122 West

Advanced Energy Analysis

Short v. Long Term Energy Storage Analysis

Susan M. Schoenung

Longitude 122 West, Inc.

William V. Hassenzahl

Advanced Energy Analysis

DOE Energy Storage Systems Program Review

November 19, 2002

Work Sponsored by the DOE ESS Program

←Home

←Agenda

Objectives

- Previous work compared energy storage technologies: power ratings, storage duration, response time, capital cost, commercial maturity.
- This work extends energy storage characterization to include life cycle cost analysis. Elements addressed: efficiency, O&M, parasitic losses and replacement costs.
- The overall goal is to provide quantitative comparison of alternative energy storage technologies in applications with varying discharge time.

Contract Tasks

1) Technology update: costs and performance

2) Life cycle cost analysis for varying sizes of energy storage

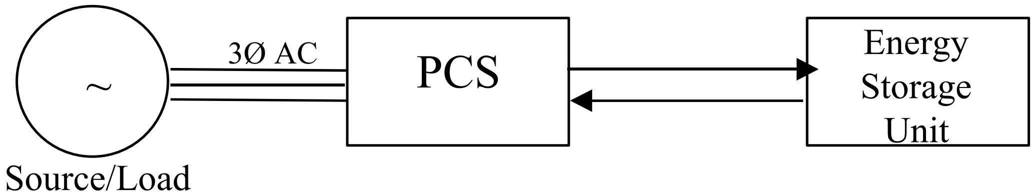
3) Comparative analysis of rechargeable batteries and fuel cells

Application Categories and Specifications

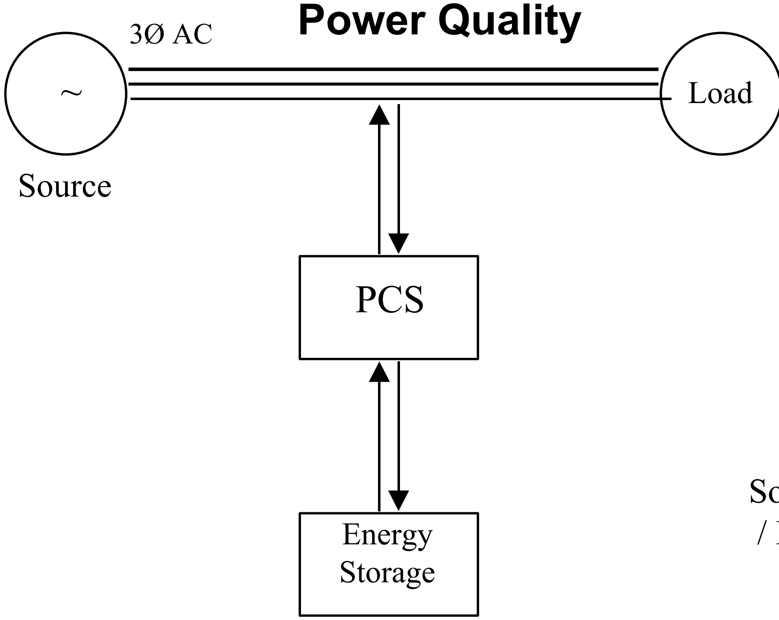
Application Category	Discharge power range	Discharge time range	Stored energy range	Representative Applications
Bulk energy storage	10 - 1000 MW	1 - 8 hrs	10 - 8000 MWh	Load leveling, spinning reserve
Distributed generation	100 - 2000 kW	0.5 - 4 hrs	50 - 8000 kWh (0.05 - 8 MWh)	Peak shaving, transmission deferral
Power quality	100 - 2000 kW	1 - 30 sec	0.1 - 60 MJ (0.028-16.67 kWh)	End-use power quality and reliability

Energy Storage Systems

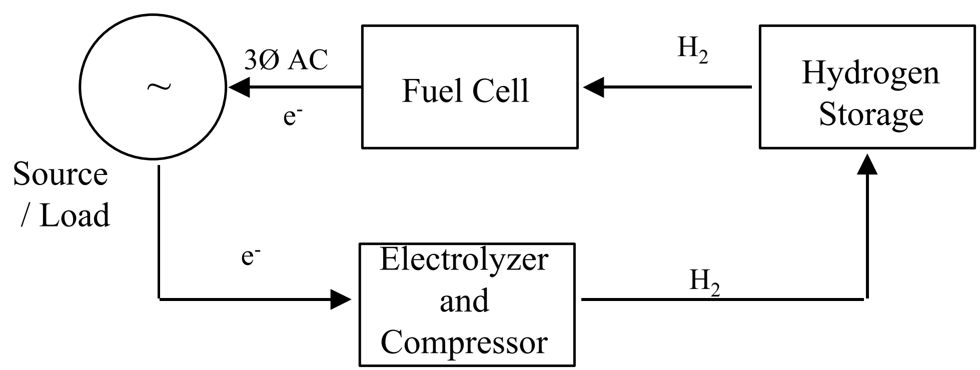
Load Management



Power Quality



Hydrogen



Approach to Life Cycle Cost Analysis

Levelized annual cost ($/kw-yr)

= Cost of capital (carrying charge on initial purchase)

+ cost of fixed O&M

+ cost of variable O&M

+ annualized replacement costs

+ consumables (fuel and electricity)

Convert to Revenue Requirement (¢/kWh) by dividing by hours of operation per year

Life Cycle Cost Analysis Data

- Capital cost: power, energy, Balance-of-Plant
- Round trip efficiency, AC-AC
- Operating costs: fixed O&M, variable O&M, electricity, fuel
- Replacement frequency and costs
- Parasitic losses (e.g., cooling)
- Economic assumptions: cost of electricity, fuel, interest and inflation rates

Economic and Operating Assumptions

Parameter	Value
General inflation rate	2.5%
Discount rate	8.5%
Levelization period	20 years
Carrying charge rate	12%
Fuel cost, natural gas	$5.00 /MBTU
Fuel cost, escalation rate	0%
Electricity cost (off-peak)	5 ¢/kWh
Electricity cost, escalation rate	0%
O&M cost escalation rate	0%
Days operation/year	250

