122 West DUA

Update on Benefit and Cost Comparison of Modular Energy Storage Technologies for Four Viable Value Propositions

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Introduction

- Goal:

  high level evaluation of modular energy storage (MES) system benefits and costs using *consistent bases*

- Objective:

  B/C for 4 viable value propositions

- Joint effort

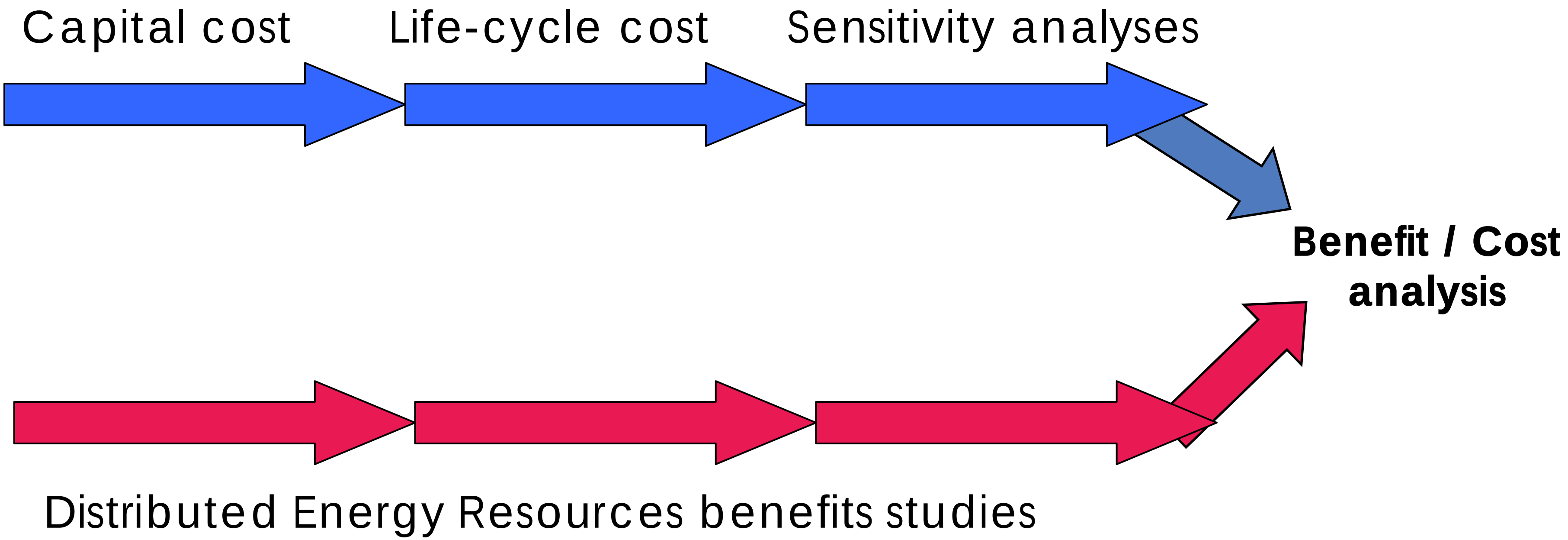
  Longitude 122 West

  - ESS costs -- update of previous work for DOE

  Distributed Utility Associates

  - ESS benefits

Energy Storage Analysis



Benefit / Cost analysis merges previous separate work;

Update of preliminary analysis

Four Value Propositions

1. Utility-owned *transportable* storage for
   - distribution upgrade deferral (alternating years)
   - localized PQ and/or or temporary power;
2. Transportable modular storage for improving local power quality in all years, at different locations
3. Utility-owned *stationary* storage for
   - one year of high value T&D upgrade deferral;
   - then wholesale electricity price arbitrage;
   - plus a generation capacity credit in all years
4. Energy end-user-owned storage
   - to reduce a) critical peak charges and
     b) on-peak energy and demand charges;

Economic Assumptions
Common Bases

Time Horizon*:	10 years
Price Escalation (inflation):	2.5%
Discount Rate:	10%
Utility Fixed Charge Rate**:	0.11
End-user Annualization Factor**:	0.15

* ESS salvage value, if any, is not included in the evaluation.

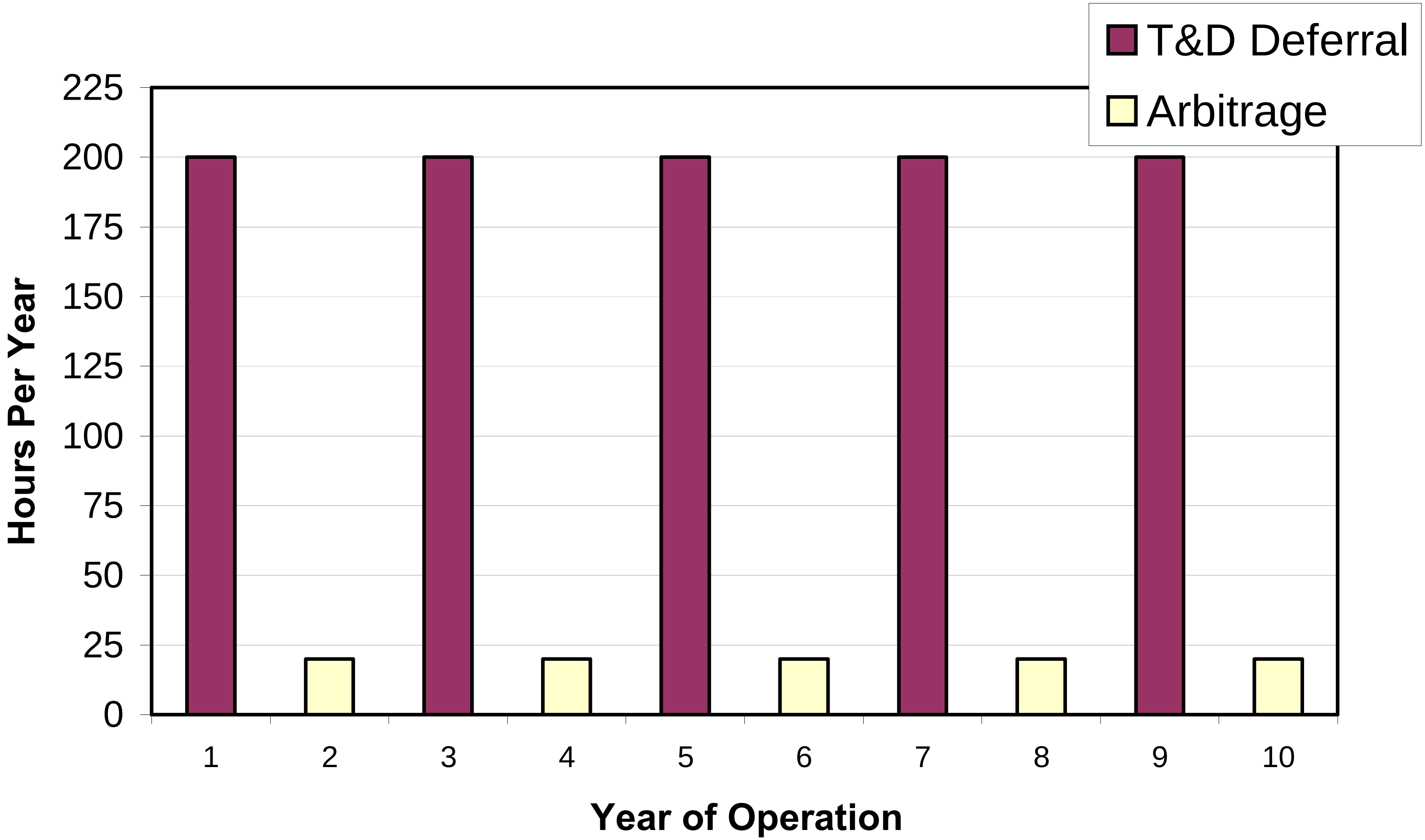
** Used to estimate annual "level" carrying charges for capital plant. 0.11 represents a "composite" fixed charge rate for utilities and 0.15 reflects relatively high opportunity cost of capital projects for commercial end-users.

