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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

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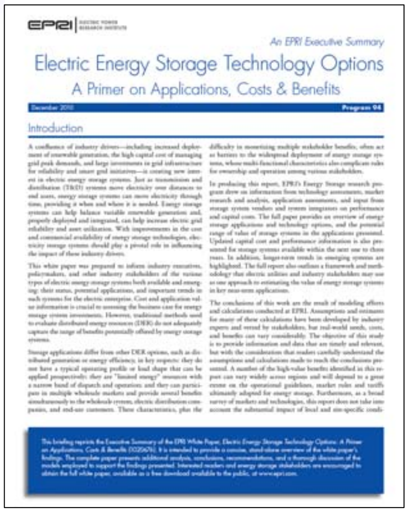
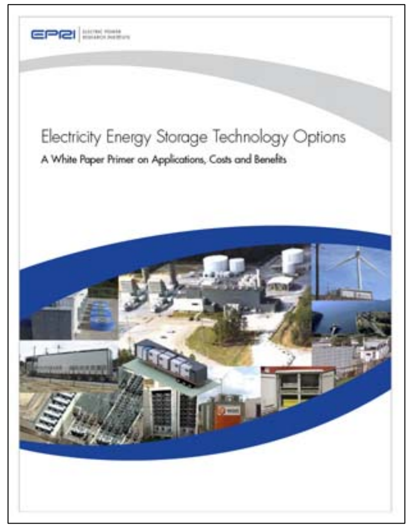
Background: EPRI Research Reports: 1022261,1020676

Applications, Benefits and Costs of Energy Storage Systems





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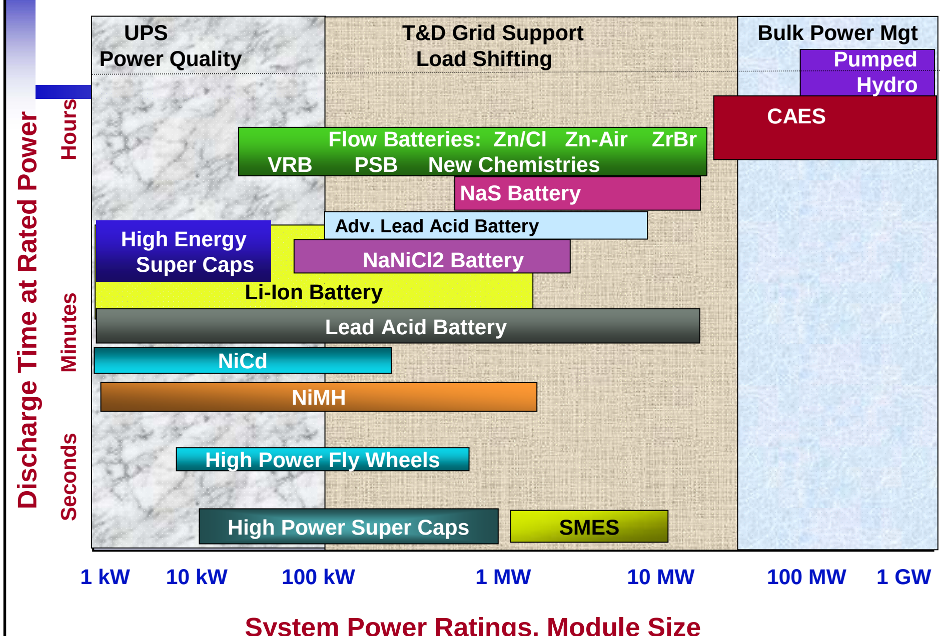
Electric Energy Storage Options – Not Complete



