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Finding Cost-Effective Opportunities for Energy Storage on the Electric Grid

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Energy Storage Program

EETD Lunch Seminar at LBNL
1/17/2014

Thought Experiment

- The Year is 1984
- Your employer would like to you perform an economic evaluation of new technology
- How would you determine the cost-effectiveness of:
  - Cell phones?
  - Computers?

Order of Presentation

- EPRI introduction
- Energy storage overview
- Key issues with energy storage modeling
- EPRI Energy Storage Valuation Tool (ESVT)
- Storage value analysis for CPUC
- CPUC energy storage decision
- Remaining challenges

The Electric Power Research Institute (EPRI)

- Independent, non-profit, **collaborative** research institute, with full spectrum industry coverage
  - *Nuclear*
  - *Generation*
  - *Power Delivery & Utilization*
  - *Environment & Renewables*
- Major offices in Palo Alto, CA; Charlotte, NC; and Knoxville, TN

EPRI Energy Storage Program Mission & Scope

Facilitate the availability and use of grid-ready storage options





- Understanding future and emerging technology
- Analysis of energy storage value and impact
- Specification and testing of storage products
- Deployment and integration of storage systems

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Energy Storage Overview

Storage: A Flexible Asset for a Changing Grid

- **Renewable integration** - Manage uncertainty and variability of wind, solar, and load
- **Long-term planning** - Build out the power system more efficiently – fewer power plants, lines, etc.
- **Operations** – Enable existing equipment to operate in efficiency sweet spots
- **Resiliency / reliability** – Backup power and outage restoration






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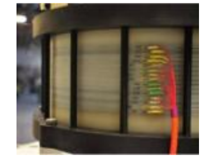
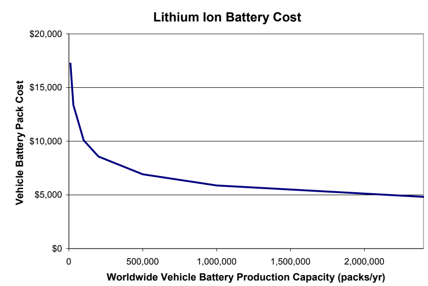
The historical challenges are starting to fade

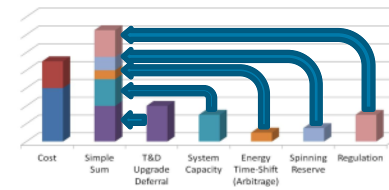
- Technical challenges
  - Performance
  - Life
  - Efficiency
- Economic Challenges
  - High Costs
  - Value streams
- Regulatory Challenges
  - Lack of clear definition
  - Framework designed for existing grid

Advanced Technologies



Lower costs



New Business Models

Regulatory Rulings

Favorable Legislation

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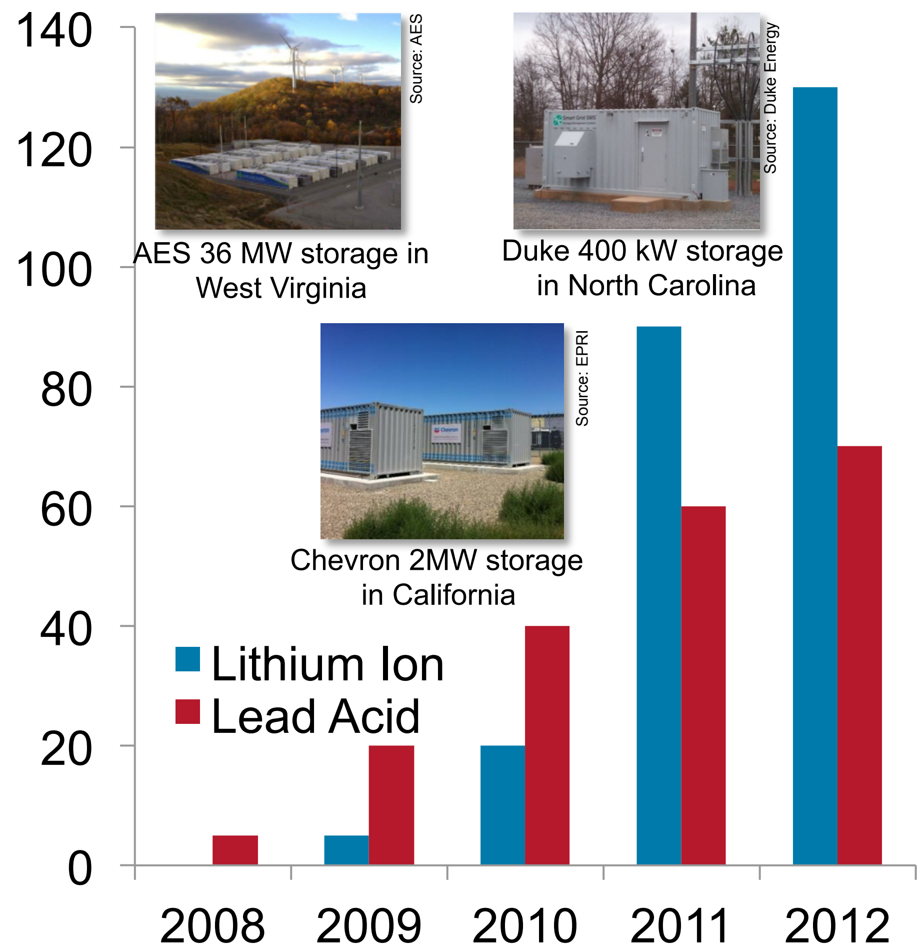
Storage deployment is growing…

- Most storage investment has come from IPPs and ESPs for ancillary services
- Deployment on customer side of the meter is often owned by developers taking advantage of favorable legislation (SGIP program, demand response)
- Many utilities are also installing demonstration projects

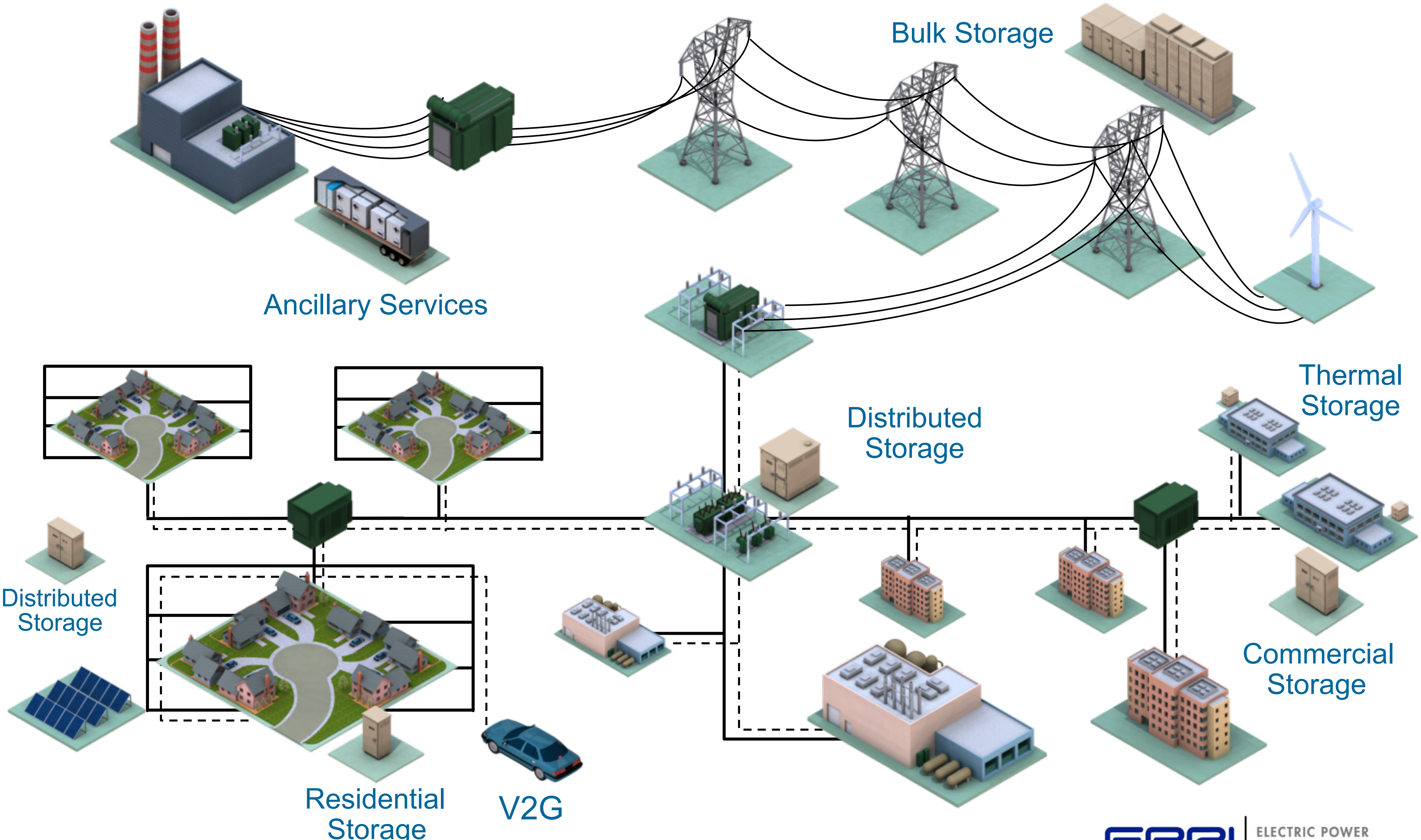
Worldwide Installation of Grid-Connected Batteries