Storage Technologies

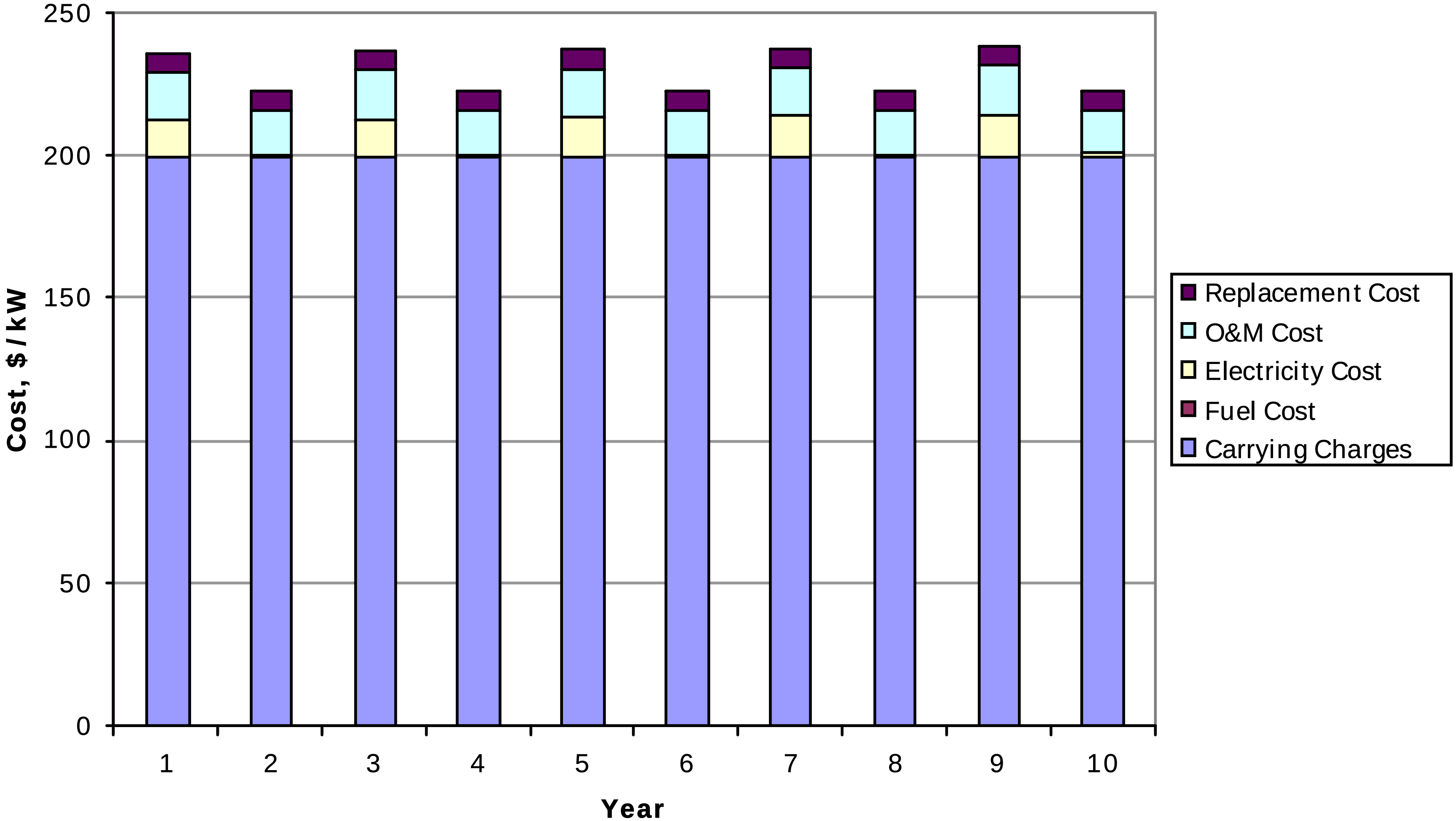
Value Proposition 1: Transportable MES for T&D Deferral and PQ	**Value Proposition 2: Transportable MES for improving PQ**	**Value Proposition 3: T&D Deferral Plus Arbitrage Plus Generation Capacity Credit**	**Value Proposition 4: Peak Plus Critical Peak Electricity Pricing**
• Lead-acid batteries (flooded and VRLA) • Ni/Cd • Na/S batteries • Li-ion batteries • Zn/Br batteries • V-redox batteries • High-speed and low-speed flywheels • Lead-carbon asymmetric caps • Hydrogen fuel cell	• Lead-acid batteries (flooded and VRLA) • Ni/Cd • Li-ion batteries • Zn/Br batteries • High-speed and low-speed flywheels • Lead-carbon asymmetric caps	• Lead-acid batteries (flooded and VRLA) • Na/S batteries • Ni/Cd • Li-ion batteries • Zn/Br batteries • V-redox batteries • Surface CAES • Lead-carbon asymmetric caps • Hydrogen fuel cell	• Lead-acid batteries (flooded and VRLA) • Ni/Cd • Na/S batteries • Li-ion batteries • Zn/Br batteries • V-redox batteries • Lead-carbon asymmetric caps • Hydrogen fuel cell