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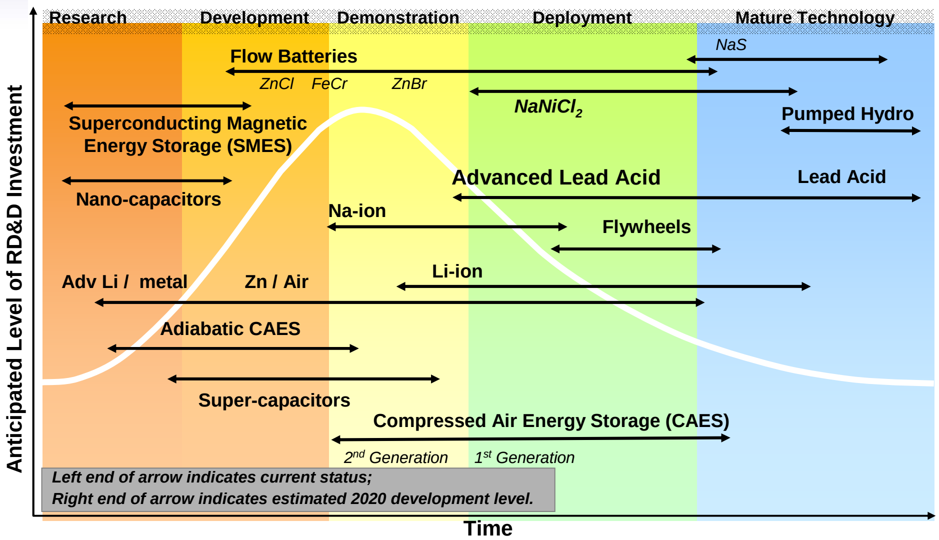
Technology Development Assessment
Energy Storage



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EPRI's Program Scope
Bulk to Distributed Storage Solutions in the Smart Grid

MWs to kWs: 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 smoothes output to ±100kW/min and controls ramps to ±1MW/min.

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

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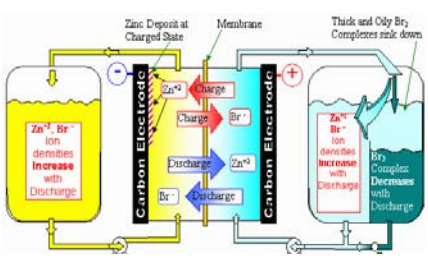
Zn / Br Systems

- 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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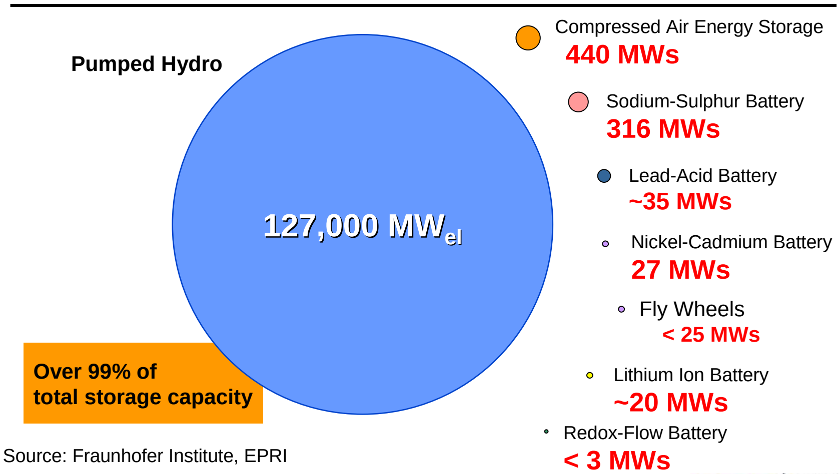
Today, Energy Storage Penetration is Very Small