Source: EPRI Estimates

Energy storage analysis and challenges

Many potential locations for energy storage



Many technologies and configurations









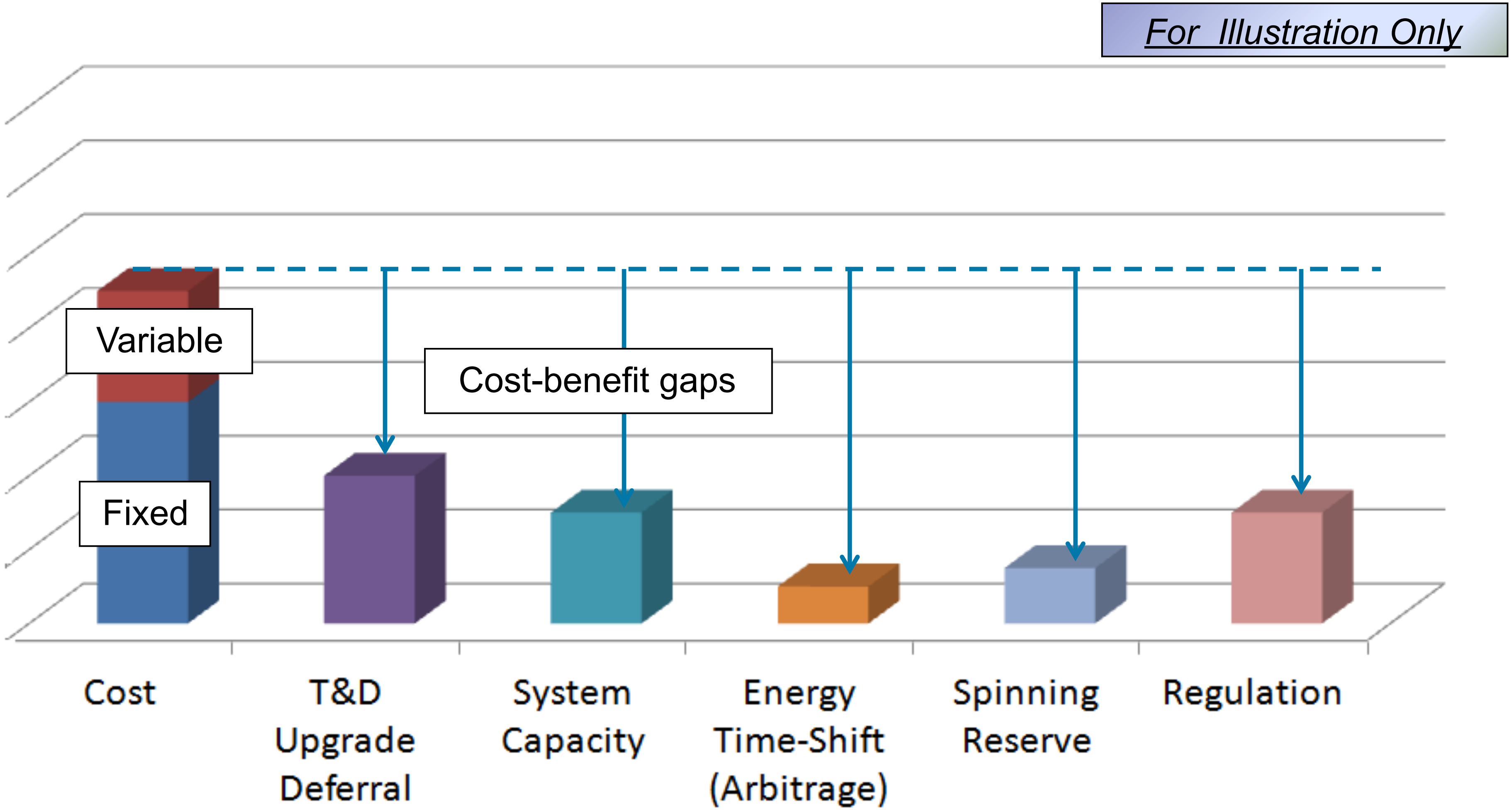

Many uses under consideration

Bulk Energy Services
Electric Energy Time-Shift (Arbitrage)
Electric Supply Capacity
Ancillary Services
Regulation
Spinning, Non-Spinning and Supplemental Reserves
Voltage Support
Black Start
Other Related Uses

Transmission Infrastructure Services
Transmission Upgrade Deferral
Transmission Congestion Relief
Distribution Infrastructure Services
Distribution Upgrade Deferral
Voltage Support
Customer Energy Management Services
Power Quality
Power Reliability
Retail Electric Energy Time-Shift
Demand Charge Management

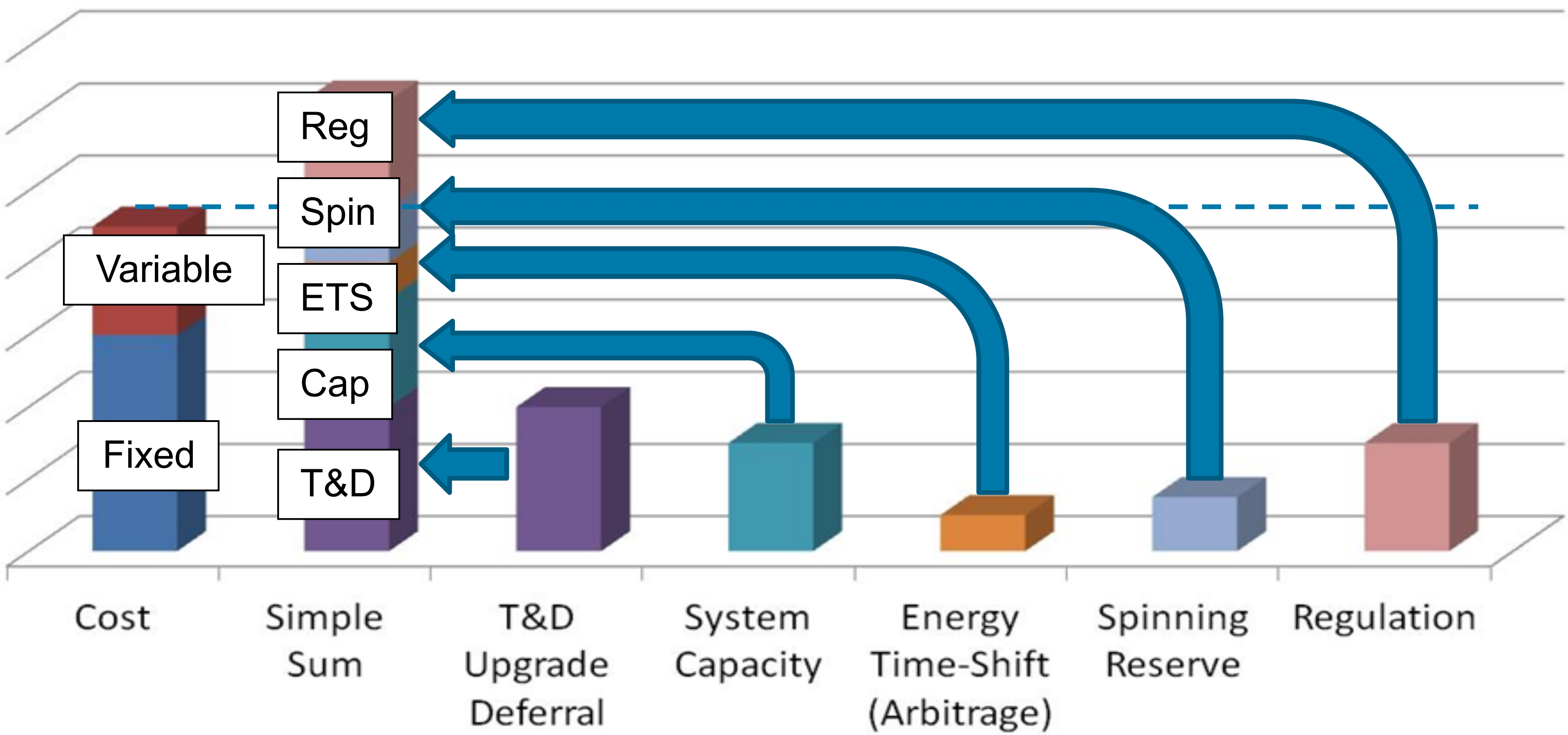
Source: DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA

Cost of storage has historically significantly exceeded benefits

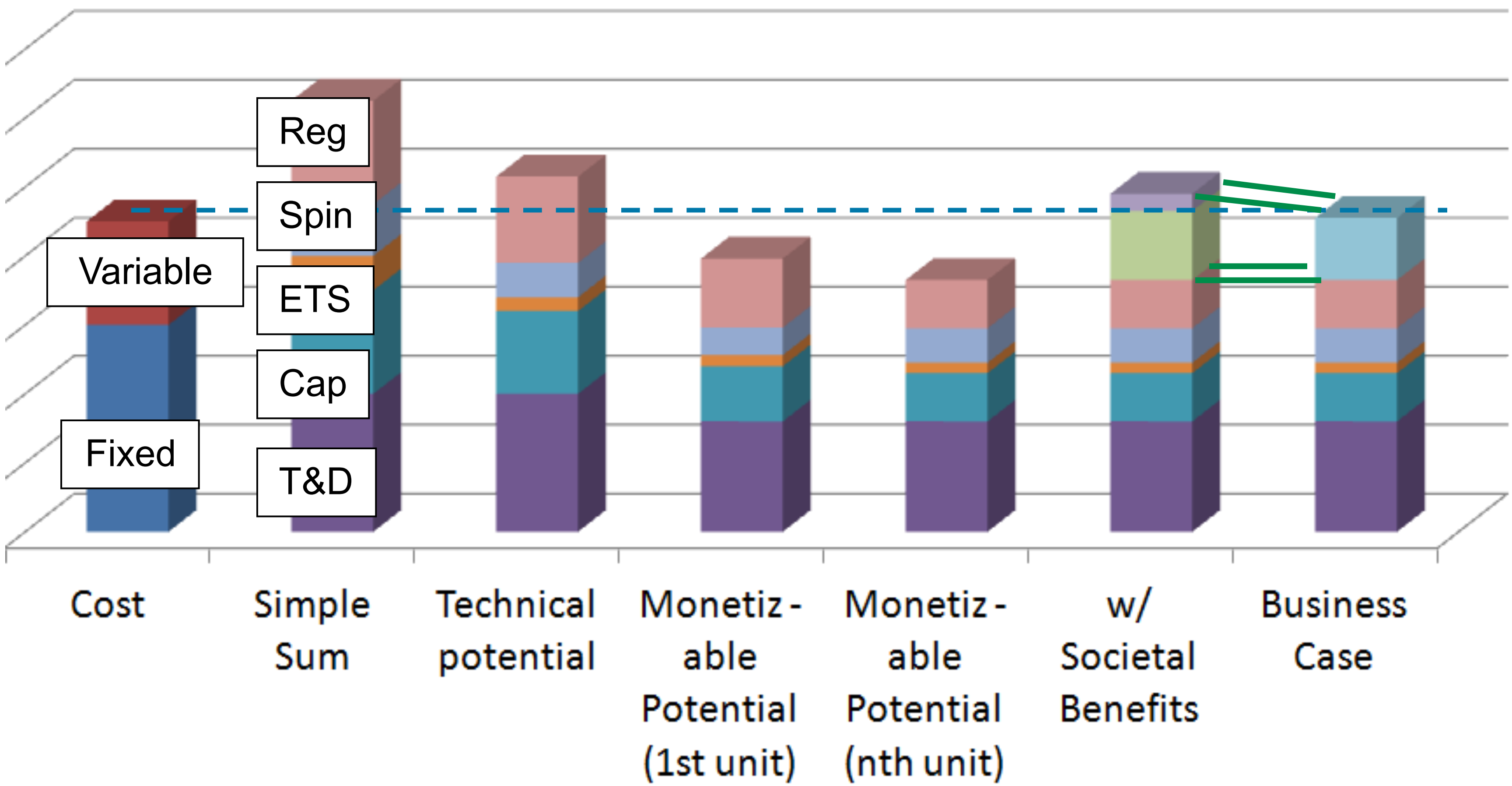


However, some benefit stacking may be possible

For Illustration Only



However, storage analysis is challenging today, and a proper analysis is a multi-stage journey