Operation for Value Proposition 1

Transportable ESS for T&D Deferral & PQ

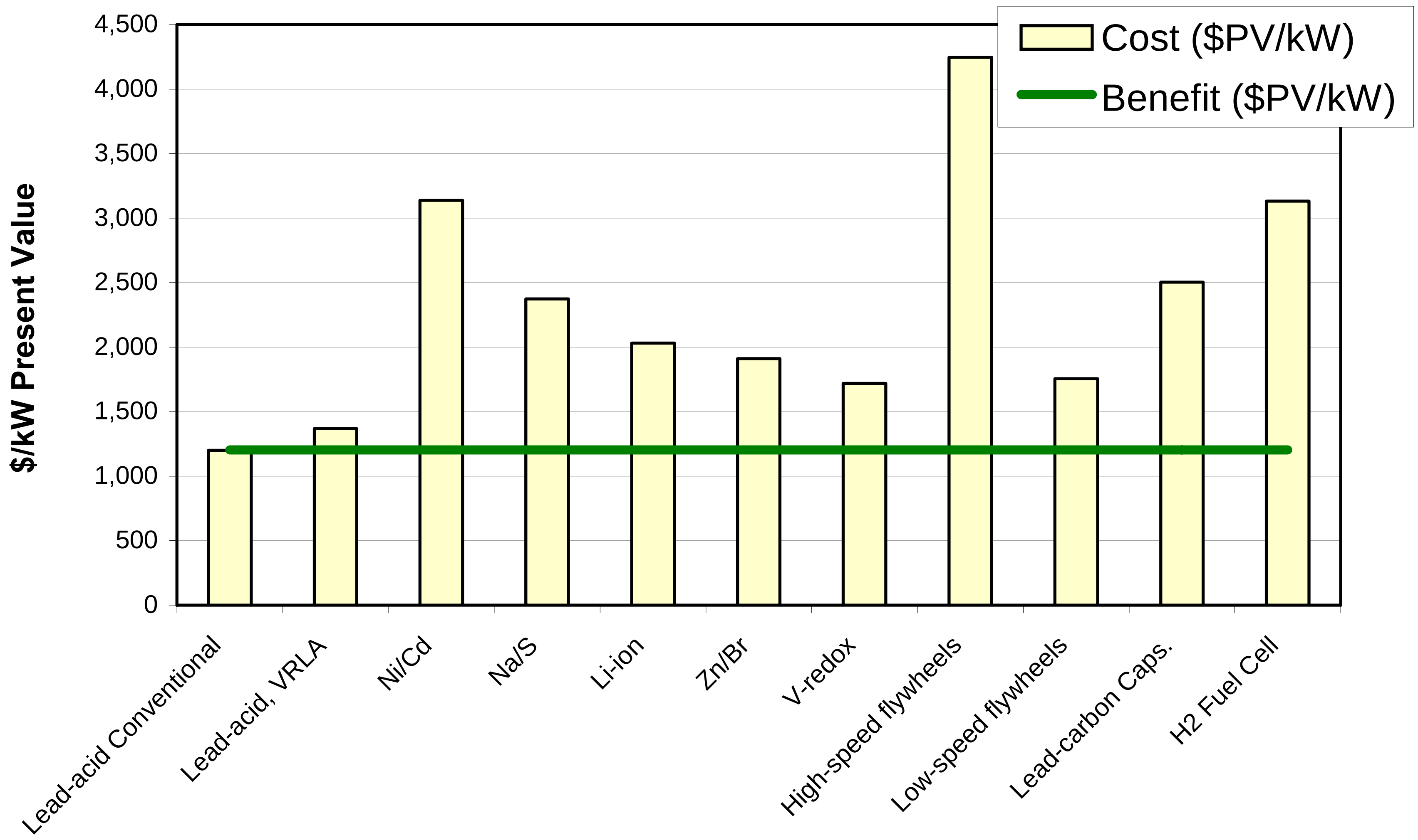


Costs for Lead-Acid Battery System in Value Proposition 1



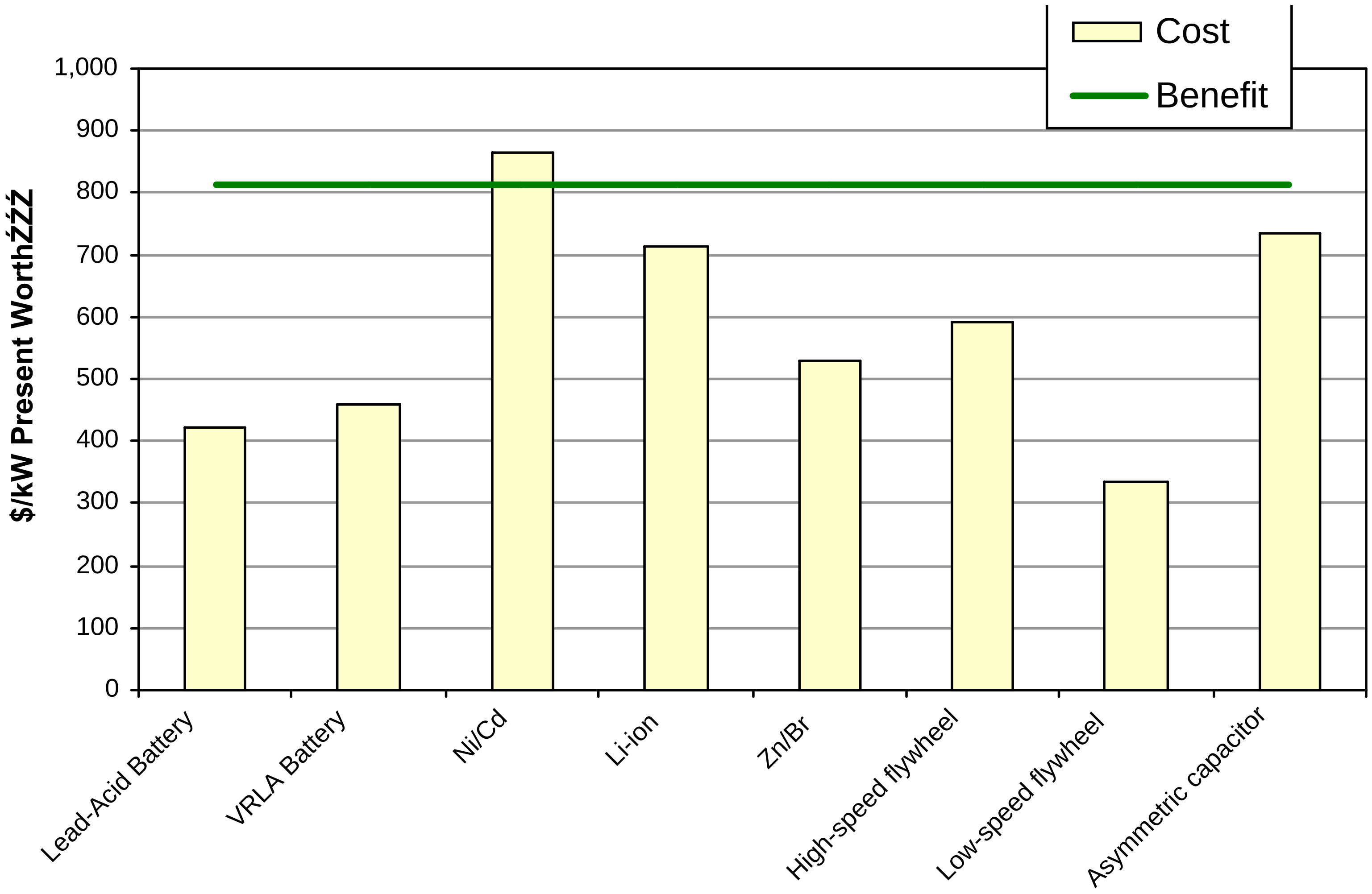
Benefit & Cost, Value Proposition 1

Transportable ESS for T&D Deferral & PQ



Benefit & Cost, Value Proposition 2

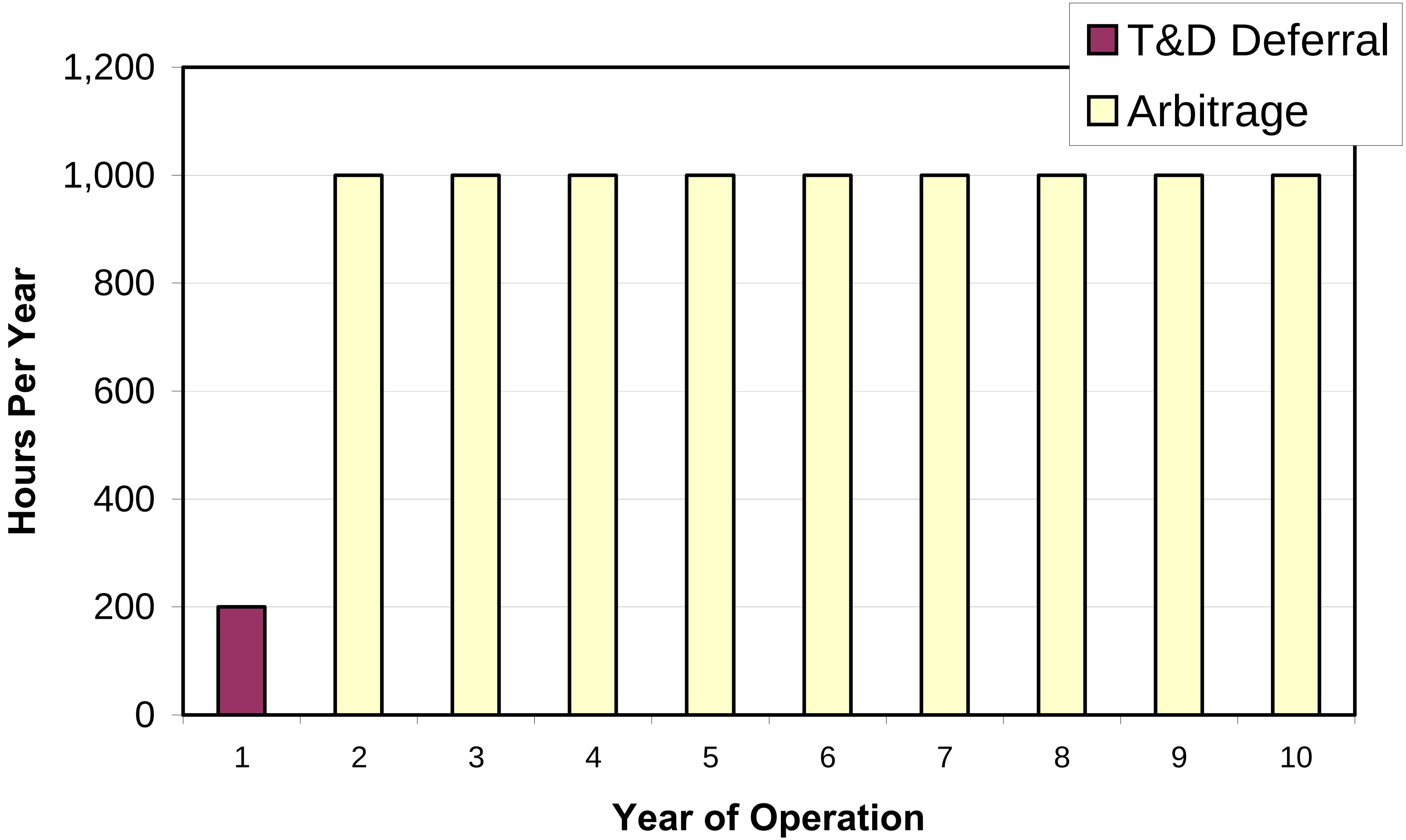
Transportable ESS for PQ Only



