Energy Storage Cost Effectiveness Evaluation,
DNV KEMA Modeling for CPUC Energy Storage Proceeding

Energy Storage Panel, EAC Meeting

June 6, 2013

Common Pitfalls

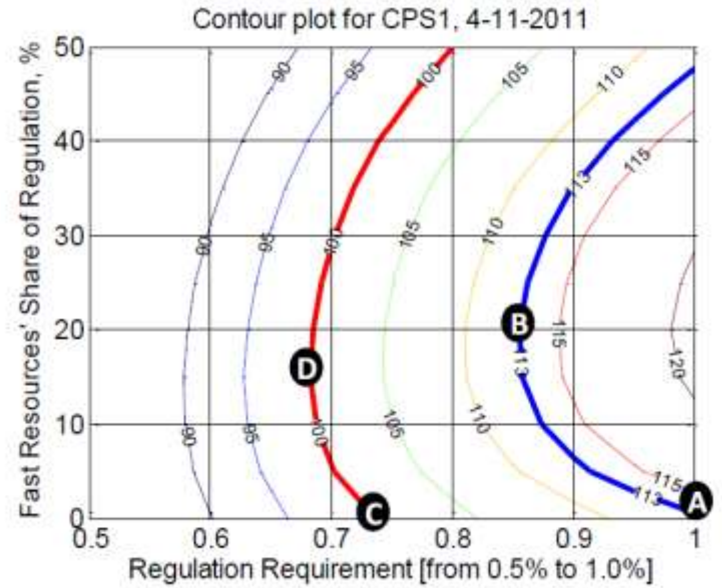
- Using historical prices
  - Prices are likely to change due to rule modifications, changes in regulation supply resources over time, changes in regulation needs over time
  - Depending on the amount of storage added to the market, the introduction of storage can change market prices
- Modeling deterministic behavior (perfect performance assuming knowledge of upcoming prices)
  - Future prices are unknown and actual revenues will likely not reflect strategy that gets maximum revenue 100% of the time
- Ignoring system effects
  - In addition to affecting prices, certain amounts of storage can affect imports/exports
  - Resource response times (portfolio, not just storage) can affect ancillary service needs and relative dispatch
  - Traditional production costing tools are not designed for maximizing system benefit with storage

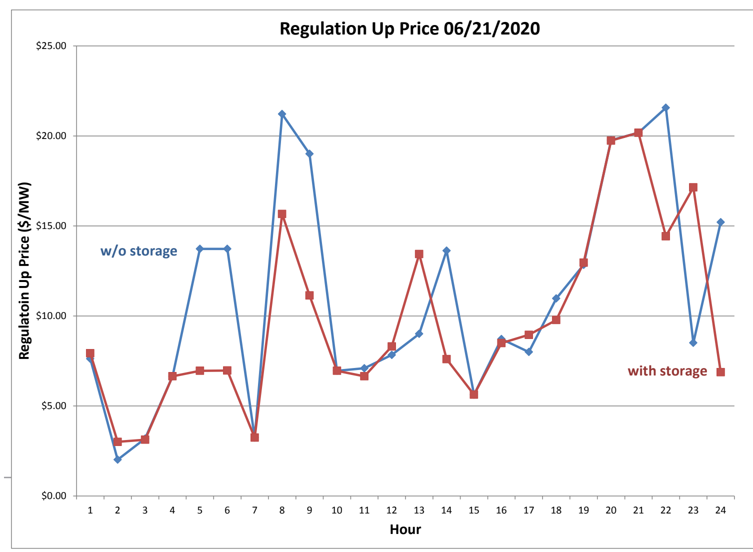
Why Systems Analysis for Energy Storage?

System

- Increasing the mixture of fast response resources can reduce system regulation requirements, to a point of diminishing returns.
- This point of diminishing returns is determined in part by the dispatch algorithm.

→ Graph from PJM FERC 755 Filing illustrates this effect. (The fast regulation signal at PJM has zero net energy over 5 minutes. This allows shorter duration storage to provide services).





