



Energy Storage Technology Status

EPRI Renewable Council Meeting



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Program Manager



April 5-6, 2011

Agenda

Energy Storage Technology Status

Cost and Performance

Uncertainty and Risks

Q&A

Background: EPRI Research Reports: 1022261,1020676 Applications, Benefits and Costs of Energy Storage Systems

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An EPRI Executive Summary

Electric Energy Storage Technology Options

A Primer on Applications, Costs & Benefits

December 2010 Program 54

Introduction

A multitude of industry drivers—including increased deployment of renewable generation, the high capital cost of satisfying peak demands, and large investments in grid infrastructure for reliability and asset gap mitigation—are creating new interest in electric energy storage systems. Just as transmission and distribution (T&D) systems are characterized by peak demands, and users, energy storage systems can store electricity through times providing a when and where it is needed. Energy storage systems can help balance variable renewable generation and provide additional and improved, can help increase electric grid reliability and asset utilization. With improvements in the cost and commercial availability of energy storage technologies, the electric energy storage should play a greater role in addressing the impact of these industry drivers.

This white paper was prepared to inform industry executives, policymakers, and other industry stakeholders of the various types of electric energy storage systems both available and emerging, their uses, potential applications, and important trends in such systems for the electric energy system. Cost and application information is provided to assist in assessing the business case for energy storage system investments. However, traditional market and investment decision energy storage (EPRI) do not adequately capture the range of benefits potentially offered by energy storage systems.

Energy applications differ from other E&E systems, such as individual generation or energy efficiency, in key respects: they do not have a typical operating profile or load shape that can be applied proportionally; they are "stored energy" systems with a narrow band of dispatch and operation; and they can participate in multiple wholesale markets and provide several benefits simultaneously to the electric system, electric distribution system, and end-use customers. These characteristics, plus the difficulty in measuring multiple stakeholder benefits, often act as barriers to the widespread deployment of energy storage systems. However, financial characteristics and complete rules for ownership and operation among various stakeholders.

In producing this report, EPRI's Energy Storage research group drew on information from technology assessments, market research and analysis, application assessments, and input from energy system readers and energy companies on performance and capital costs. The full paper provides an overview of energy storage applications and technology options, and the potential range of value of energy storage in the applications presented. Updated capital cost and performance data are provided for energy storage systems available within the time set to close this report. In addition, key trends in emerging systems are highlighted. The full report also outlines a framework and methodology that electric utility and industry stakeholders may use as an approach to estimating the value of energy storage systems in their own applications.

The conclusions of this work are the result of modeling efforts and calculations conducted at EPRI. Assumptions and limitations to the results of these calculations have been developed by industry experts and noted by stakeholders, but not model results, costs, and benefits are not necessarily. The objective of this study is to provide information and data that are timely and relevant, but with the understanding that readers should understand the assumptions and calculations made to reach the conclusions presented. A number of the high-value benefits identified in this report can vary widely across regions and will depend to a great extent on the operational guidelines, market rules and models ultimately adopted for energy storage. Furthermore, as a broad survey of market and technology, this report does not take account the substantial impact of local and site-specific needs.

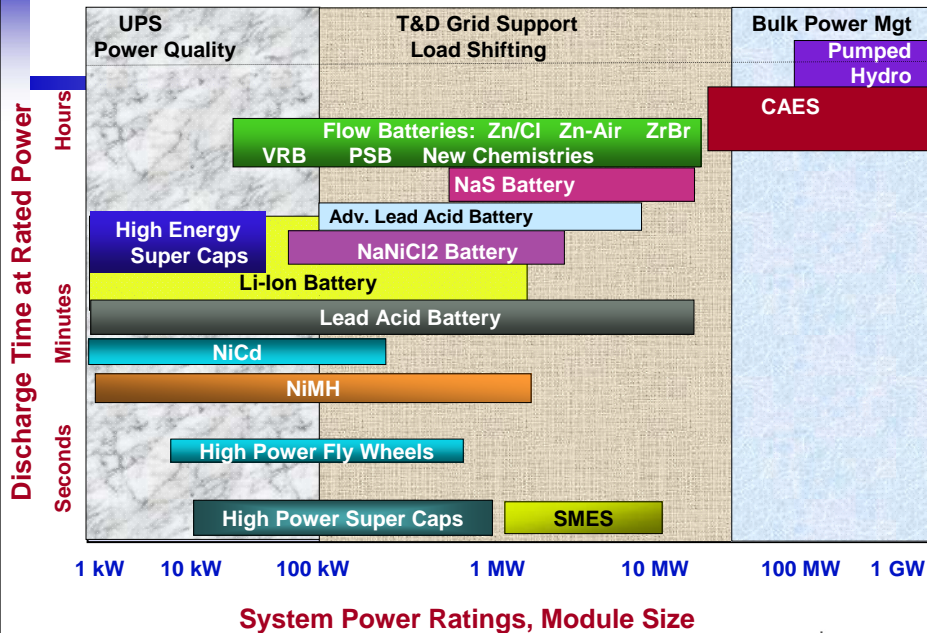
The findings represent the Executive Summary of the EPRI White Paper, Electric Energy Storage Technology Options: A Primer on Applications, Costs & Benefits (1022261). It is not intended to be a substitute for the full report. The complete paper provides additional details, definitions, recommendations, and a thorough discussion of the findings. To learn more about the report, the Department of Public and Business Affairs and Energy Storage, and its publications, please contact the author of this paper, available in a box (found at the end of the paper), or via email at epri@epri.com.