Operation for Value Proposition 3

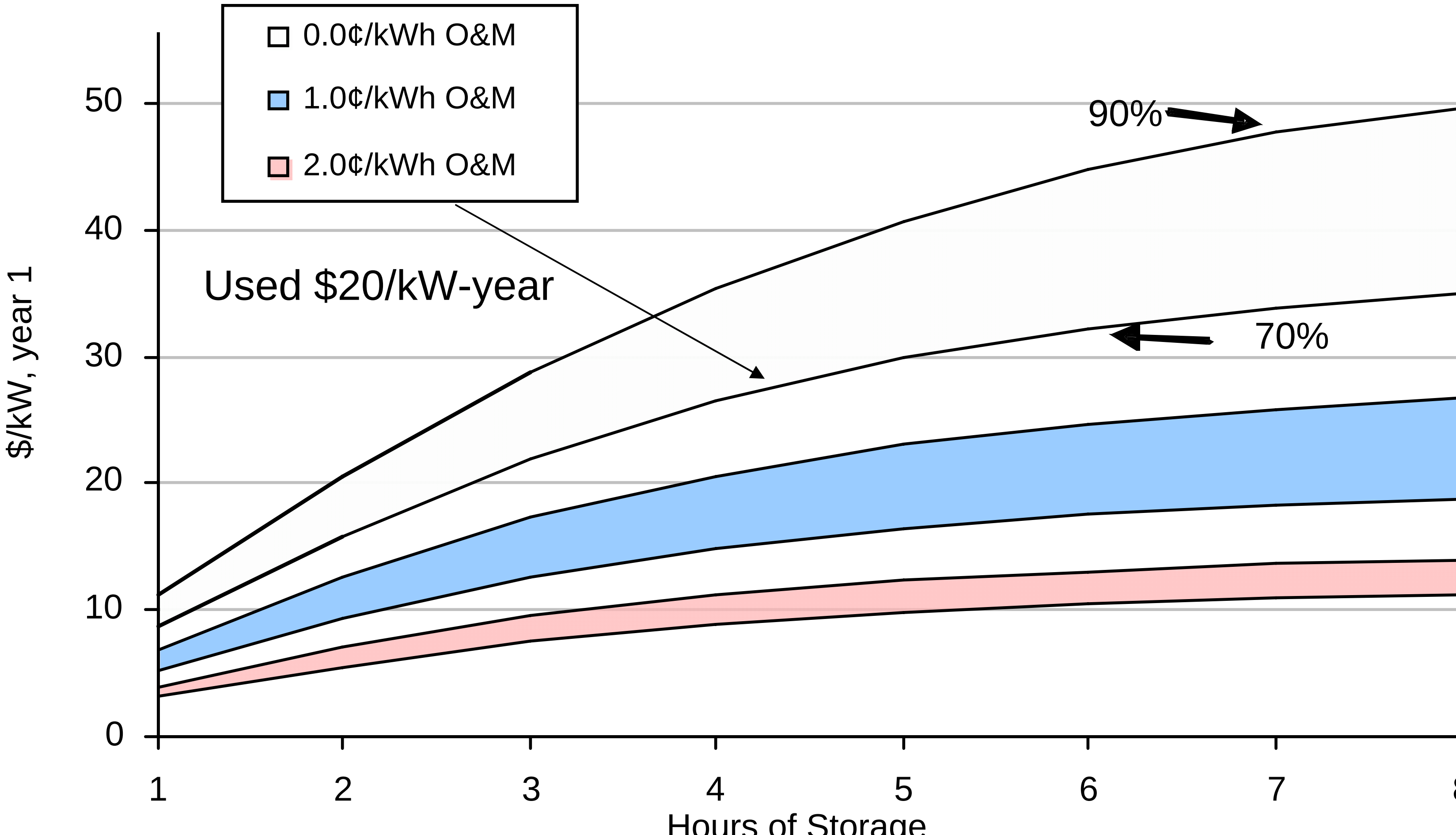
1 Year High Value T&D Deferral

+ Arbitrage + Generation Capacity Credit



*Net** Arbitrage Benefits

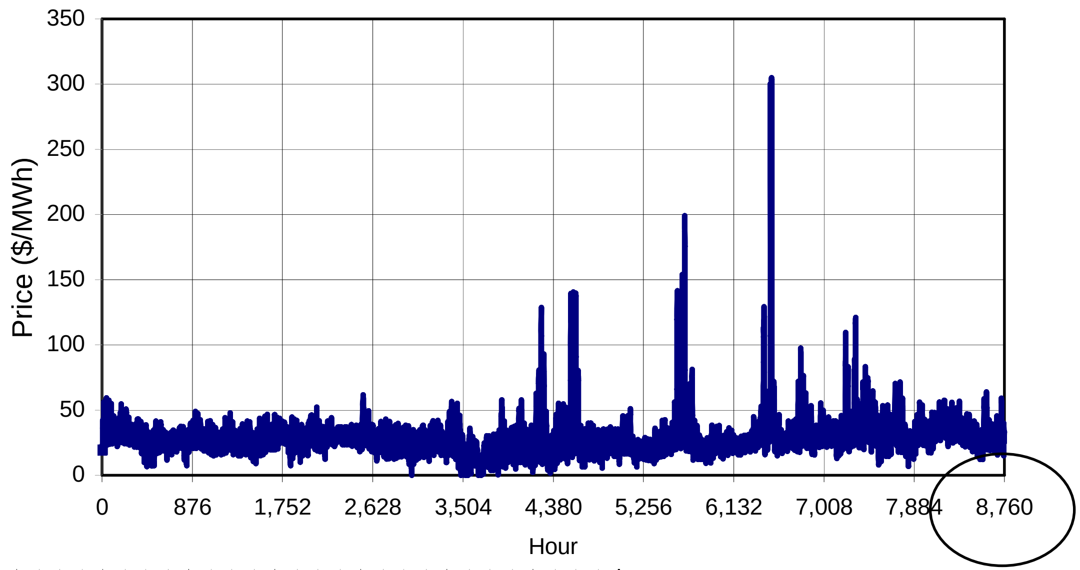
California - one year

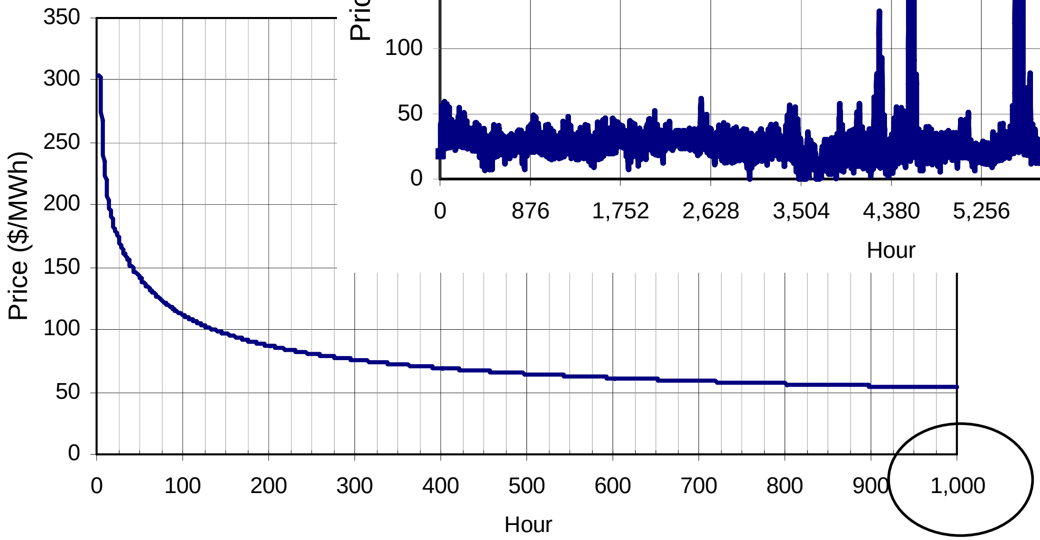


California Electric Energy Prices

- 8,760 hourly wholesale prices
  - from CEC, production simulation model results