Operating assumptions:

- discharge/charge time: assume equal, except for hydrogen systems
- discharges per day: assume once per day
- operations per year: assume 250 days per year

Bulk Energy Storage Technologies

- Lead-acid (flooded) and VRLA batteries
- Regenesys® system
- High temperature sodium/sulfur batteries
- Zn/Br batteries
- Vanadium-redox batteries
- Ni/Cd batteries
- CAES
- Pumped hydro and pumped hydro with variable speed drive

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Bulk Energy Storage - Preliminary Results

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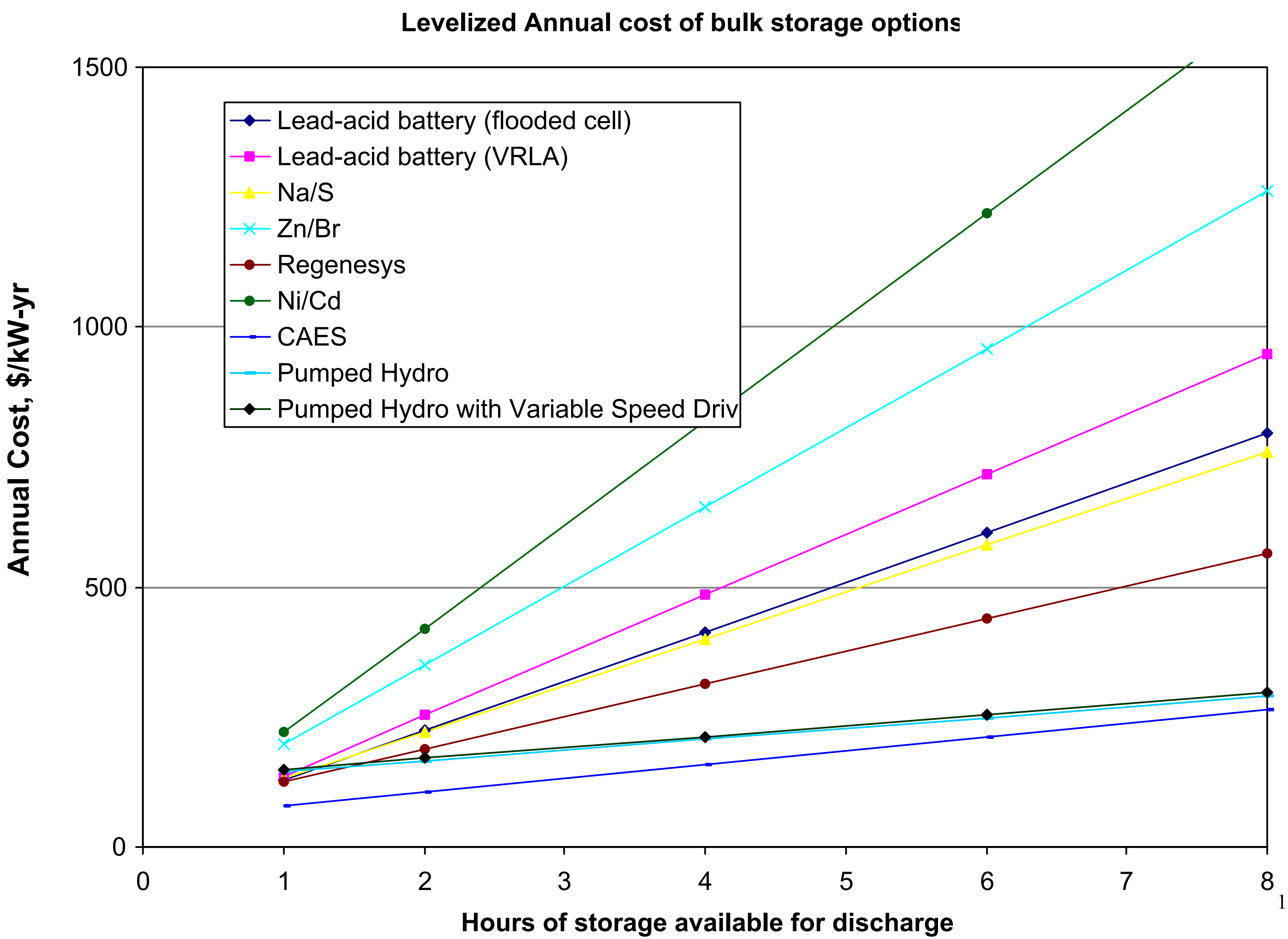
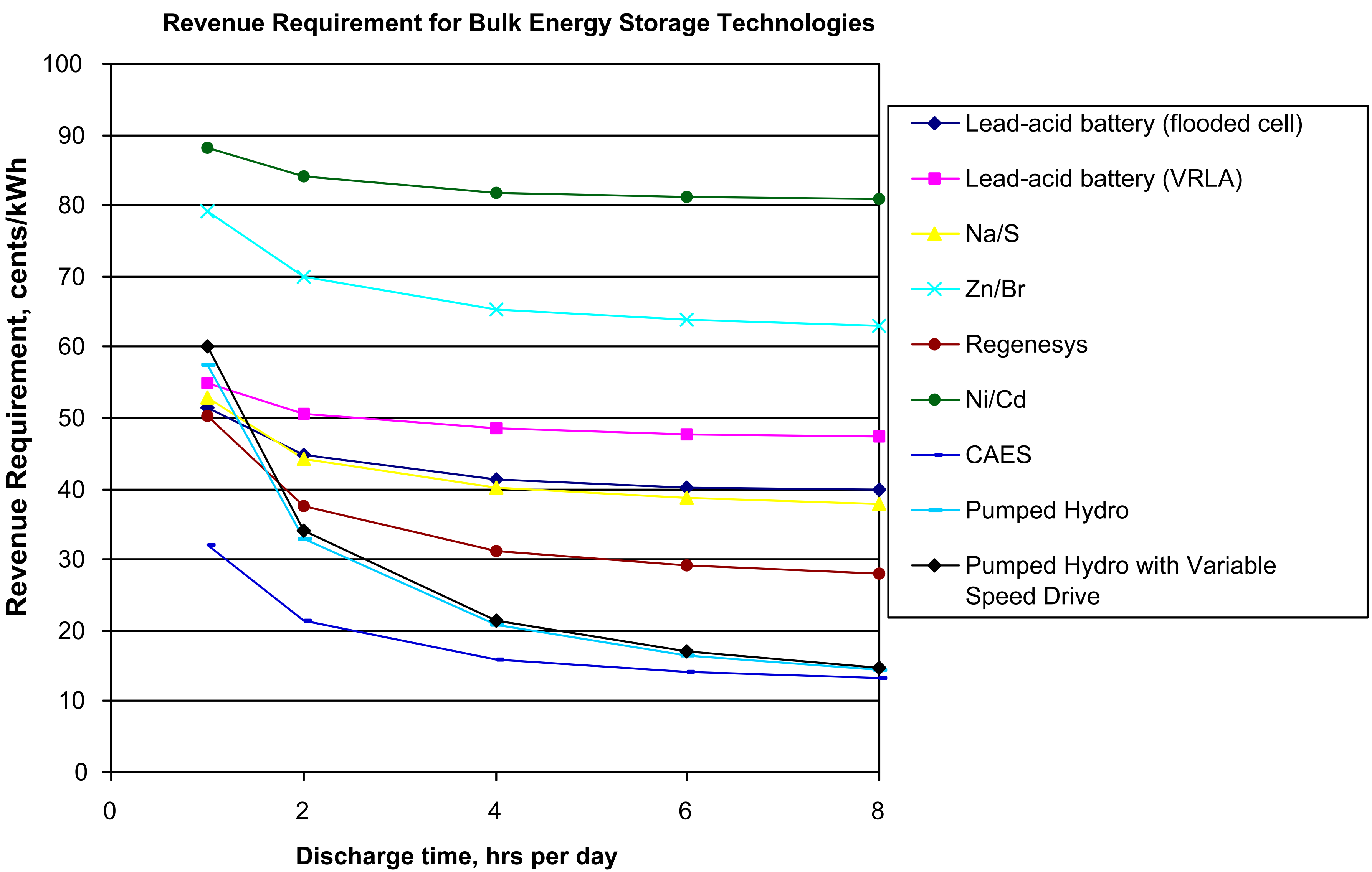