Why is storage analysis challenging?

- Limited duration resource
  - Challenges traditional static capacity planning approaches for generation, T&D
- Enhanced capabilities of storage, e.g. fast response / ramping
  - Not (fully) supported by existing grid operational approaches
- Envisions monetization of multiple benefit streams
  - Challenges traditional static capacity planning approaches for generation, T&D
  - Current markets and regulations are barriers
- Numerous technologies
  - Varying capabilities, cost structures

Our approach to storage analysis

- Develop user-friendly, transparent, and customizable tools and methods to determine where energy storage makes sense
    - Uses
    - Technologies
    - Locations
- Perform case studies to apply new tools and methods
- Work with commercial utility software developers to determine a path to accurate energy storage implementation

Overview of EPRI Storage Value Estimation - Energy Storage Valuation Tool (ESVT)

INPUTS

Quantify Grid Services

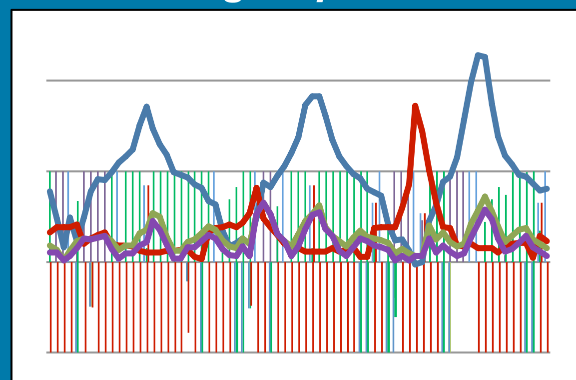
Define Financial Perspective

Define Storage Capability

MODEL

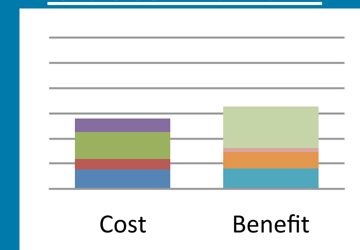
Simulate

Storage Operation

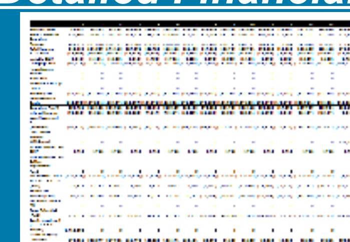


OUTPUTS

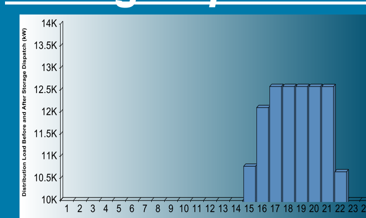
Cost / Benefit



Detailed Financials



Storage Operation



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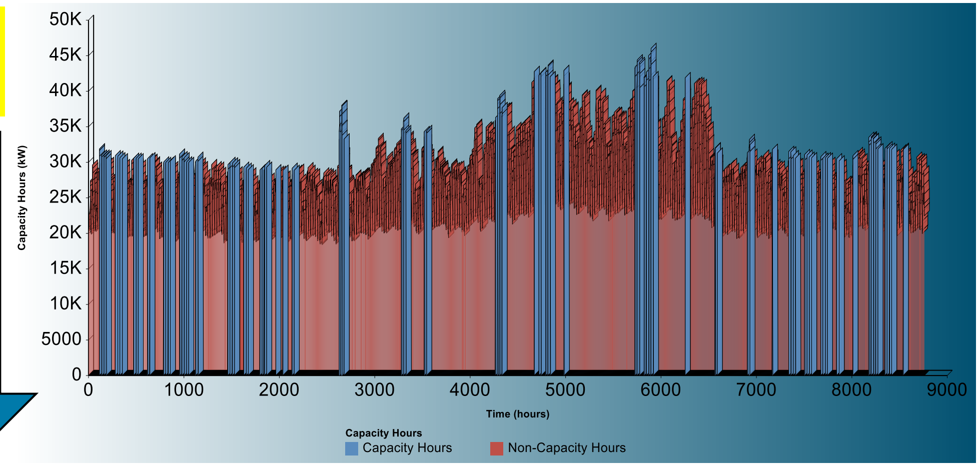
ESVT Combines Functions of Storage
Ex: Resource adequacy and markets

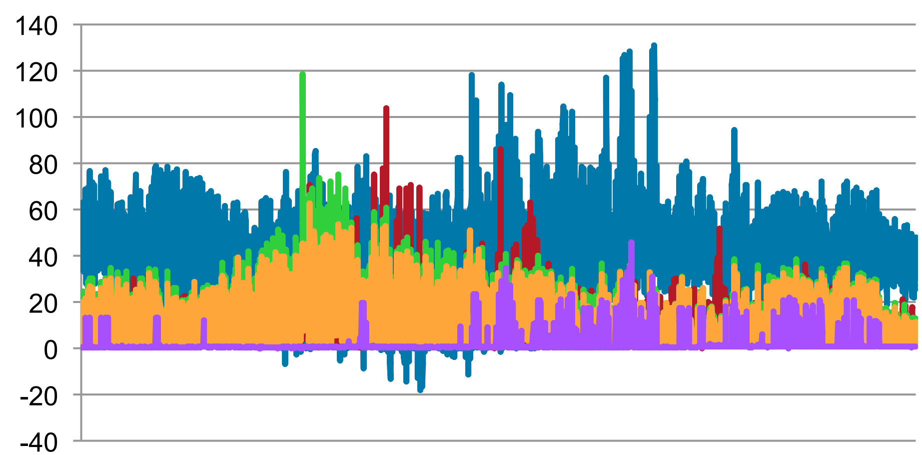
Top 20 hours reserved each month

•Reserve top 20 load hours per month for providing energy to earn system capacity value



Energy and Ancillary Services Dispatch

- Can be co-optimized for profitability between energy and ancillary services (reg up, reg down, spin, non-spin)



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ESVT Analysis for CPUC

Background: California Storage Rulemaking

California AB 2514 (Sept 2010)

- Started out as a bill establishing specific storage procurement targets
- Final bill stated that CPUC must "open a proceeding to determine appropriate targets"
- CPUC conducted an "Order Instituting Rulemaking" Proceeding, to determine framework for analyzing storage needs

Overview of ESVT Application in California

- CPUC Storage Proceeding needed to assess storage cost-effectiveness
- CPUC requested use of ESVT to analyze CPUC-defined storage use cases
- EPRI team utilized inputs defined by CPUC its stakeholders to analyze storage project cost-effectiveness in 31 scenarios
- EPRI produced public report in June 2013: http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001162

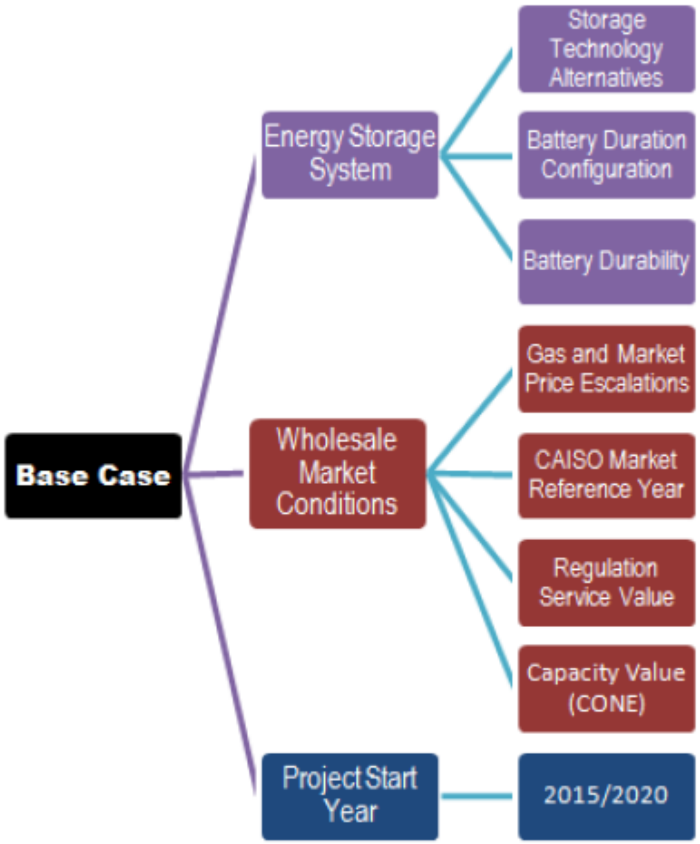
Analyzed 3 general use cases – walk before running