Prices for all hours in the year, in chronological order

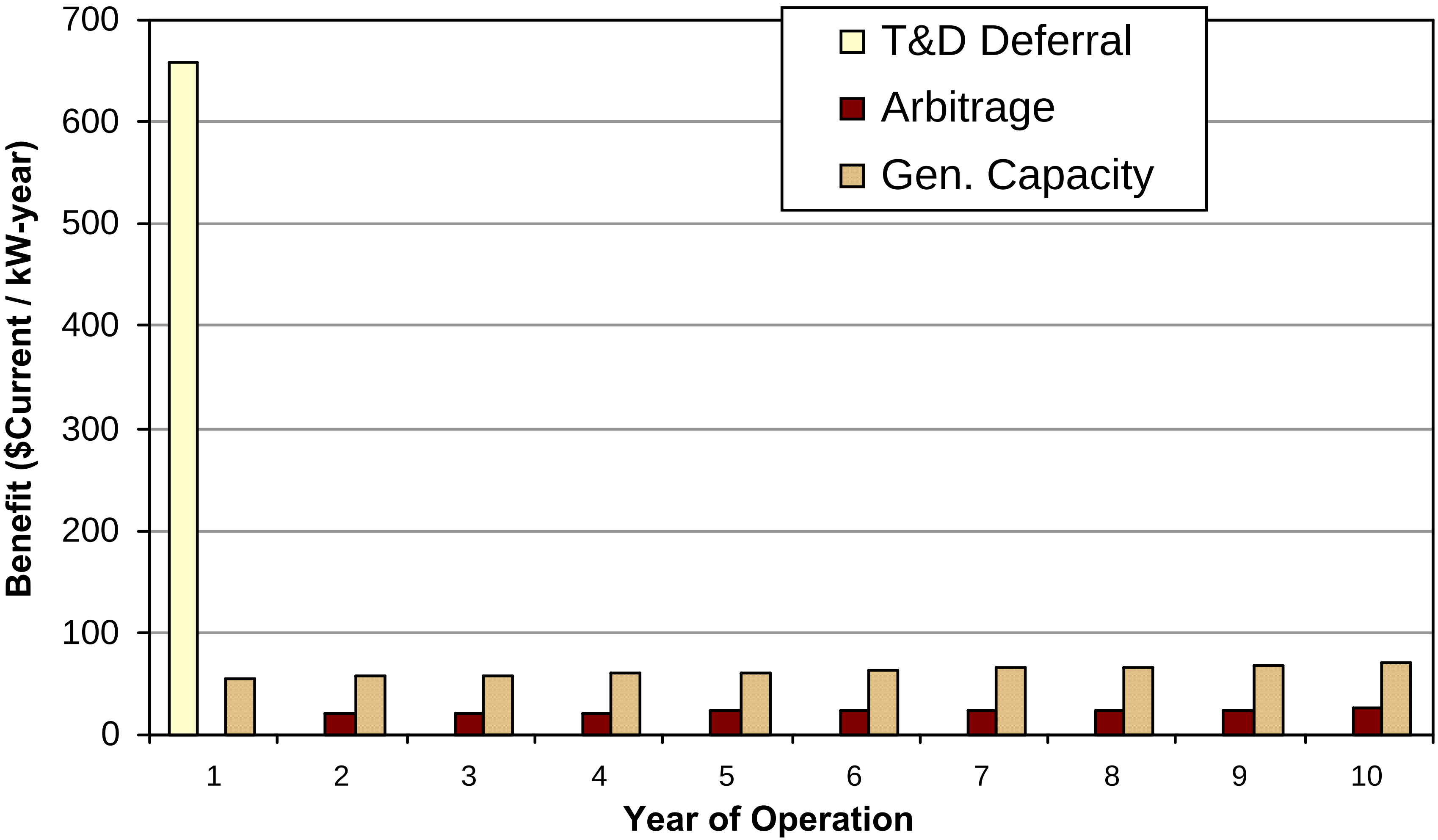




1,000 hours with the highest priced energy

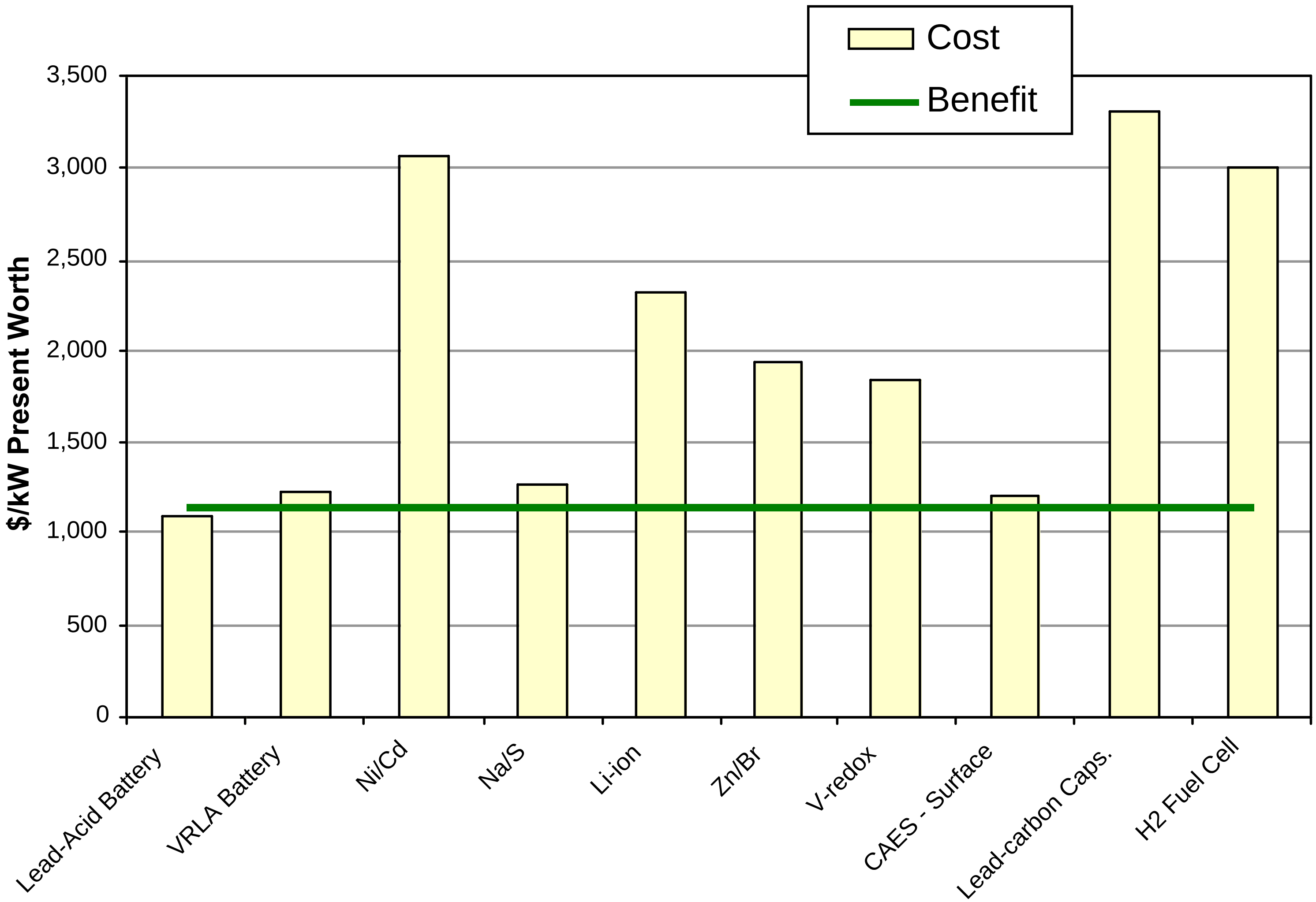
Annual Benefits for Value Proposition 3

1 Year High Value T&D Deferral
+ Arbitrage + Generation Capacity Credit



Benefit & Cost, Value Proposition 3

1 Year High Value T&D Deferral
+ Arbitrage + Generation Capacity Credit



Value Proposition 4
ESS for Critical Peak Pricing

- PG&E Critical Peak Pricing:
  For discount during most hours of the year, customer agrees