Bulk Energy Storage - Preliminary Results



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Bulk Energy Storage - Preliminary Results

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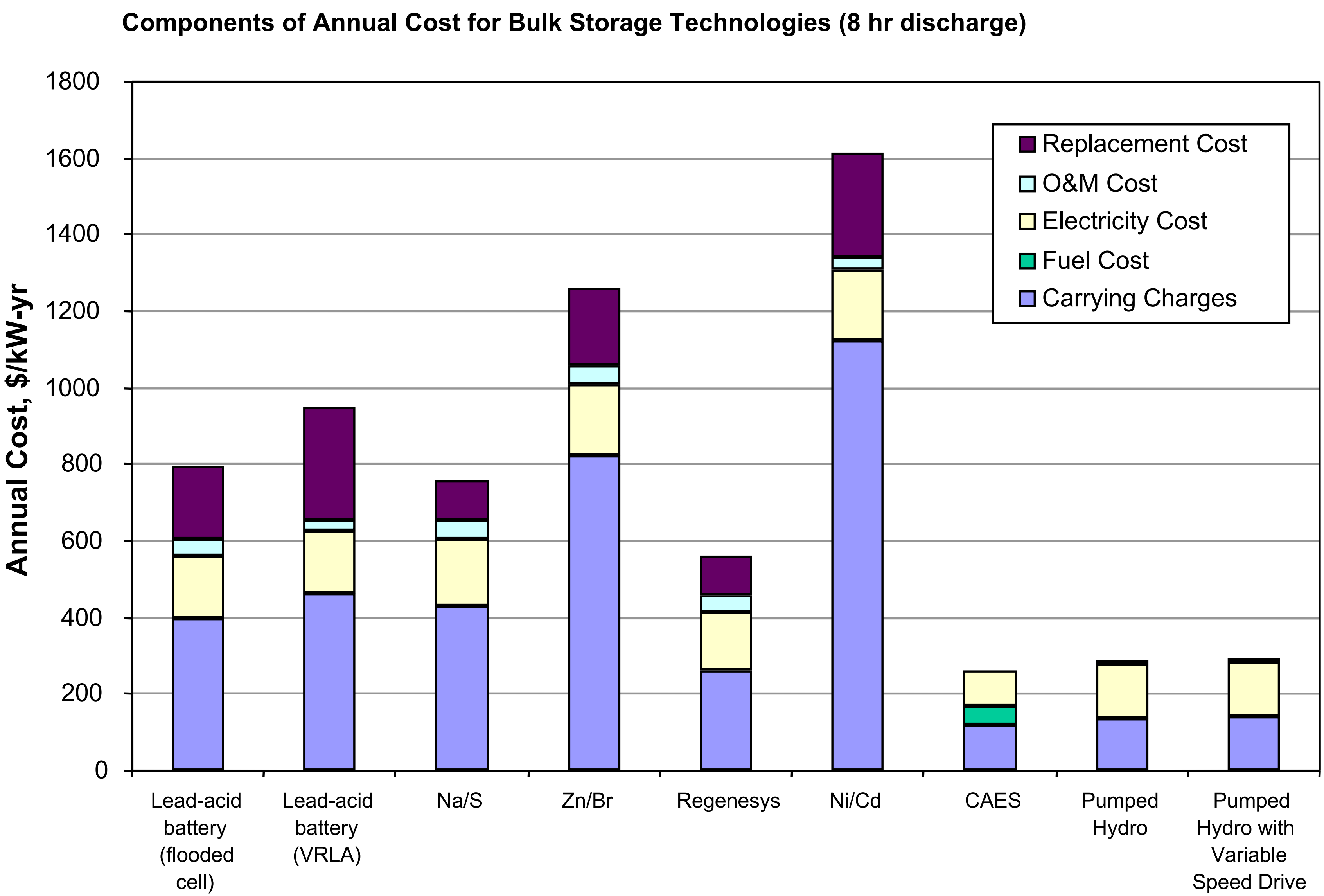