Individual

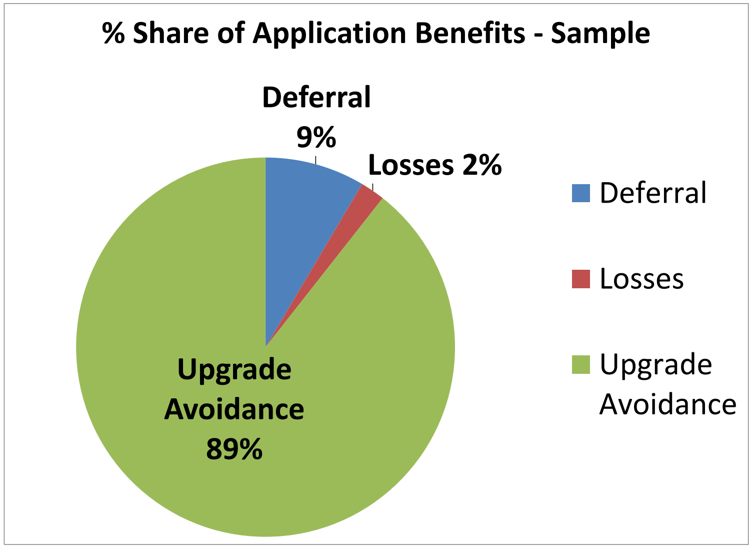
- Pay-for-performance (P4P) will attract fast response resources. How will prices for change as more fast response resources join the mix?
- Computing P4P revenues requires knowing *what the control signal will look like with significant fast resources in the mix. Last year's prices will not give a good projection.*

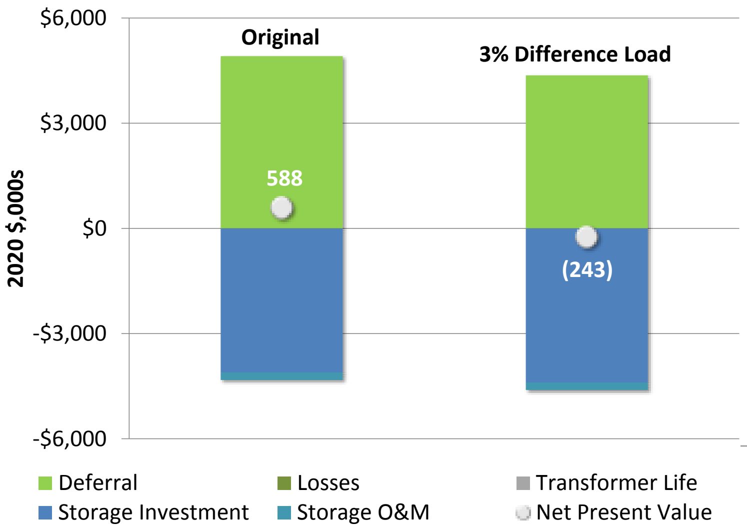
Why Systems Analysis for Energy Storage? (2)

System

- On the distribution system, storage cause indirect effects, such as changing system losses or facilitating upgrade deferral (while supporting PV).
- Storage sizing can also effect ability to accrue benefits, and some benefits are step changes (e.g., upgrade deferral or avoidance)

→ Graph from interim results, CPUC Rulemaking Cost-Effectiveness Analysis. (Distribution storage for PV integration).