  - to pay “very high” price for energy
    - up to 5x normal peak energy charge
  - “several times” (events) per year
    - PG&E Target: 12
  - for a target of 3 to 6 hours per event
- Note: some end-users could benefit from better onsite PQ and/or reliability.

Critical Peak Pricing

PG&E Pacific Gas and Electric Company San Francisco, California		Revised	*Cal. P.U.C. Sheet No.*	23450-E
	Cancelling	Original	*Cal. P.U.C. Sheet No.*	21686,
				22861-E

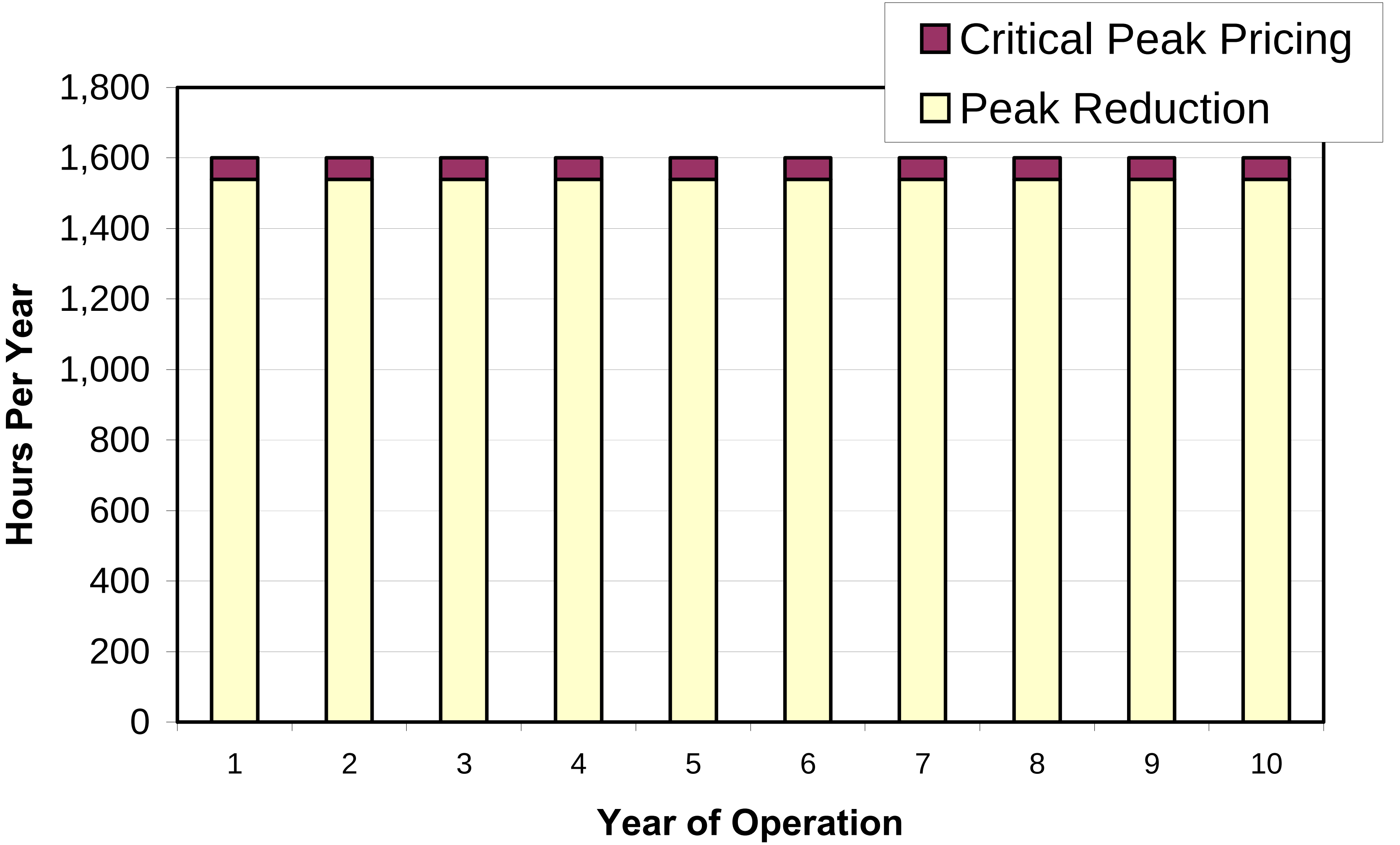
SCHEDULE E-CPP—CRITICAL PEAK PRICING PROGRAM