Distributed Generation Technologies

- Lead-acid (flooded) and VRLA batteries
- High temperature sodium/sulfur batteries
- Zn/Br batteries
- Vanadium-redox batteries
- Ni/Cd batteries
- Li-Ion batteries
- High-speed flywheels
- CAES with surface storage
- Hydrogen – fuel cells and engines

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Distributed Generation - Preliminary Results

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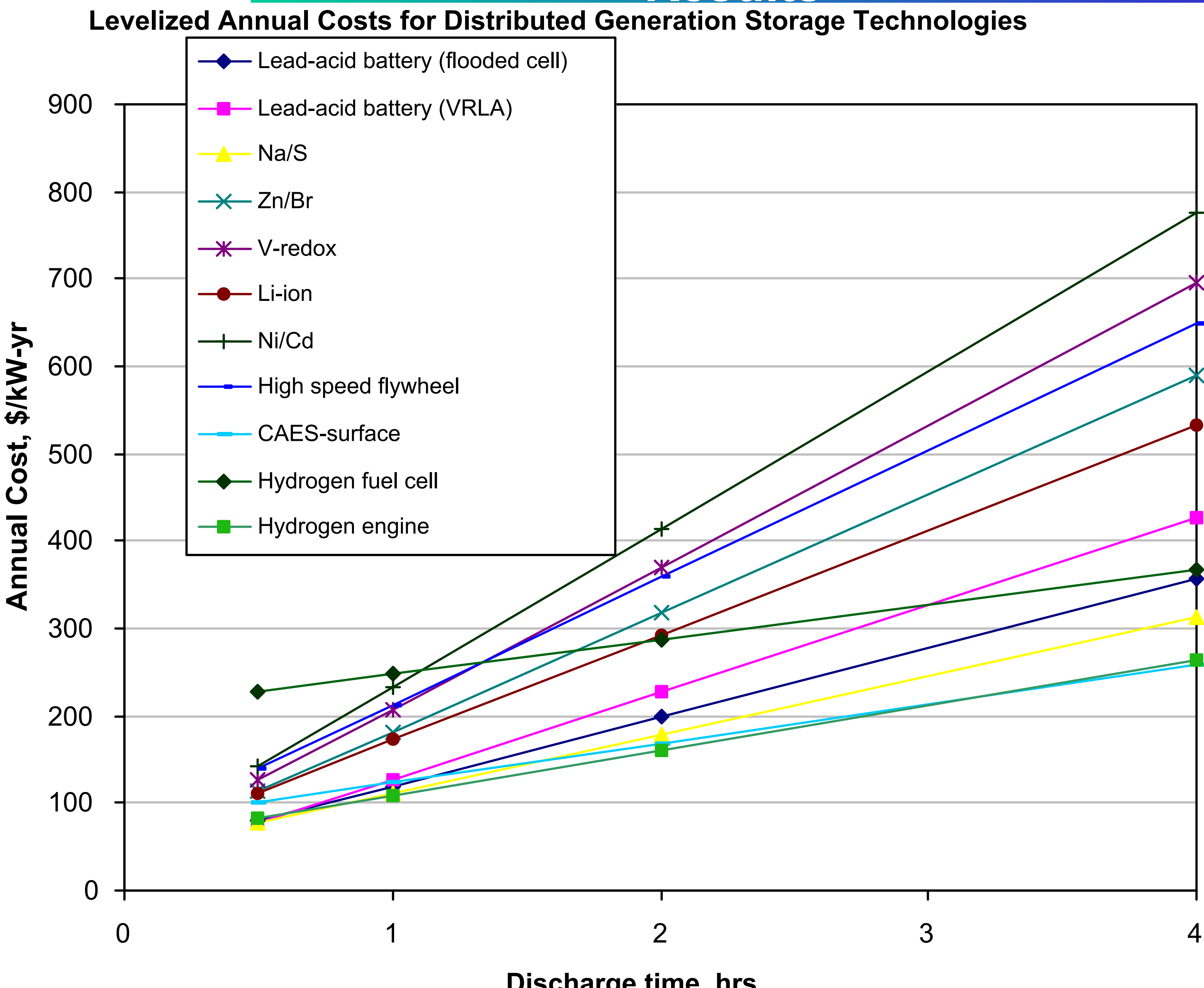
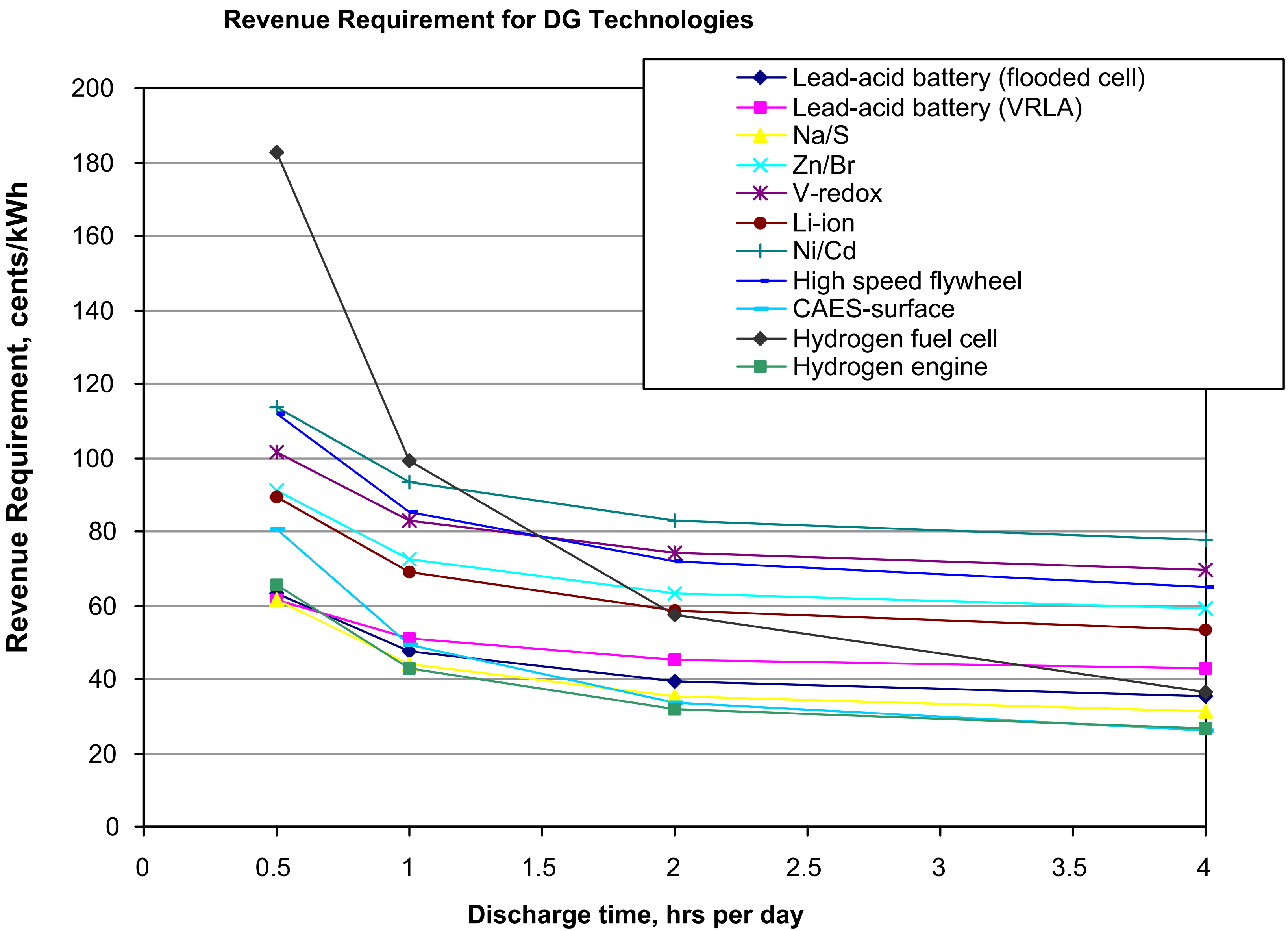