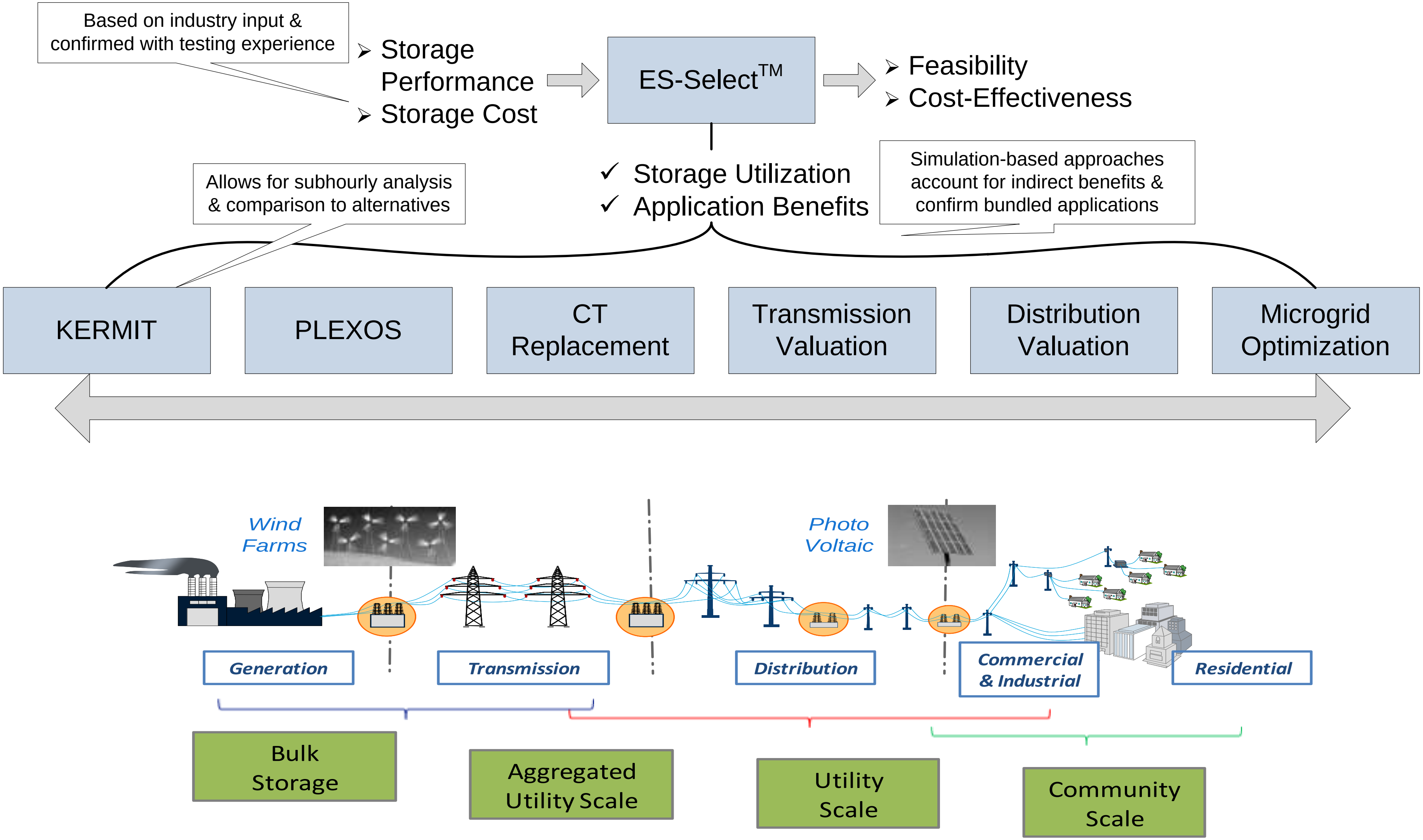
Individual

- For the same set-up and storage control scheme, small changes in estimated load can result in big change in cost-effectiveness estimates.
- *Using a single data series can to estimate value can over or underestimate total value.*
- Better approaches are needed for dealing with stochastics.

Energy Storage Valuation, CPUC Use Cases

Phase	Category	Priority	Use Case Prioritization	Primary Benefit	Conventional Technology Priority #1	Storage Technology Priority #1	Storage Technology Priority #2	Storage Technology Priority #3
Phase 1	T-Connected Bulk Storage	1	Peaker Plant	Capacity, Energy, A/S	CT	Battery	Flow Battery	
		2	Ancillary Services Only	A/S	CT	Flywheel	Battery	
		3	Base Load Plant	Capacity, Energy	CCGT	Pumped Hydro	CAES	Flow Battery
	Distribution Energy Storage	**4**	Distributed Peaker	Upgrade deferral & Market $	Circuit Upgrade & CT	Battery	Flow Battery	
		5	Substation-Sited Storage	Voltage Reg	Circuit Upgrade	Battery		
		6	Community Energy Storage	Voltage Reg	Circuit Upgrade	Battery		
Phase 2	Behind-the-Meter Energy Storage	**7**	Behind the Meter	Bill Mgt/ Avoid Cost, Market $	Circuit Upgrade & CT	Battery	Flow Battery	
		8	Behind the Meter Utility Controlled	Bill Mgt/ Avoid Cost, Market $, Grid Rel	Circuit Upgrade & CT	Battery	Flow Battery	
		9	Permanent Load Shifting	Bill Mgt/ Avoid Cost, Grid Rel	CT	Thermal	Battery	

Energy Storage Valuation, Applying a Systems Perspective



Approach Overview: Energy Storage Ancillary Services

PLEXOS

- Simulate unit commitment & production costs for varying levels of storage penetration providing regulation
- Regulation capacity awards
- Regulation costs
- Generator commitments

KERMIT

- Simulate system operation for varying levels of storage penetration providing regulation
- Evaluate operational statistics for each level of storage penetration
- Develop benefits curve

Benefit Cost Analysis

- Estimate mileage bids & costs
- Calculate total regulation payments for each case
- Calculate total production costs for each case
- Calculate emissions for each case
- Determine system benefits for storage participating in AS