APPLICABILITY: The critical peak pricing (CPP) program is a voluntary alternative to traditional time-of-use rates. Schedule E-CPP is available to PG&E bundled-service customers with billed maximum demands of 200 kW or greater during any one of the past 12 billing months, and served on PG&E Demand Time-Of-Use (TOU) electric rate schedules A-10 TOU, E-19 (including E-19 voluntary), E-20, AG-4 (rates C and F only), AG-5 (rates C and F only) or their successors. Each customer must continue to take service under the provisions of their otherwise-applicable schedule (OAS). The CPP program only operates during the summer months (May 1 through October 31). Customers on this tariff must agree to allow the California Energy Commission (CEC) or its contracting agent to conduct a site visit for measurement and evaluation, and agree to complete any surveys needed to enhance the CPP program. This program will remain in place until superseded by a mandatory CPP rate schedule, which is expected in the Advanced Metering OIR, Rulemaking (R.) 02-06-001 or subsequent filings. (T)

	Non-CPP Days (Credit) per kilowatt hour of usage		**CPP Days (Charge)** per kilowatt hour of usage	
	On-Peak	Part-Peak	Moderate-Price	High-Price
E-20T	$0.02682 (R)	$0.00146 (R)	$0.09116 (R)	$0.45124 (R)
E-20P	$0.03012 (R)	$0.00153 (R)	$0.10010 (R)	$0.48280 (R)
E-20S	$0.03424 (R)	$0.00349 (R)	$0.10415 (R)	$0.58900 (R)
E-19T	$0.03102 (R)	$0.00259 (R)	$0.14360 (R)	$0.54340 (R)
E-19P	$0.03104 (R)	$0.00230 (R)	$0.11879 (R)	$0.49672 (R)
E-19S	$0.03656 (R)	$0.00394 (R)	$0.12429 (R)	$0.59652 (R)
A-10T	$0.01392 (R)	$0.00627 (R)	$0.11735 (R)	$0.22991 (R)
A-10P	$0.04076 (R)	$0.00318 (R)	$0.21143 (R)	$0.67480 (R)
A-10S	$0.04686 (R)	$0.00322 (R)	$0.22008 (R)	$0.65292 (R)
AG-4C, F	$0.02305 (R)	$0.00583 (R)	$0.12857 (R)	$0.41080 (R)
AG-5C, F	$0.01874 (R)	$0.00504 (R)	$0.09670 (R)	$0.34808 (R)