Distributed Generation - Preliminary Results



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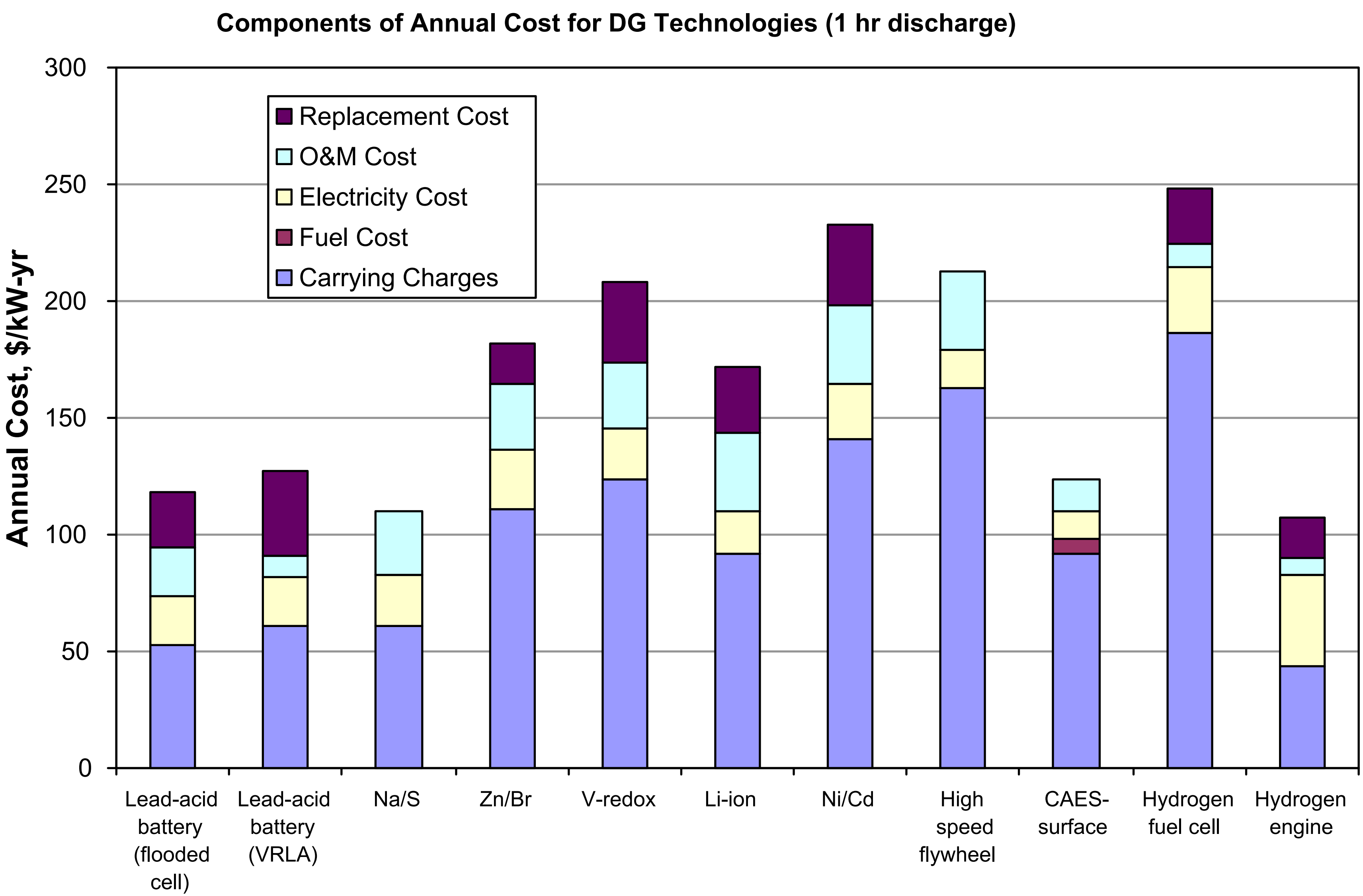
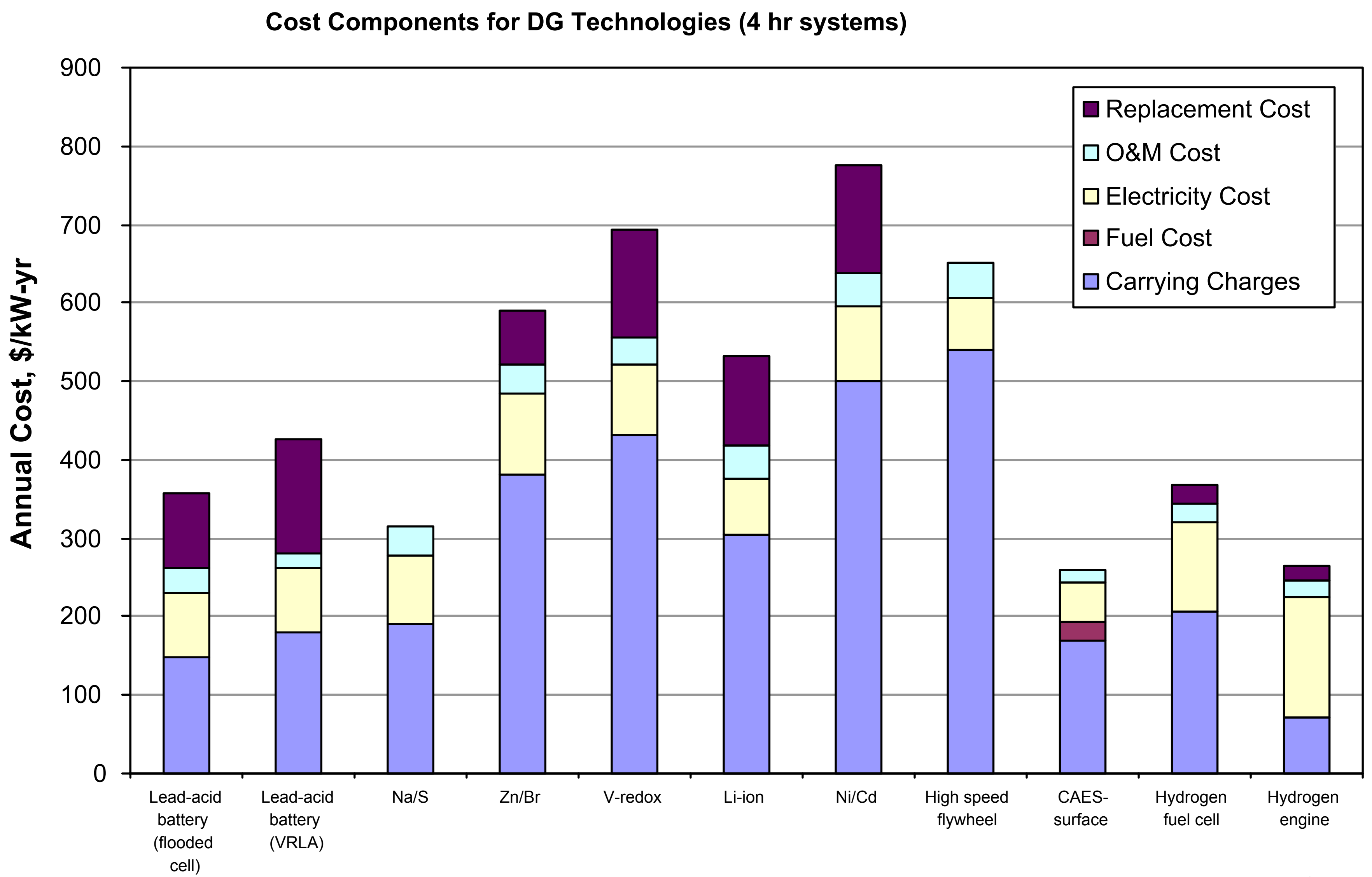


