Together…Shaping the Future of Electricity

EPRI’s Mission
Advancing safe, reliable, affordable, and environmentally responsible electricity for society through global collaboration, thought leadership and science & technology innovation.
Agenda

- Drivers of energy storage adoption
  - Technologic developments
  - Policies related to renewable energy
  - Incorporation of smarter control and monitoring systems.

- Challenges to further adoption

- How storage is being promulgated - global perspective.

- Projections of storage growth

- Vision of future energy grids
What is Driving Adoption of Utility Storage? Need to keep system balanced 24/7

- **Resources supplying energy have to match loads consuming energy** - always
- System has to be kept at 60 or 50Hz (depending on grid) – deviations are unacceptable
- Rigorous controls and rules keep resource and loads balanced
- Renewables are an added challenge due to intermittency
  - Frequency stability
  - Efficient use of generation resources

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![Graph showing frequency stability and efficient use of generation resources.](image-url)
What is Driving Adoption of Utility Storage? Increased Renewables

- Higher efficiency
- Lower cost
- Smarter integration
- Better understanding of intermittency and how to deal with it
What is Driving Adoption of Utility Storage? Aging Infrastructure

• Average age of substation transformer is close to original design life 25-30 years

• Many operating much longer - 35-40 yr Asset Wall

• Utility focus on “life extension”

• Bathtub curve relates failure rates and aging - Increasing failure rates are experienced as the fleet ages
## What is Driving Adoption of Utility Storage? Lower Storage Costs

“Projecting a 9% total global battery demand CAGR till 2020.

Peak Shifting will be predominant application and strong growth in C&I”
Source: UBS

“According to market research firm IHS, energy storage growth will ‘explode’ from .34 GW in 2012-2013 to 6 GW by 2017 and over 40 GW by 2022”
Source: ESA

Peak-shaving by commercial and industrial customers is the most promising application

$331-400/kWh common breakeven installed cost for peak shaving
Source: Moodys

<table>
<thead>
<tr>
<th>Li Ion Projected Capital Cost</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell</td>
<td>11.5 W for 1 hour</td>
<td>$2.00-$2.50</td>
</tr>
<tr>
<td></td>
<td>$180-$225/kW</td>
<td>$100-$120/kW</td>
</tr>
<tr>
<td>Battery Pack</td>
<td>10 kW for 1 hour (dc power)</td>
<td>$3,500-$5,000</td>
</tr>
<tr>
<td></td>
<td>$350-$500/kW</td>
<td>$200-$250/kW</td>
</tr>
<tr>
<td>Residential ES System</td>
<td>10 kW for 1 hour (ac power)</td>
<td>$10,000-$12,000</td>
</tr>
<tr>
<td></td>
<td>$1000-$1200/kW</td>
<td>$500-$600/kW</td>
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</tbody>
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11% CAGR Battery B to B
Source: Panasonic

Compare to smart phone forecast of CAGR of 7.1-13%
Sources: CCS Insight, PRN Newswire, Forrester
What is Driving Adoption of Utility Storage? Retirement of Base Load Coal resources

• Numerous scenarios have been modeled by EPRI to understand generation fleet future composition
• Scenarios adopt different policies and fuel price inputs
• All scenarios point to significant decline in coal generation
  - Old age
  - Cheap gas
  - Environmental regulations

Source: BNEF, historical from EIA 923 or 860; future from BNEF forecast
Notes: 17% of the U.S. coal fleet, equivalent to 53 GW, will stop burning coal between 2015 and 2020. The three main drivers of coal retirements are old age, cheap gas, and EPA regulations.
Technologies at Play - Energy Storage Options – Power Rating Versus Discharge Durations

- Lithium Ion battery technology will be the dominant technology for stationary application in the foreseeable future
How does storage fit currently in the technology development cycle?

