a buyer of energy storage equipment to easily capture the value streams. Some companies such as Sunverge Energy are developing models to address this concern and provide value to both the utility and end user.
LANDMARK LEGISLATION

Assembly Bill 2514:

• Bill was passed on June 3, 2010 by The California State Assembly to create a smarter, cleaner electric grid, increase the use of renewable energy, and save California's money by avoiding costly power plants.

• The bill required the California Public Utilities Commission by March 1, 2012 to consider procurement for viable and cost-effective energy storage systems.

• “This landmark bill puts California at the forefront of a growing global market that will spur economic development. Given major advances in energy storage, the industry is now ready to provide affordable, reliable products for California’s utilities and consumers.” Janice Lin, Director of the California Energy Storage Alliance.
CALIFORNIA LEADS THE CHARGE!

• In 2011 Senate Bill 412 (Kehoe, 2009) expanded the Self-Generation Incentive Program to include Advanced Energy Storage as an eligible technology. Why is this important?

• The Self Generation Incentive Program (SGIP) provides financial incentives for the installation of new qualifying technologies that are installed to meet all or a portion of the electric energy needs of a facility.
  • The purpose of the SGIP is to contribute to Greenhouse Gas (GHG) emission reductions
  • Demand reductions and reduced customer electricity purchases resulting in the electric system reliability through improved transmission and distribution system utilization
  • Market transformation for distributed energy resource (DER) technologies such as AES!
    • By providing incentives for adolescent technologies manufacturers are able to deploy products at a more rapid pace. This increased production leads to economies of scale and lower installed costs to the end user.
CALIFORNIA ENERGY STORAGE ALLIANCE (CESA)

• CESA is a membership-based advocacy group focused on advancing the role of energy storage in the electric power sector.

• Members include technology manufacturers, project developers, systems integrators, consulting firms, and other clean tech industry leaders.

• CESA was founded in January 2009 by Janice Lin, Managing Partner of Strategen Consulting LLC, and Don Liddell, Principal of Douglass & Liddell.

• CESA is trying to change how California thinks about its electric infrastructure by helping to shape current policies as new advancements in energy storage develop.
KEY PLAYERS

- AQUION ENERGY
- SolarCity
- amprius
- Sunverge
- CESA (California Energy Storage Alliance)
- TESLA
- eos