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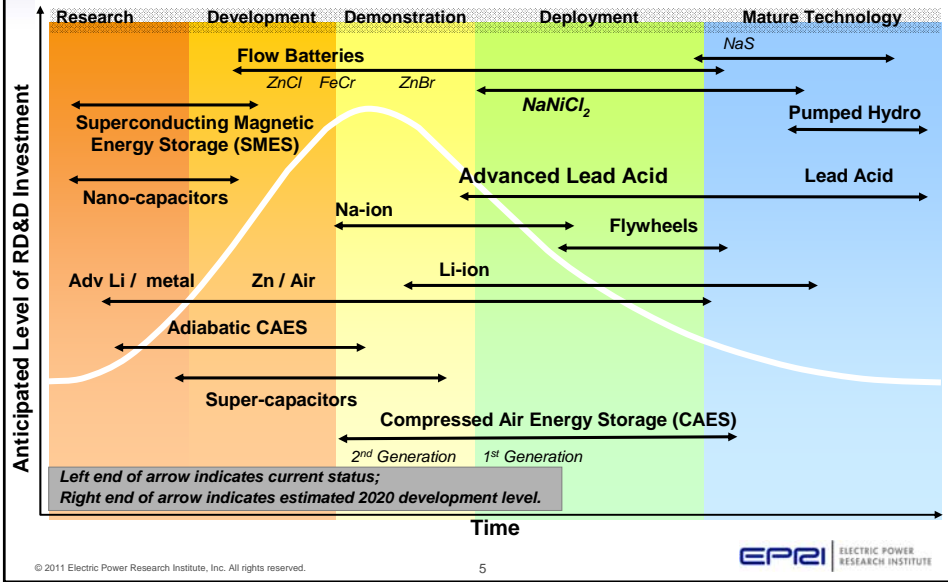
Electric Energy Storage Technology Options

A White Paper Primer on Applications, Costs and Benefits

Electric Energy Storage Options – Not Complete



Technology Development Assessment Energy Storage



EPRI's Program Scope

Bulk to Distributed Storage Solutions in the Smart Grid



MWs to kW: seconds, min, hours of energy duration

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NaS Battery at Xcel – Luverne, MN

- 1.25 MVA / 1.0 MW – Outdoor Installation
- Wind smoothing
- Dispatched wind
- Peak shaving
- Energy arbitrage



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Advanced Lead Acid Battery

Shown below is Xtreme Power 1.5 MW / 1 MWh
Applied in Wind PPA and PV Smoothing Applications



Kaheawa Wind Power



1.5 MW / 1.0 MWh

The first utility-scale Xtreme Power™ DPR™ operates on a 30 MW wind farm on a 80-200 MW grid. Systems smooths output to $\pm 100\text{kW}/\text{min}$ and controls ramps to $\pm 1\text{MW}/\text{min}$.

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1-MW/15-min Beacon Power flywheel in an ISO ancillary service application



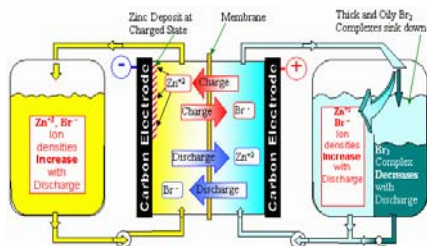
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Zn / Br Systems

- 0.5 MW / 2.8 MWh Prototype
- Small Systems for rural and DESS applications
 - 5 kW / 20 kWh



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Li-ion Energy Storage Systems