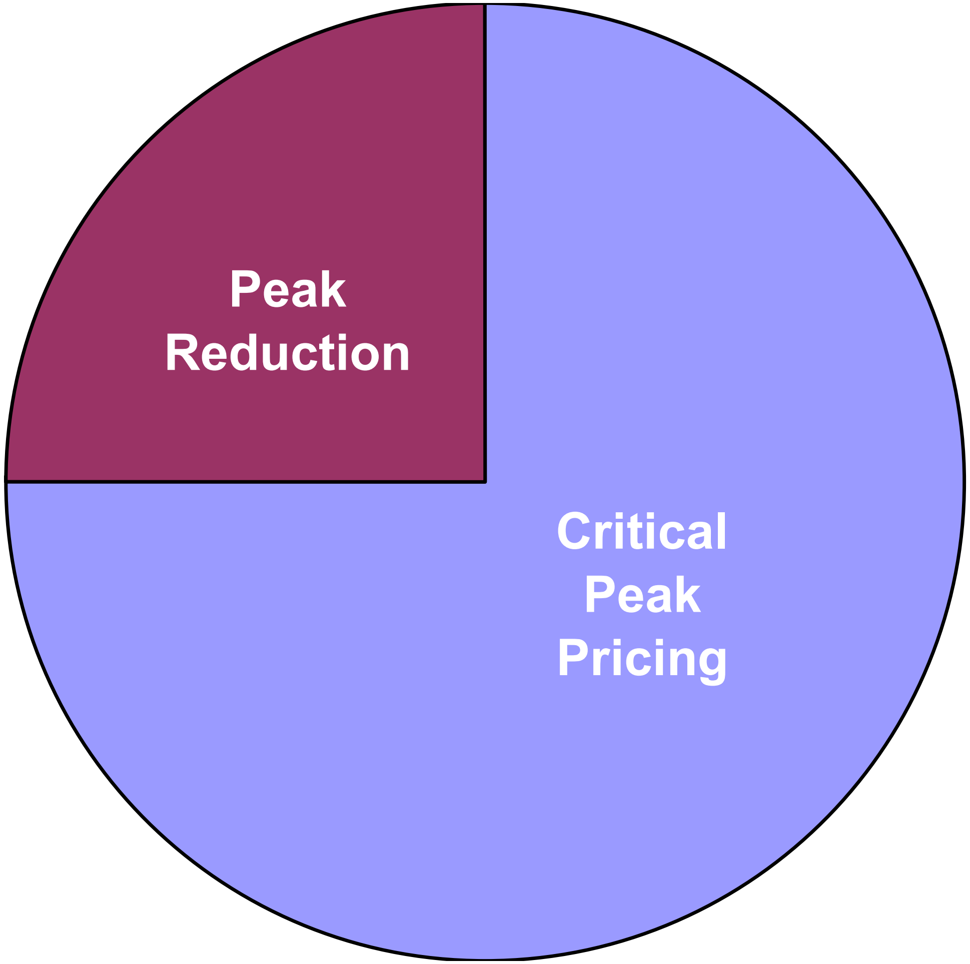
Operation for Value Proposition 4

ESS for Critical Peak Pricing



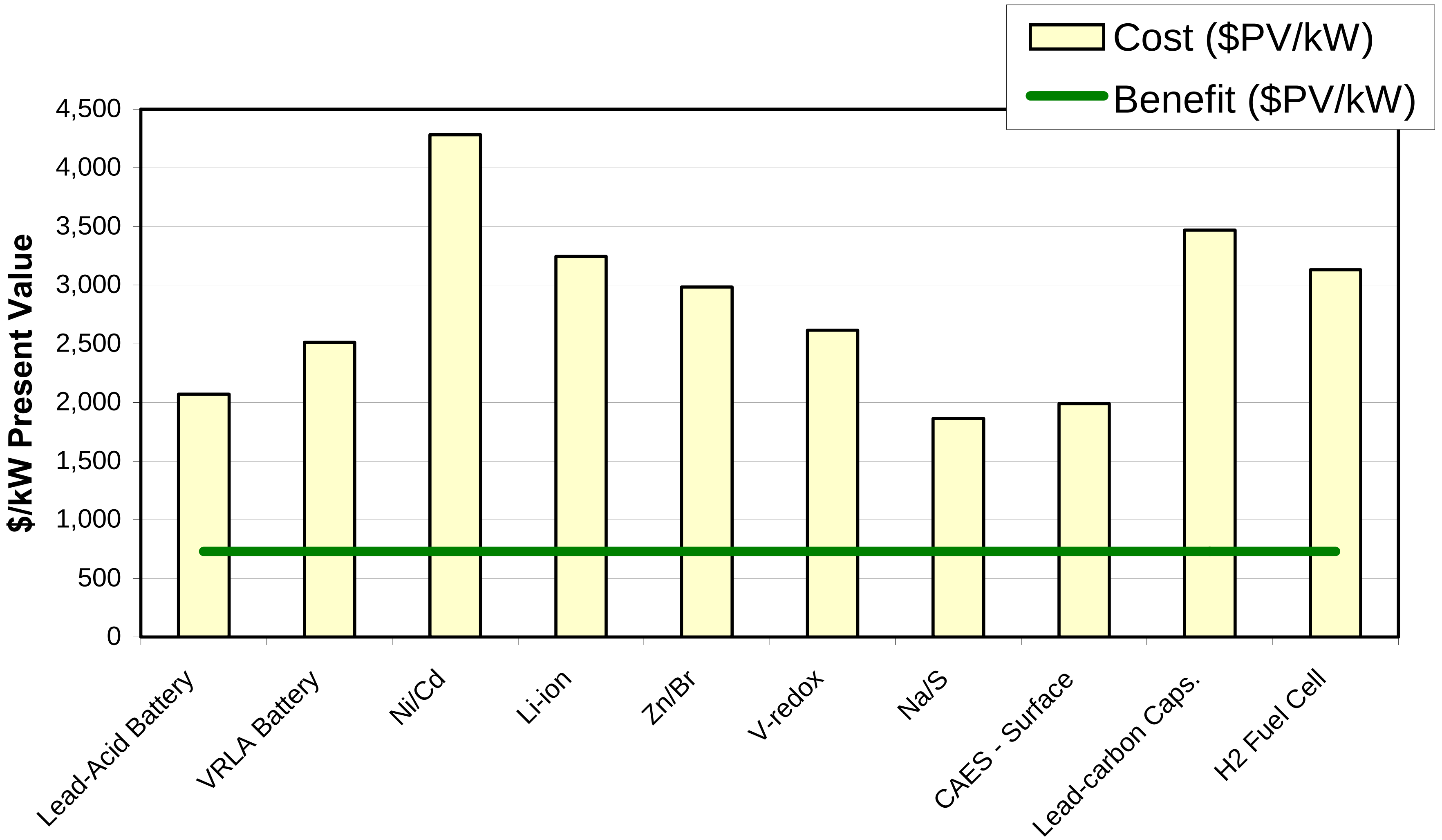
Benefit for Value Proposition 4

ESS for Critical Peak Pricing



Benefit & Cost, Value Proposition 4

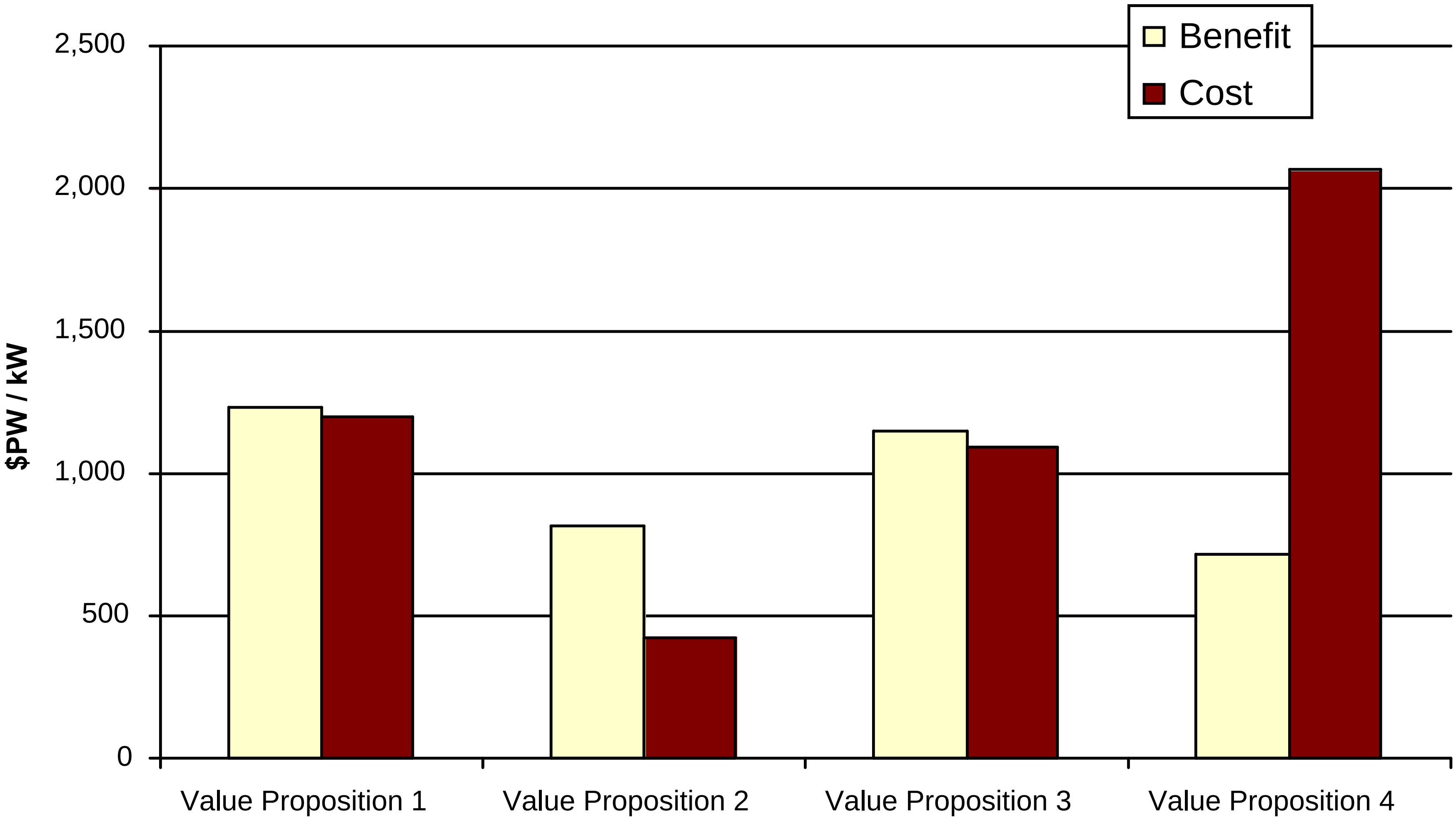
ESS for Critical Peak Pricing



Conclusions

- Value propositions 1, 2 and 3 are viable, yielding benefit/cost ratios greater than 1 for some technologies.
- Value proposition 2 is the most overall attractive for a number of technologies.
- Lead-acid batteries have the most applicability at current costs for modular energy storage use.
- MES used as “Capacity Resources” are attractive for offsetting other capital expenses.
- Benefit aggregation is an important way to improve storage value propositions. Transportable ESSs offer opportunities to aggregate benefits.

Summary Results for Conventional Lead-Acid Batteries



Recommendations (1)

Identify and characterize three to five emerging value propositions for MES characterized by specific criteria:

1) degree to which the value proposition is viable given: a) existing market mechanisms and b) expected and emerging market mechanisms,

2) ability to reduce regional blackouts (e.g. by proving local VARs),

3) expected utility infrastructure needs,

4) increasing penetration of intermittent renewables,
5) increasing interest in “demand response” resources.

Recommendations (2)

Identify key technical and institutional challenges affecting the prospects for otherwise cost-effective use of MES by utilities, electricity end users, load aggregators and other third party electricity services providers, and characterize specific ways to reduce those challenges.

Given results indicating that flywheel energy storage may be cost-effective for transportable power quality, investigation of that value proposition for flywheels is warranted.