Category	Quantifiable Grid Services	CPUC Use Cases Incl. in Analysis		
		Bulk-"Peaker Sub"	Ancillary Services	Dist. Sub. Storage
Energy	Electric Supply Capacity	X		X
	Electric Energy Time-Shift	X		X
A/S	Frequency Regulation	X	X	X
	Spinning Reserve	X		X
	Non-Spinning Reserve	X		X
Transmission	Transmission Upgrade Deferral			
	Transmission Voltage Support			
Distribution	Distribution Upgrade Deferral			X
	Distribution Voltage Support			
Customer	Power Quality			
	Power Reliability			
	Retail Demand Charge Mgmt			
	Retail Energy Time-Shift			

The 1984 cell phone valuation approach –

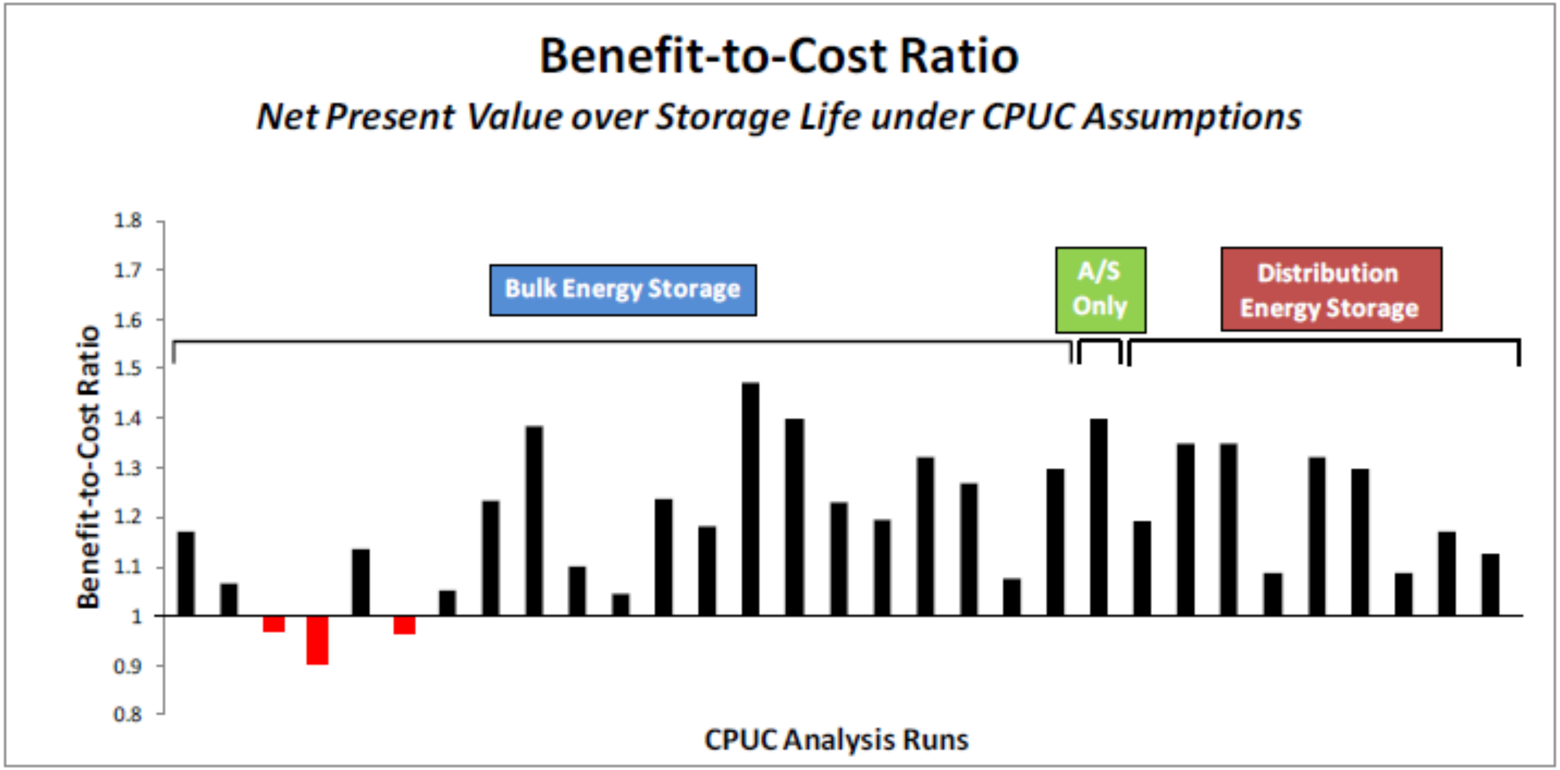
Quantifiable avoided cost and revenues

Investigated a variety of technical and economic scenarios and sensitivities



Only a subset of sensitivity results shown in this presentation

30,000 foot results overview



Conclusion: Under the cost, performance, and future value assumptions defined by CPUC (from its stakeholders), net present value of lifetime benefits exceeded lifetime costs in most cases.
Caveats: Modeled cost and performance has not been observed, future is uncertain. Does not evaluate impact of storage deployments on future valuation.

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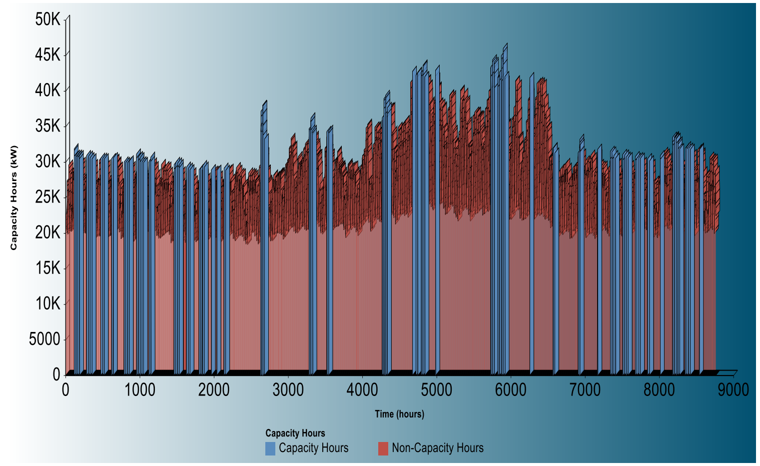
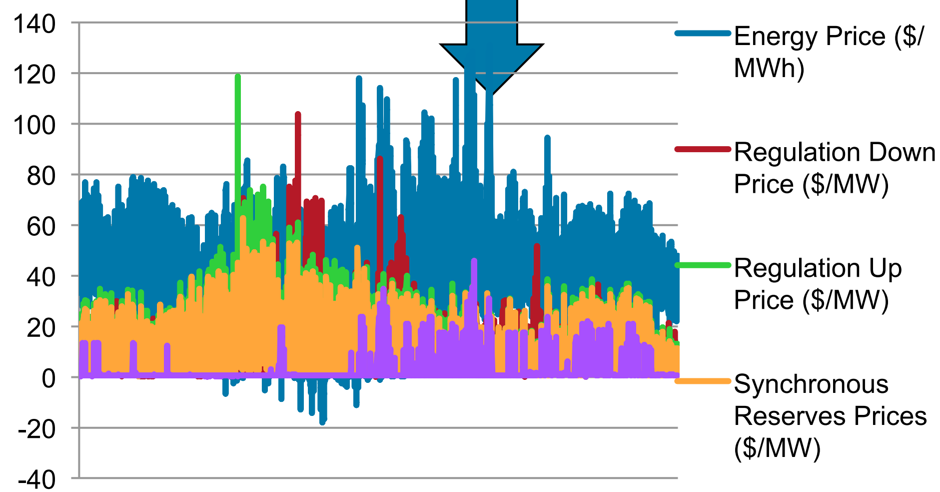
Use Case 1: Bulk Storage as Gas Peaker Substitution

- Reserve top 20 CAISO load hours per month for providing energy to earn system capacity value



- Co-optimize for profitability between energy and ancillary services (reg up, reg down, spin, non-spin)



Bulk Energy Storage Base Case with CPUC Inputs

- **Benefit/Cost Ratio** = 1.17
- **Breakeven Capital Cost:** $842/kWh ($1684/kW) in 2013 inflation adjusted dollars

<u>Base Case Inputs</u>

Year 2020

50MW, 2hr (battery)

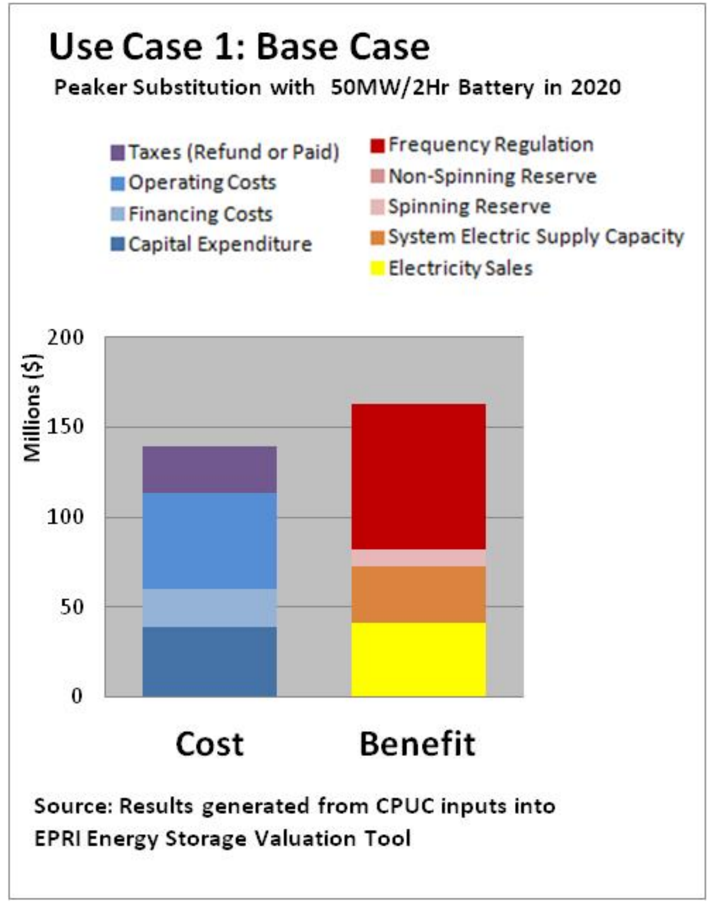
CapEx = $1056/kW, $528/kWh

1 Batt Replacement @ $250/kWh

11.5% discount rate

83% RT Efficiency

Energy & A/S prices escalated 3%/yr from CAISO 2011



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Sensitivity to Frequency Regulation Value