1 MW / 15 min A123 system



50 kW / 46 kWh BYD system



2 kW / 9 kWh Residential system

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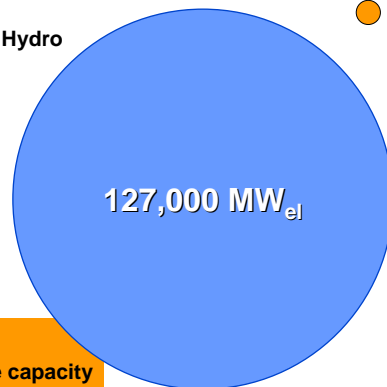
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Today, Energy Storage Penetration is Very Small

Worldwide installed storage capacity for electrical energy

Pumped Hydro



Over 99% of total storage capacity

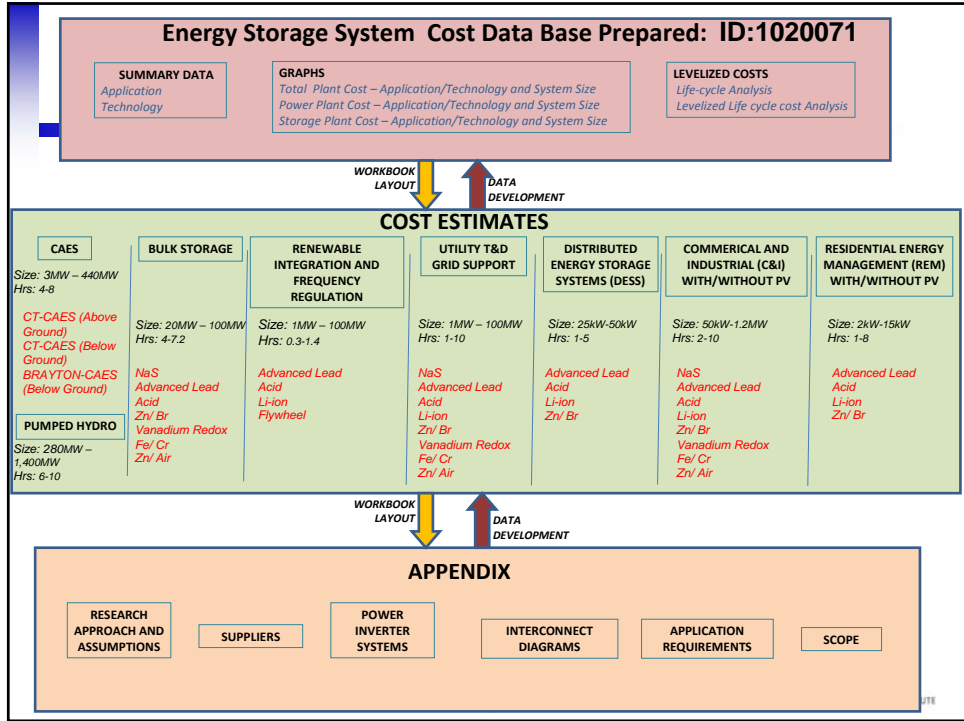
- Compressed Air Energy Storage **440 MWs**
- Sodium-Sulphur Battery **316 MWs**
- Lead-Acid Battery **~35 MWs**
- Nickel-Cadmium Battery **27 MWs**
- Fly Wheels **< 25 MWs**
- Lithium Ion Battery **~20 MWs**
- Redox-Flow Battery **< 3 MWs**

Source: Fraunhofer Institute, EPRI

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Energy Storage Options

Note: Today's Costs; Site Specific Application Cost can Vary

Storage Option	Application	Level of Maturity	Energy Duration hrs (cycles)	Efficiency ac/ac %	Total Installed Capital Cost \$/kW	Total Installed Cost \$/kWh
Pumped Hydro	ISO Services Wind Integration	Mature	10-20 (>13000)	76-85	\$1900-\$3800	310-380
Compressed Air	ISO services Wind Integration	Demo	10-20 (>13000)	4000 Btu/kWh 0.7 ER	\$810-\$1020	81-102
NAS	Grid Support Wind Integration	Mature	6 (4500)	72-78	\$3900-\$4190	650-700
Lead Acid Battery Adv. Lead Acid Battery	Grid Support ISO Services Wind / PV	Mature Demo	4 (2200-4500)	85-90	\$2020-\$3040	505-760
Flow Battery (Various Types)	Grid Support Wind / PV Integration	Demo	4 (>10000)	60-70	2350-4500	470-1125
Li-ion Battery	ISO Services Grid Support C&I Energy Mgt PV Integration	Demo	0.25 (>10000) 2 (5000)	85-90	1500-1800 2100-4650	6000- 7200 1050-1550
Fly Wheels	ISO Services	Demo	0.25 (>>20,000)	~90	1900-2250	7800-7900