The Gartner Hype Curve

- Microgrids
- Peak of Inflated Expectations
  - Behind-the-Meter Energy Storage
  - Distribution Energy Storage
- Trough of Disillusionment
- Plateau of Productivity
- Slope of Enlightenment
- Technology Trigger

Bulk Energy Storage
Natural Gas Distributed Generation
The historical challenges are being overcome

- Technical challenges
  - Performance
  - Life
  - Efficiency

- Economic Challenges
  - High Costs
  - Small Value Streams

- Regulatory Challenges
  - Lack of clear definition
  - Framework designed for existing grid

Advanced Technologies

Lower costs

New Business Models

Regulatory Rulings

Legislative Action
Addressing the Remaining Challenges to Storage

- Costs and performance factors of technology solutions must be better understood
- Tools for understanding the value and grid impacts of storage are being developed
- Ensuring that storage technology solutions are safe, secure, reliable, affordable, and practical
- Create best practices for deployment, integration, operations, maintenance, and disposal
- Integrate storage technology into utility planning and operations processes to improve reliability and reduce costs
### Total Deployed Grid Storage Worldwide, January 2016

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>Capacity (MW)</th>
<th>Energy (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumped Hydro</td>
<td>144,000</td>
<td>2,700,000</td>
</tr>
<tr>
<td>Batteries</td>
<td>887</td>
<td>1,700</td>
</tr>
<tr>
<td>(2015</td>
<td>540</td>
<td></td>
</tr>
<tr>
<td>Thermal Storage</td>
<td>2,300</td>
<td>17,000</td>
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<tr>
<td>Compressed Air</td>
<td>437</td>
<td>4,011</td>
</tr>
<tr>
<td>Flywheels</td>
<td>965</td>
<td>19</td>
</tr>
<tr>
<td>Hydrogen Storage</td>
<td>4</td>
<td>52</td>
</tr>
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California Procurement Target: 1325 MW
Deployment of stationary storage continues

- Storage deployment will rapidly expand in the next few years
  - About 110 MW installed in PJM, with 100 MW backlog
  - AES claims 1000 MW of storage in development pipeline
  - A number of awards in California
- Deployment driven by policy, regulatory, and market considerations
- Majority of new projects are lithium ion batteries

Lithium Ion and Lead-Acid-based Storage Systems Installed Worldwide

Source: U.S. DOE, EPRI Estimates
Global Application of Storage – Where is it happening?

Technology
(Multiple values)典范
Status
Operational典范
Start Date
1905 - 2020典范
Rated Power (MW)
≤ 20.0典范
40.0典范
60.0典范
80.0典范
≥ 100.0典范
Country
(All)典范

3.83 GW
686 Projects

Note: Excludes Pumped Hydro
Source: DOE ESS Storage Database
The Traditional Electric Power System

Central Generation

One way power flow from central generation to distributed loads

Predictable Consumption

Power Flow
Looking Forward to the Integrated Grid

Distributed Energy Resources (DER) – Key Elements of the Future Grid

- Combined Heat and Power
- Distributed Storage
- Demand Response
- Home Energy Management
- Rooftop Solar
- Electric Vehicles
- Large-Scale Solar
Energy storage can play key roles in the transformation of the Power System

**Bulk Storage:** Provide peaking and ramping service and increase grid flexibility

**Distribution Storage:** Give operators more control over power flow

**Customer-Sited Storage:** Decouple loads from the grid
Where is this growth expected?

Behind-the-meter storage will account for 45 percent of the overall market by 2019
Source: GTM Research

Source: GTM Research/ESA U.S. Energy Storage Monitor

Solar PV plus Energy ….this technology represents a less than $1 billion market worldwide today, but this number is expected to grow to $14 billion by 2024, with residential customers leading the market
Source: Forbes/Navigant

Stationary Storage Peak Shifting in Energy Capacity by Region and Global Revenue: 2013-2020
Source: CAIRN Energy Research Advisors
A Possible Timeline for Widespread Deployment – Spectrum of Technologies

- A wide variety of technology approaches are at play with large R&D budgets (stemming from auto industry in part)
- Highly dependent on economics and regulatory policy
Further Development of Li-Ion Based Batteries

Huge increases in projected energy density – parallel to PV efficiency increases?

Secondary Source: JCESR
Grid of the Future

- **Features**
  - Many new technologies
    - Generation
    - Storage
    - Load Control
    - Microgrids
    - Mini grids (developing countries)
  - 2 way power flow
    - Distribution grid originally designed for 1 way flow
  - New roles for consumers
  - High penetration of renewables
  - Sophisticated pricing
  - Sophisticated controls
  - Lots of data

- **Requirements**
  - Efficient and reliable technologies
  - New network/grid power flow models
    - Dynamic/fast acting
  - New rules/regulations
    - Who owns what?
  - Educated/Incentivized consumer
  - Maintenance of system inertia (replace thermal inertia from departing fossil fuel units)
  - Back office utility platforms hosting a lot of data from a lot of point and making automated, accurate and sophisticated commands to numerous resources
  - All this while maintaining cyber security
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