	Base Case	Base Case + 2x Reg	Base Case w/ o Reg
Breakeven Capital Cost in 2013 dollars	$842/kWh ($1684/kW)	$1593 /kWh ($3186/kW)	$433/kWh ($865/kW)

Input Summary

Year 2020

50MW, 2hr (battery)

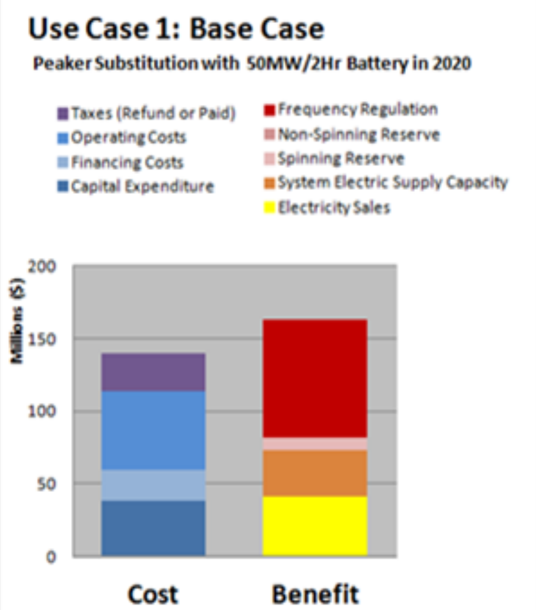
CapEx = $1056/kW, $528/kWh

1 Batt Replacement @ $250/kWh

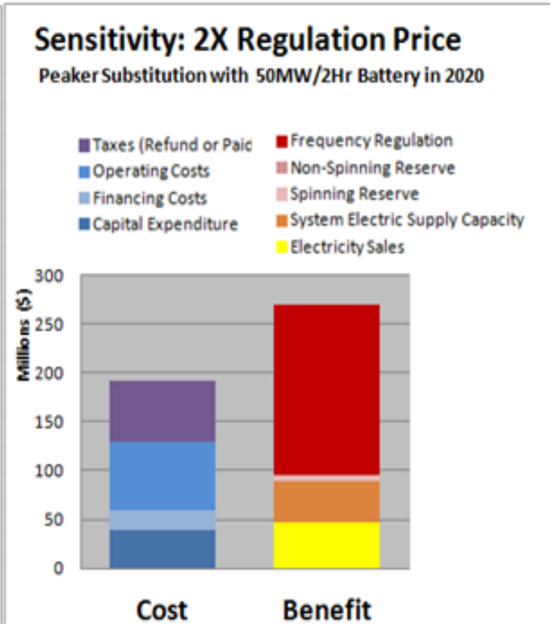
11.5% discount rate

83% RT Efficiency

Energy & A/S prices escalated 3%/yr from CAISO 2011



Source: Results generated from CPUC inputs into EPRI Energy Storage Valuation Tool



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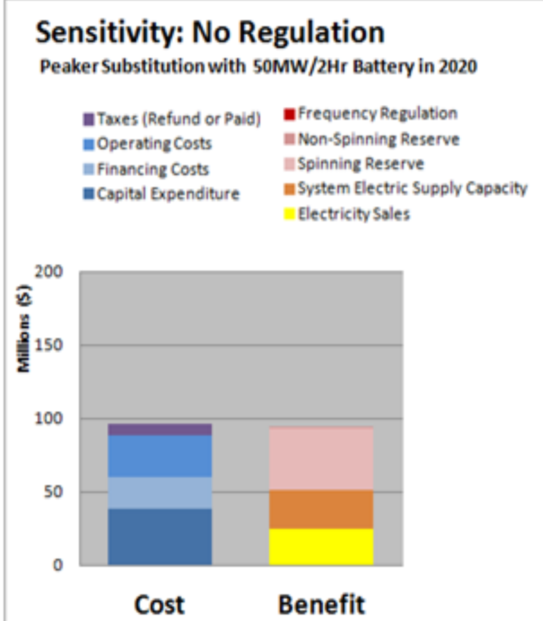
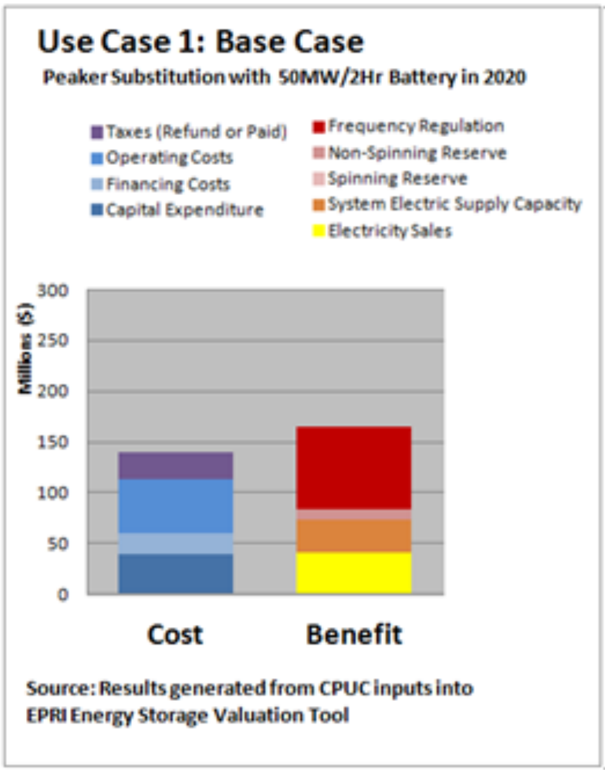
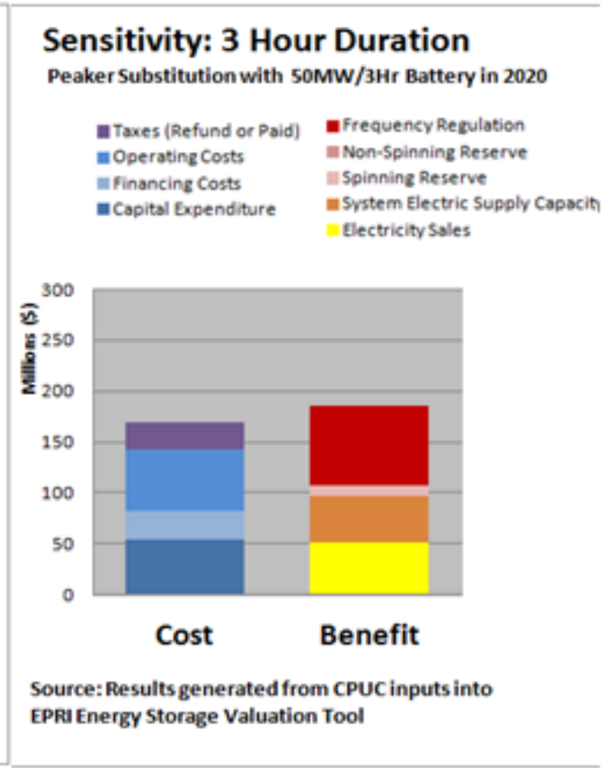


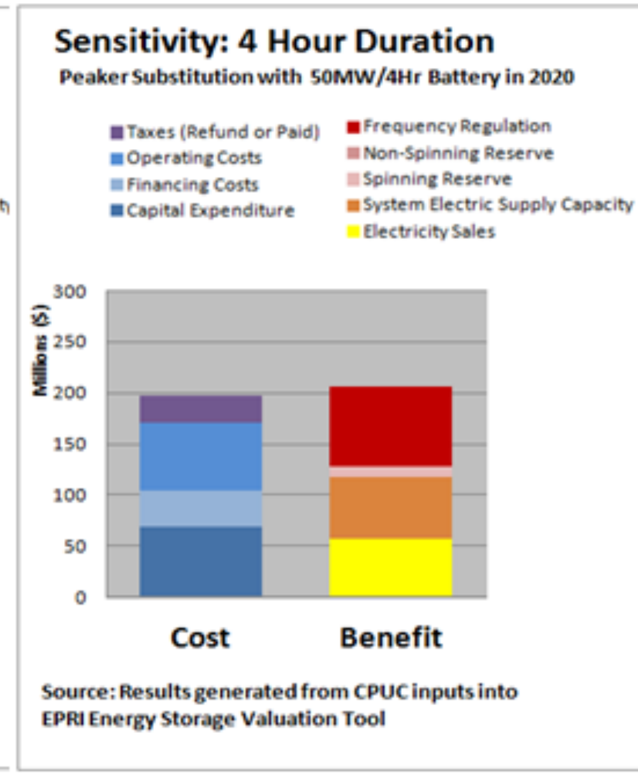
Source: Results generated from CPUC inputs into EPRI Energy Storage Valuation Tool

Sensitivity to Storage Duration Configuration Base Case (2hr) vs. 3hr vs. 4hr

	Base Case	Duration 3hr	Duration 4hr
Breakeven Capital Cost in 2013 dollars	$842/kWh ($1684/kW)	$594 /kWh ($1781/kW)	$465 /kWh ($1860/kW)







Base Case Inputs

Year 2020; 50MW, 2hr (battery); CapEx = $1056/kW, $528/kWh; 1 Batt Replacement @ $250/kWh; 11.5% discount rate; 83% RT Efficiency; Energy & A/S prices escalated 3%/yr from CAISO 2011