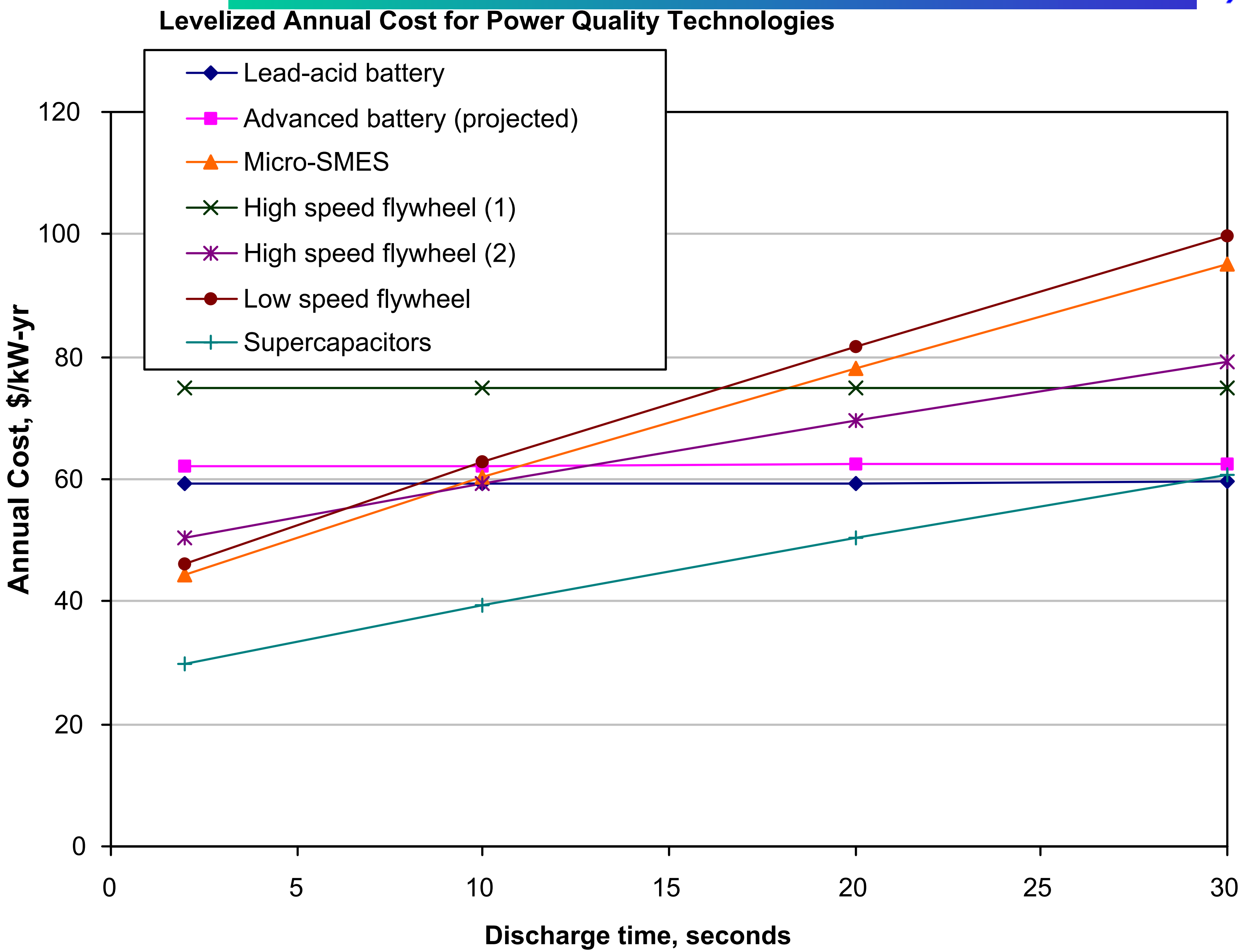
Distributed Generation - Preliminary Results



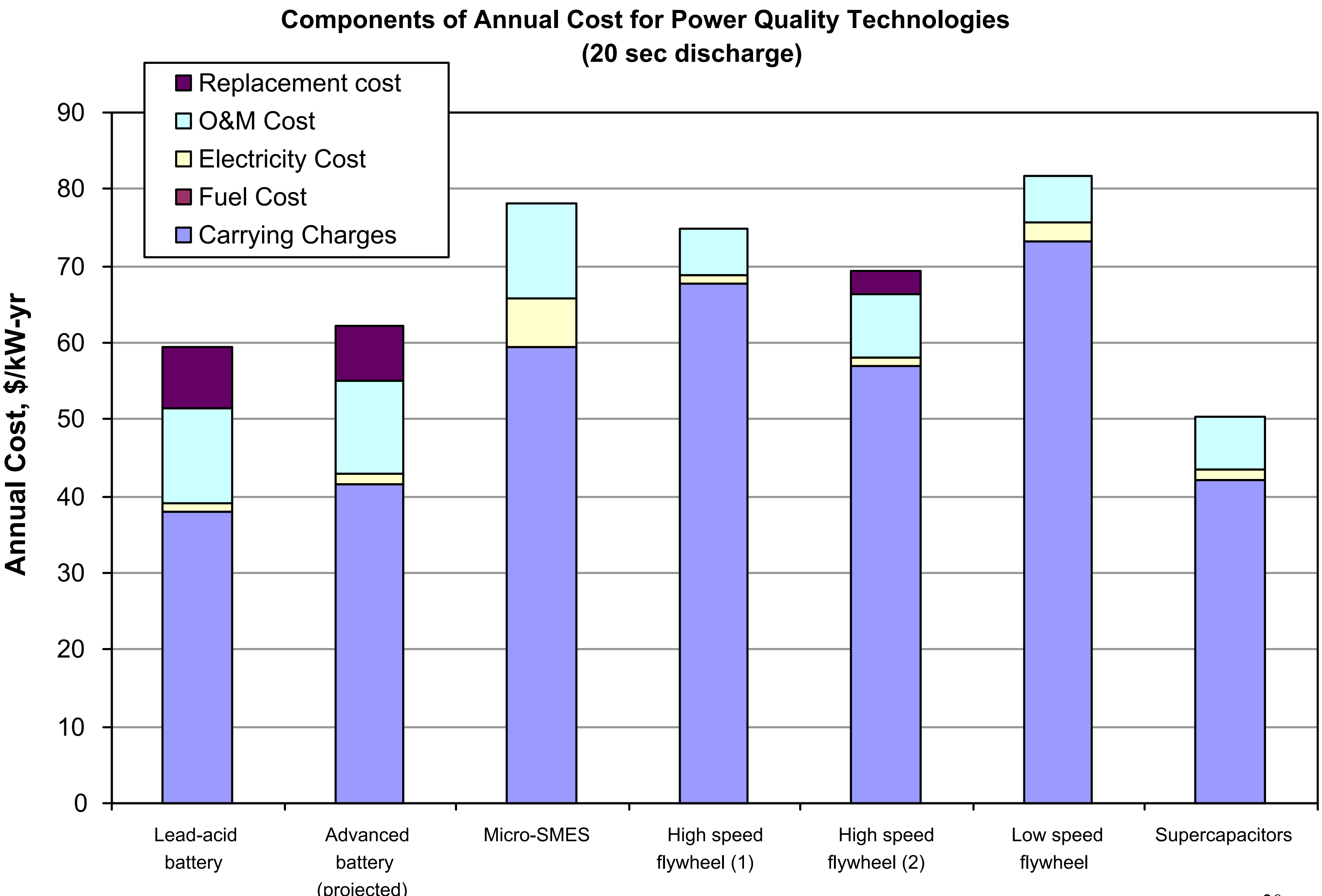
Power Quality Technologies

- Lead-acid and advanced batteries
- Micro-SMES
- High-speed flywheels
- Low-speed flywheels
- Supercapacitors