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Bulk Storage Options for Renewable Integration

EPRI R&D Benchmarking Reference Designs of 50 MW / 5 hr Systems
Ref: EPRI 1020071

Technology Option/ Characteristics	CAES Above Ground	NAS	A-Pb Adv. Lead Acid	Zn/Br Redox	Vanadium Redox	Fe/Cr Redox	Zn/Air Redox
Unit Capacity MW	50	50	50	50	50	50	50
MWh	250	300	250	250	250	250	250
Ac-Ac Efficiency,% (heat rate)* Energy Ratio**	----- (4000) 1.0	75-80	85-90	60-65	75-78	70-75	70-75
Foot print Ft ² /kW	1.6	2.0	1.9 - 5.1	0.9	2.0	1.1	1.3
Total Capital Costs (\$/kW)	1700- 1950	3060- 3200	1750-4900	1660- 1800	3500- 3700	1800	1400- 1700
Technical Maturity and readiness	Demo	Commercial	Commercial- Demo	Demo	Demo	R&D Lab	R&D Lab

*Heat rate is Btu/ kWh, LHV

**Energy ratio is kWh - in / kWh-out

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Approach to Site-Specific Analysis

Factors which need to be considered

Levelized Cost of Energy: Cost per kWh Delivered

Installed Capital Cost; Discount Rate

Efficiency (ac / ac)

Cost of off-peak power

O&M

Life: years

kWh / Cycle and total cycles over life (depth of discharge, begin or end of life considerations)

Fuel and Energy Ratio – if a Compressed Air Storage Plant

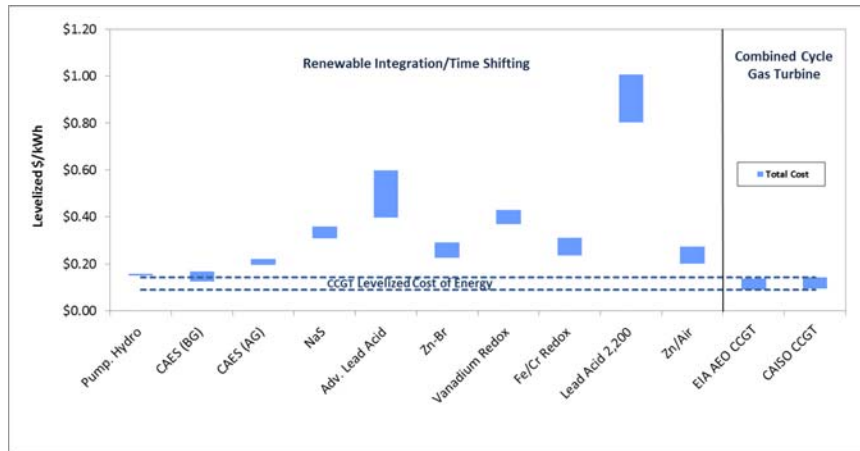
Life Cycle Cost expressed as \$/kWh delivered

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Levelized Cost of Delivered Energy for Energy Storage Technologies



See: EPRI 1020676

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Energy Storage System Comparison and Maturity Status

Technology type	Advantages (relative)	Disadvantages (relative)	Maturity
Pumped Storage	High capacity, Lower Cost	Site requirements	Mature
CAES	High Energy capacity, Lower Cost Low incremental cost for added kWh	Site and fuel requirements Not CO2 neutral	Mostly mature
Flow batteries Various	High capacity, Independent Power and Energy ratings	Low energy Density (large footprint) Low efficiency	Demonstration - R&D
Metal-Air	High Energy Density Low material cost	Recharge capabilities unproven	R&D
NaS NaNiCl2	High power & energy densities good efficiency	Cost -High temp ops Lower costs – smaller modules	Deployment Demonstration
Li-ion	High power density High efficiency	Need BMS; limited to < 4-6 hrs Safety	Demonstration
Ni-Cd	High energy density Good efficiency	Cost	Demonstration
Lead-Acid (conventional)	Most experienced	High life time cost Low efficiency Low cycles w/ deep discharge	Mature
Advanced	Longer cycle life		Demonstration
Flywheels	High Power Long life	Low energy density High first cost	Commercial Deployment
Electrochemical Capacitors	High efficiency High power density	Low energy density High first cost	Semi-commercial

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Uncertainty and Risks – Vary by Technology

- Durability
- Life cycles
- O&M
- Performance
- CapEx

Demonstrations and Field Trials Needed to Establish Track Record

Questions & Discussion