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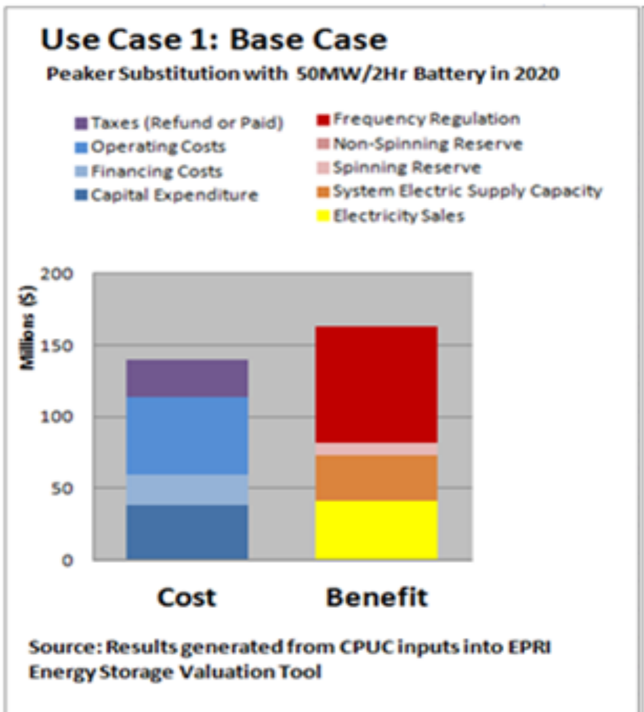
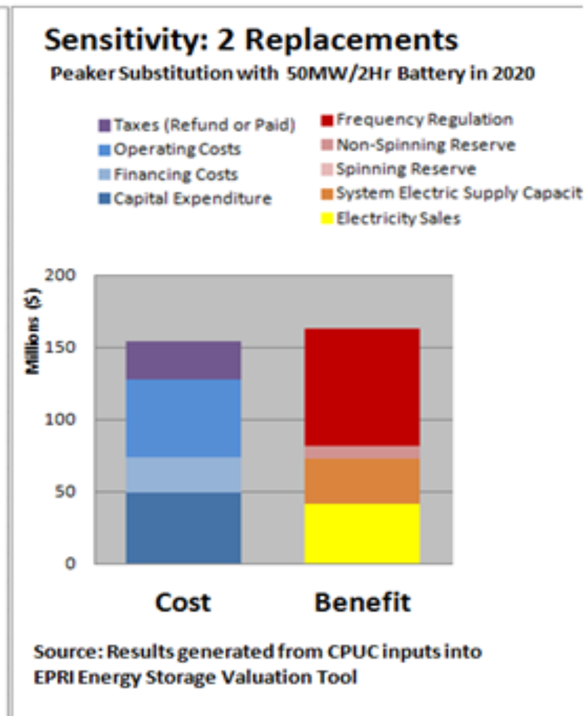
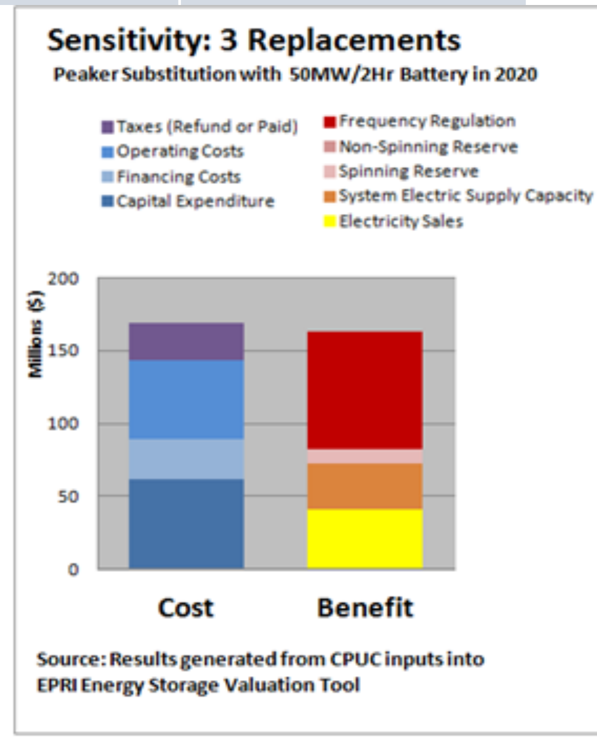
Sensitivity to Durability: Battery Replacement Frequency

No. of Replacements	Base Case	Base + 2X replacement	Base + 3X replacement
Breakeven Capital Cost in 2013 dollar	$842/kWh ($1684/kW)	$619 /kWh ($1238/kW)	$377 /kWh ($754/kW)







Base Case Inputs

Year 2020; 50MW, 2hr (battery); CapEx = $1056/kW, $528/kWh; Batt Replacements @ $250/kWh; Battery replacements equally spaced over 20 yr life; 11.5% discount rate; 83% RT Efficiency; Energy & A/S prices escalated 3%/yr from CAISO 2011

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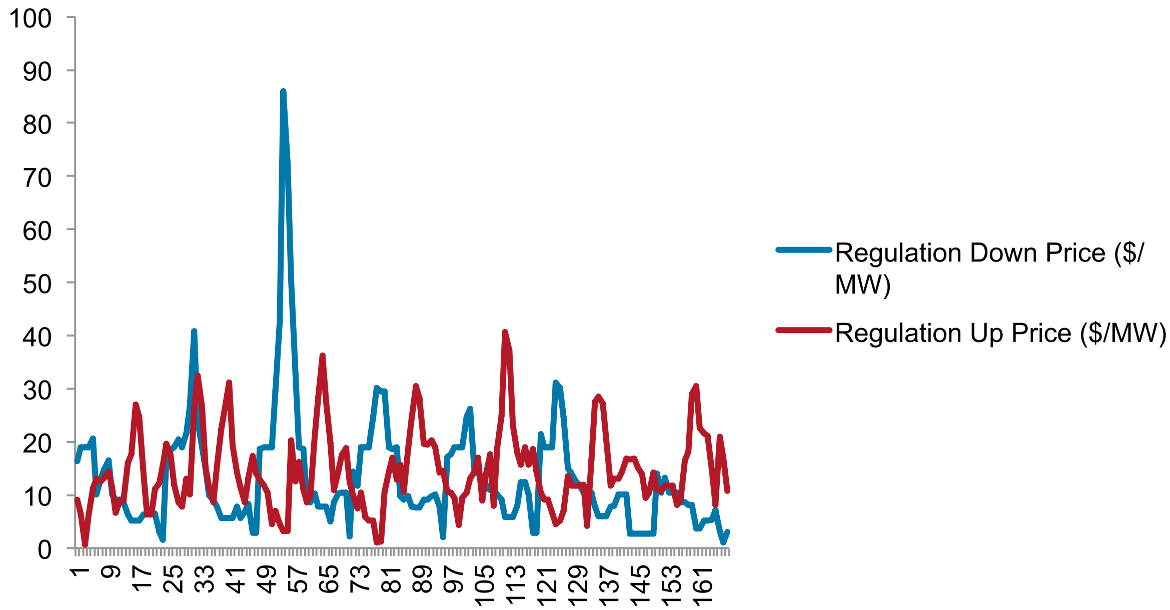
Use Case 2: Fast Frequency Regulation

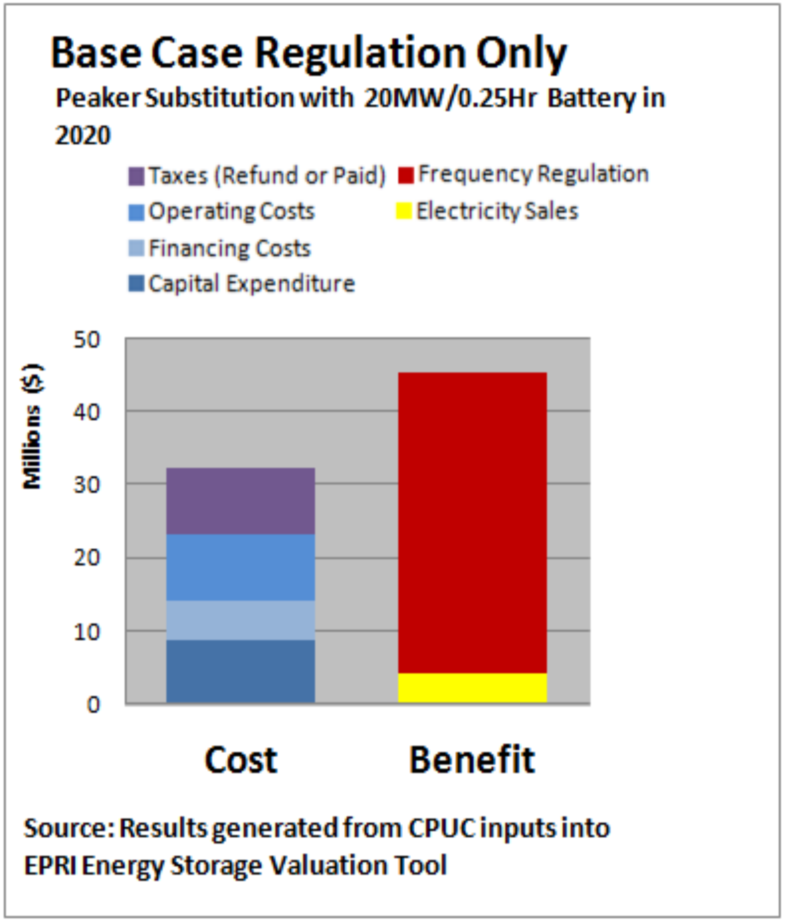
- Optimize for profitability between regulation up, regulation down, and no action; manage storage state-of-charge
- Account for associated charging / discharging costs and revenues



Ancillary Services: Fast Frequency Regulation Only

B/C Ratio	1.40
Breakeven Capital Cost in 2013 dollars	$1678/kW ($6712/kWh)

Category	Input	2020
		Battery
Technology Cost / Performance	Nameplate Capacity (MW)	20
	Nameplate Duration (hr)	0.25
	Capital Cost ($/kWh) -Start Yr Nominal	3112
	Capital Cost ($/kW) - Start Yr Nominal	778
	Project Life (yr)	20
	Roundtrip Efficiency	83%
	Variable O&M ($/kWh)	0.00025
	Fixed O&M ($/kW-yr)	15
	Major Replacement Frequency	1
	Major Replacement Cost ($/kWh)	250
	MACRS Depreciation Term (yr)	7