Power Quality - Preliminary Results



Power Quality - Preliminary Results



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Power Quality - Preliminary Results

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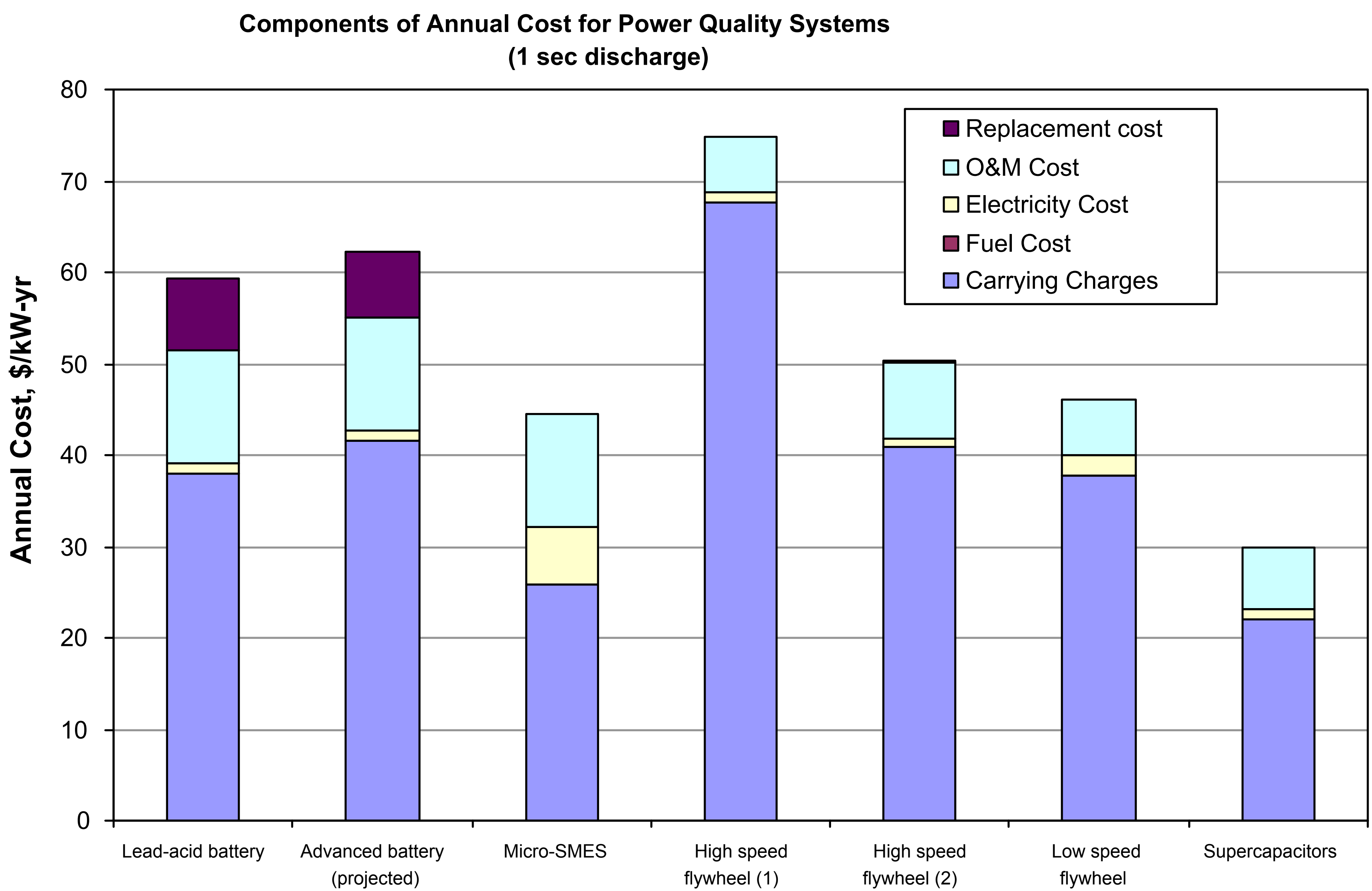

Issues

- Data difficult to get, and to distinguish current costs from projections.
- For some technologies, difficult to separate power and energy components.
- Difficult to be generic, e.g., batteries, flywheels
- Algorithm complications: replacements, parasitics
- Balance-of-Plant: buildings included in bulk, not DG

Preliminary Conclusions

- Bulk storage in geologic formations or tanks is least expensive for long-duration applications.
- Regenesys and Na/S batteries look attractive for bulk storage, but all advanced battery types are immature and cost conclusions are preliminary.
- Revenue requirements are high for most technologies - suitable for select peak shaving/arbitrage applications only.
- Replacement frequency and cost are significant cost factors, and are highly uncertain.
- Hydrogen has a role to play in clean DG situations.
- Power quality systems need accurate time duration specifications to optimize technology selection.

Follow-on Analysis

- Sensitivity of results to cost assumptions and replacement frequency
- Add UPS category: 30 sec to 15 minutes
- Consider taxes and other economic factors
- Compare annual costs / revenue requirements with markets
- Revisit costs for surface CAES
- Consider additional technologies