Worldwide installed storage capacity for electrical energy



Source: Fraunhofer Institute, EPRI

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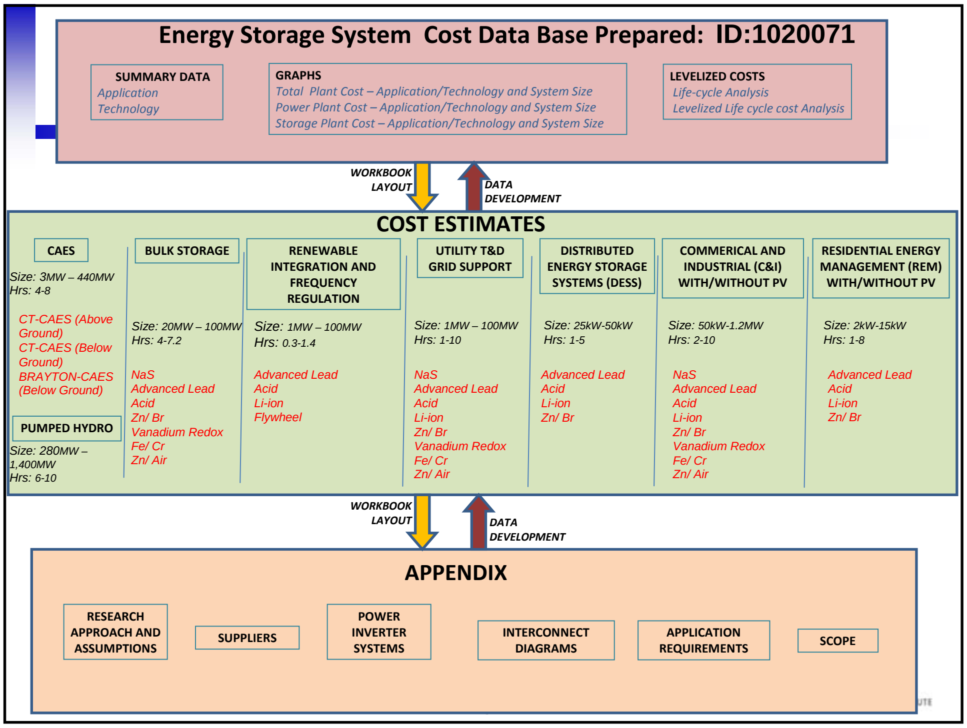

Energy Storage Options

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 MWH	50 250	50 300	50 250	50 250	50 250	50 250	50 250
Ac-Ac Efficiency,% (heat rate)* Energy Ratio**	-------- (4000) 1.0	75-80	85-90	60-65	75-78	70-75	70-75
Foot print Ft2/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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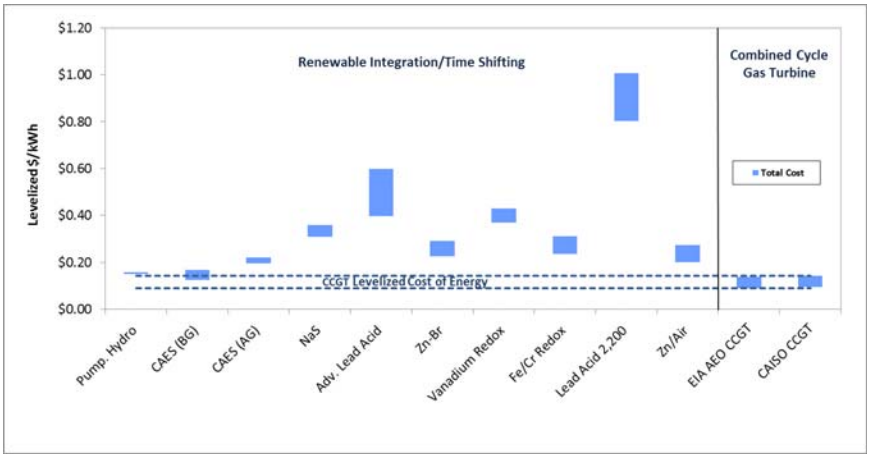
Levelized Cost of Delivered Energy for Energy Storage Technologies



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) Advanced	Most experienced Longer cycle life	High life time cost Low efficiency Low cycles w/ deep discharge	Mature 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

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Questions & Discussion

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