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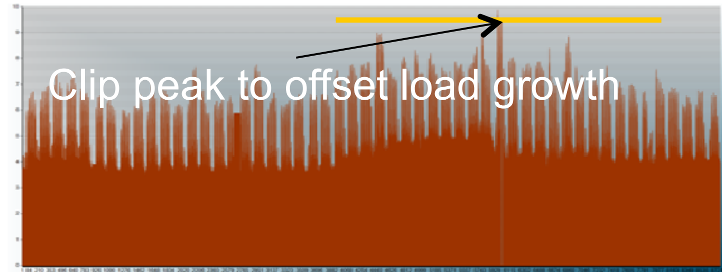
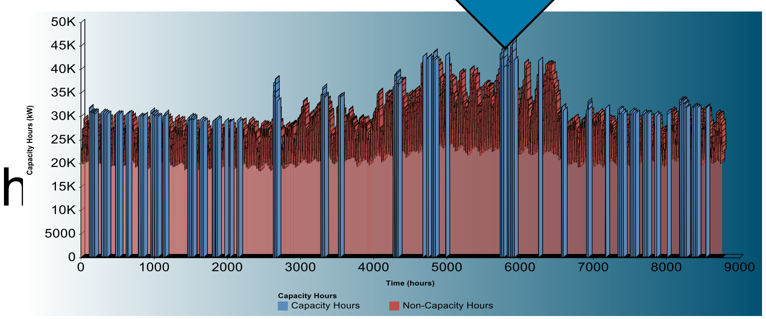
Use Case 3: Distributed Peaker with Distribution Asset Upgrade Deferral

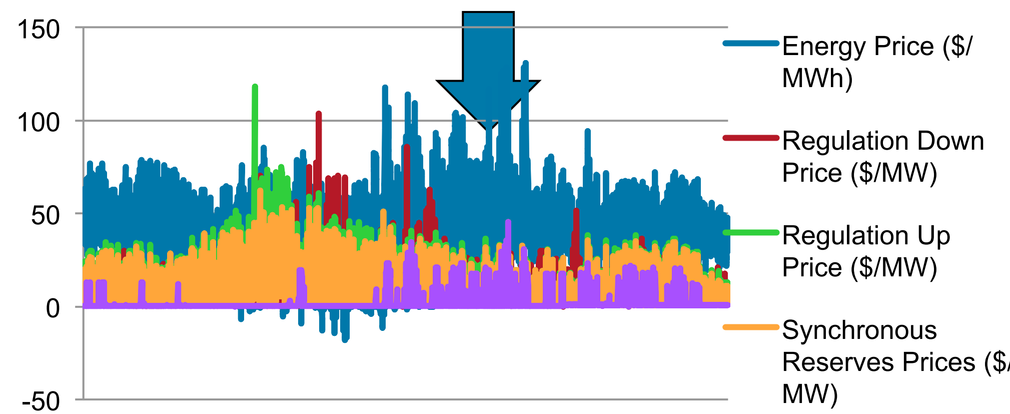
- Top priority: Peak shave annual peak distribution load to offset load growth and defer upgrade investment for years



- Second priority: Reserve Top 20 CAISO load hours per month for providing energy



- Co-optimize for profitability between energy and ancillary services (reg up, reg down, spin, non-spin)



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Distribution Storage at Substation Result

- **Benefit/Cost Ratio** = 1.19
- **Breakeven Capital Cost:**

  $866/kWh ($3464/kW)

<u>Base Case Inputs</u>

Year 2015

1MW, 4hr (battery)

CapEx = $2000/kW, $500/kWh

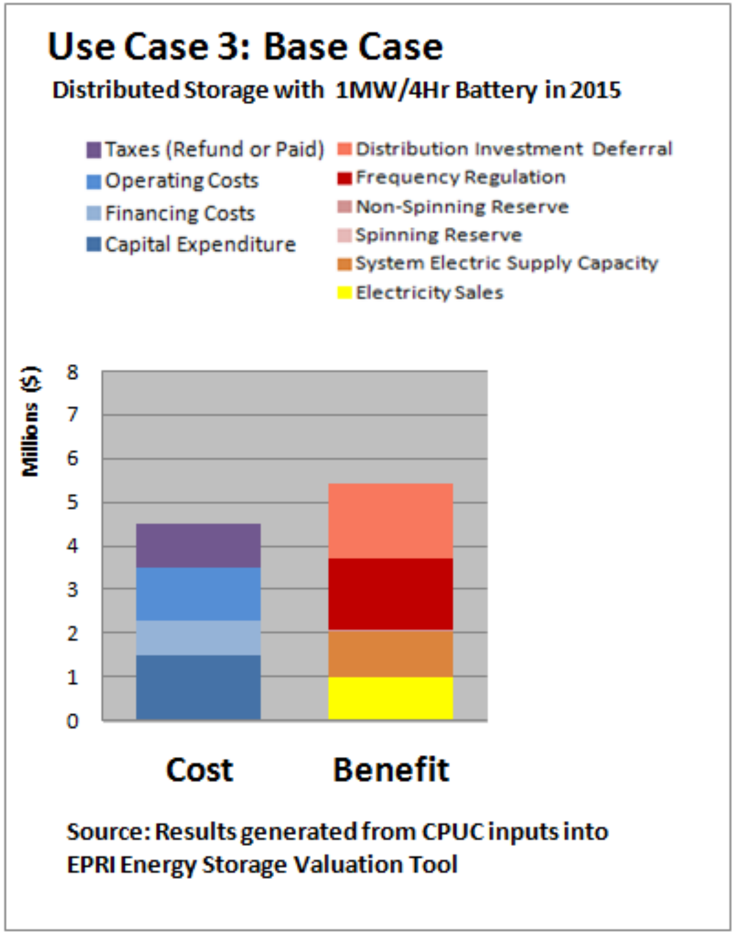
11.5% discount rate

83% RT Efficiency

Energy & A/S prices escalated 3%/yr from CAISO 2011

$279/kW upgrade cost

2% load growth rate



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Sensitivity to Load Growth: 2% (base) vs. 4% annual

	Base Case (2%)	Base Case (4%)
Breakeven Capital Cost in 2013 dollars	$866/kWh ($3464/kW)	$634 /kWh ($2537/kW)

Inputs

1MW, 4hr (battery)

CapEx = $2000/kW, $500/kWh

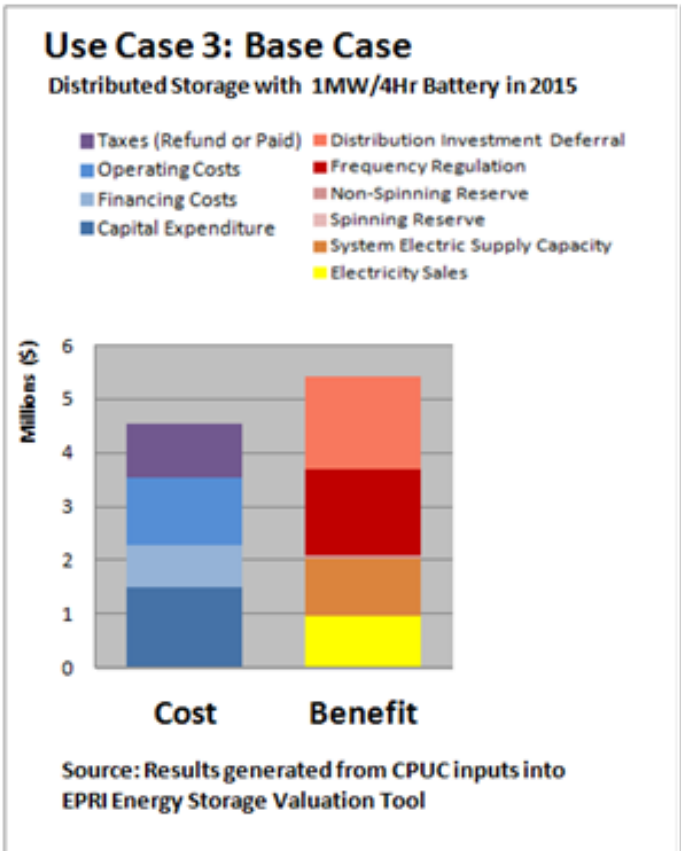
11.5% discount rate

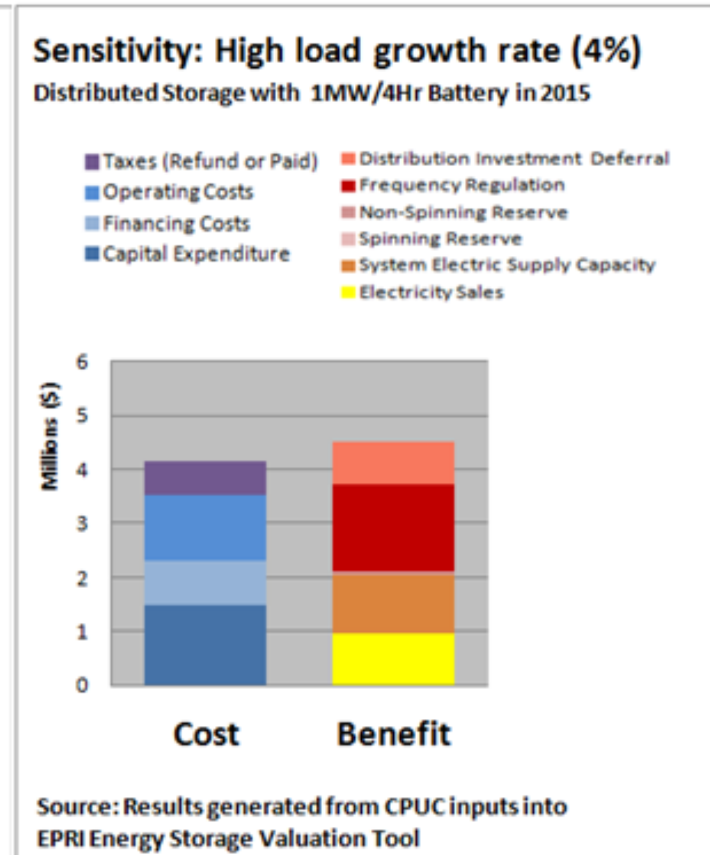
83% RT Efficiency

Energy & A/S prices escalated 3%/yr from CAISO 2011

$279/kW upgrade cost

2% load growth rate





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Key Conclusions from California Storage Cost-Effectiveness Investigation

- Transparent, stakeholder-defined analysis for energy storage project value estimation is possible
- Using storage industry capability assumptions for 2015/2020 and forward-looking projections based off reference historical values, storage could make economic sense
  - Using 1984 cell phone valuation approach
- Energy storage duration, lifespan/durability, and cost are very key sensitivities
- Highest value “traditional benefits” appear to be deferral of underutilized fixed generation / T&D costs; also frequency regulation (but how much is needed?)

CPUC Energy Storage Decision

Post-Analysis: California Storage Procurement Target

- 1.325 GW of storage in California by 2020
  - Pumped hydro >50 MW not eligible
- Bi-annual targets (starting in 2014) with location / utility breakdown
  - ~30% CAGR of storage capacity until 2020
- Procurement through Request for Offer
- Deferment possible if storage not cost-effective (Up to 80%)
- No more than 50% utility ownership, regardless of interconnection point
- Details available at: http://www.cpuc.ca.gov/PUC/energy/electric/storage.htm

CPUC Storage Procurement Targets – Very Specific

Proposed Energy Storage Procurement Targets (in MW)[22]

Storage Grid Domain Point of Interconnection	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	**90**	**120**	**160**	**210**	**580**
Pacific Gas and Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	**90**	**120**	**160**	**210**	**580**
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	**20**	**30**	**45**	**70**	**165**
Total - all 3 utilities	**200**	**270**	**365**	**490**	**1,325**

From "Proposed Decision of Commissioner Peterman Adopting Energy Storage Procurement Framework and Design Program", published 3 Sep 2013, adopted17 Oct 2013

Remaining Challenges

Challenges Ahead

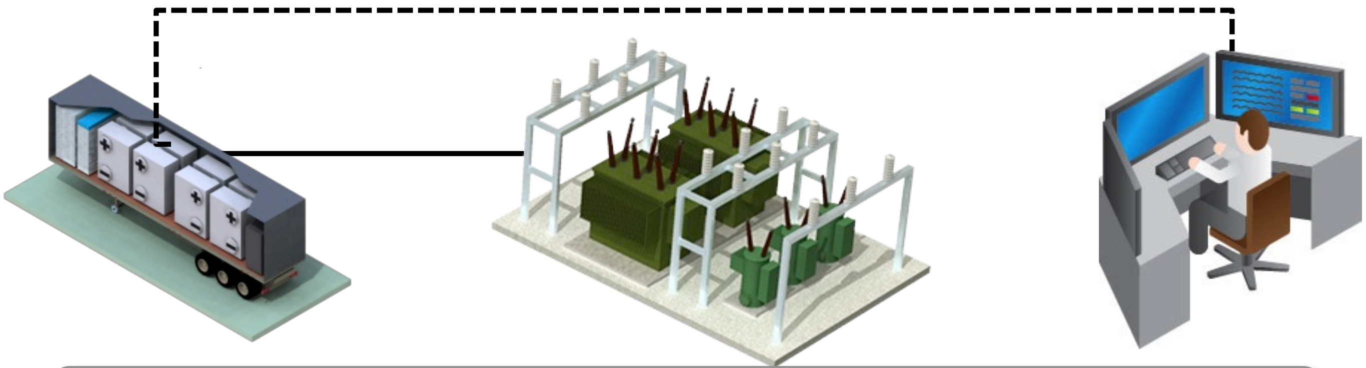
- Commercial tools for understanding the value and grid impacts of storage are still in development
- Grid-ready technology solutions are the exception, not the rule
- Grid deployment, integration, and operation of storage are still major unknowns

Technology solutions will not be viable without a concerted and targeted, industry-wide effort

Users of Energy Storage Need Fully Integrated Products to Unlock the Value of Storage

- System Development

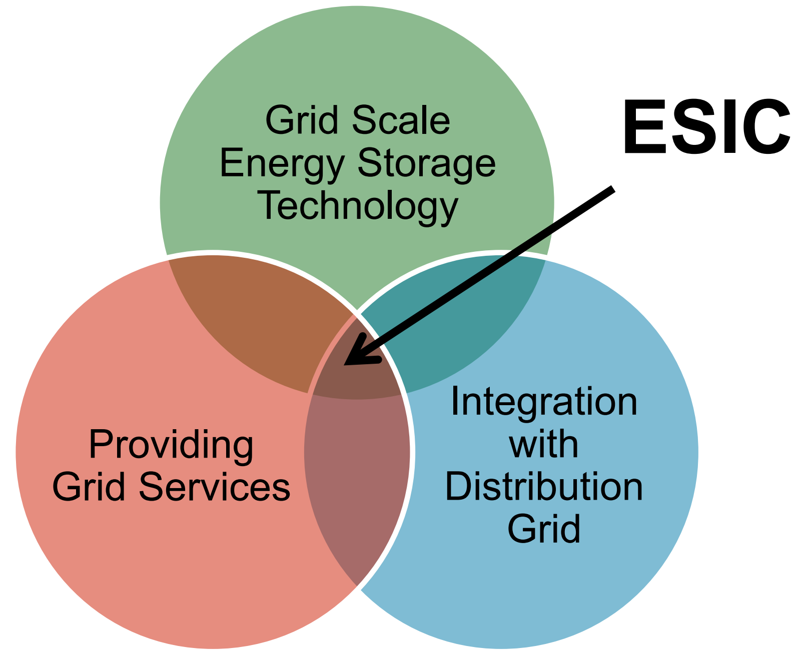
- Grid Integration

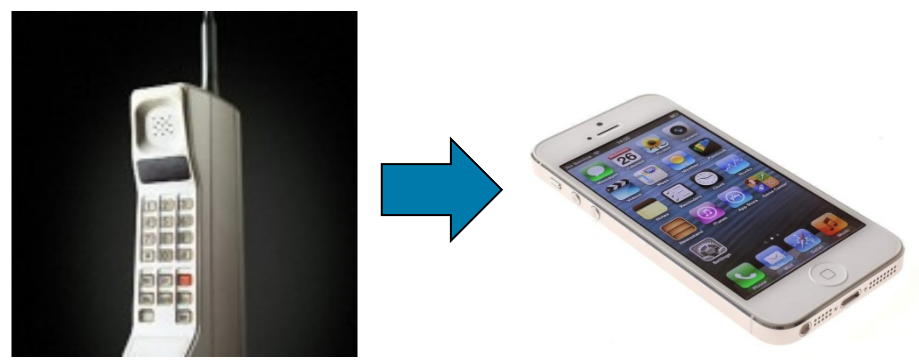


Technology solutions will not become viable without a concerted, targeted, industry-wide effort

The EPRI Energy Storage Integration Council (ESIC)

A technical forum to collaborate on common approaches for the development and deployment of safe and reliable energy storage solutions, based upon seamlessly integrated, customizable, and cost-effective energy storage products.





Seamlessly integrated solutions are better!

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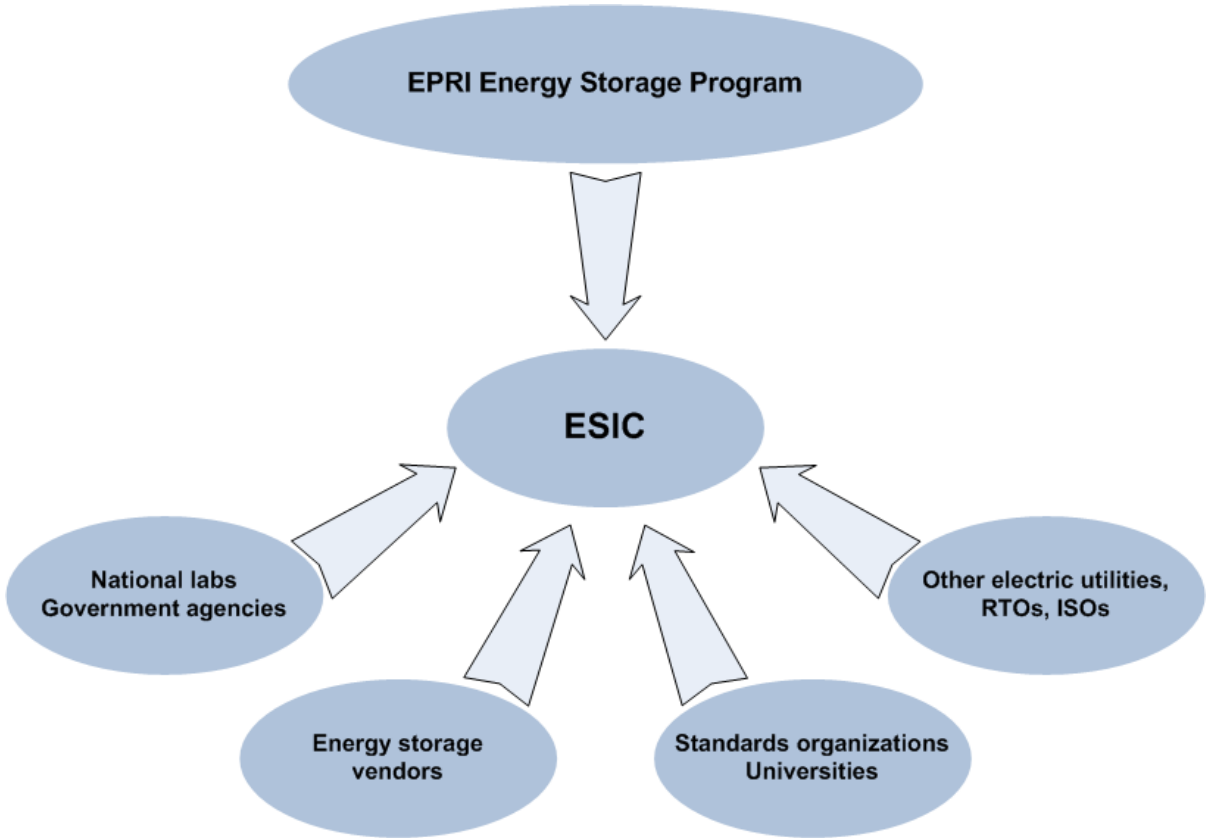
Collaborators Welcome

- EPRI funds and facilitates ESIC for all key stakeholders supporting its mission and activities



Together…Shaping the Future of Electricity

Thank you for your time!

Ben Kaun

Energy Storage Program

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