Rerun PLEXOS cases based on updated required regulation capacity (KERMIT result)

Approach Overview: Energy Storage Ancillary Services (2)

PLEXOS

- Add storage unit to base case
- Assess change in regulation costs
- Determine hourly regulation capacity awards
- Determine hourly generation commitments

KERMIT

- Use PLEXOS results to initialize KERMIT
- Determine regulation mileage
- Determine regulation performance (ACE, NERC metrics)
- Identify net hourly regulation energy

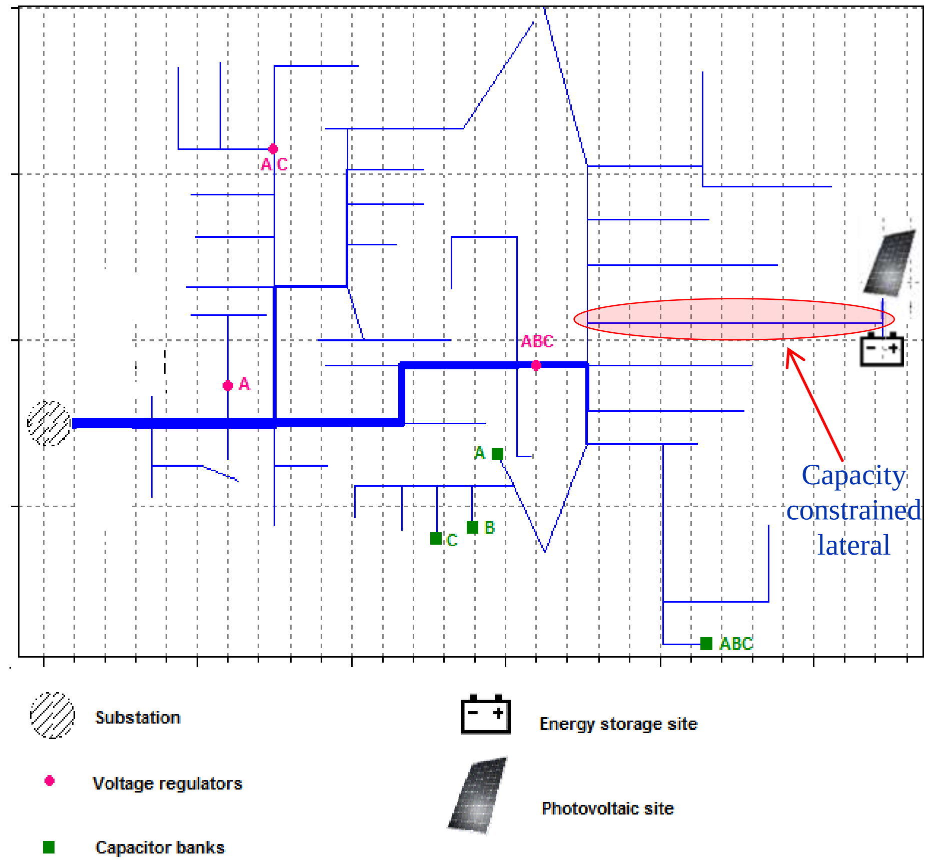
Benefit Cost Analysis

- Estimate mileage bids
- Calculate total regulation payments
- Breakeven pro forma analysis for storage device

Approach Overview: Distribution Storage

Physical Modeling

- Distributed large-scale, utility-owned PV plant
  - Co-located energy storage, point of interconnection at primary distribution level
  - IEEE 123 Test Node Feeder with sample planning load profiles
  - 1500 kW PV plant (CA-based NREL profile)
  - PV sited on lengthy capacity constrained lateral (per-phase capacity limit 354 kW)
  - 5,000 kVA substation transformer with 90% loading



coincident peak Total Load	PF	kW 4,049	kVAR 2,017	kVA 4,523
% Residential	0.87	17%	19%	18%
% Commercial	0.85	52%	64%	55%
% Industrial	0.8	27%	41%	30%

Financial Modeling

- Financial calculations focus on asset investments
  - Sensitivities test storage cost, storage sizing, re-conductoring cost and deferral value

Approach Overview: Behind the Meter Storage

- Simulation of customer storage and PV for bill management is used to estimate demand side energy storage cost-effectiveness.
- Time horizon of financial evaluation is 15 years.
- Storage operation is simulated on a hourly basis, over 24 hour periods for the time-horizon of financial evaluation.
- Storage is operated to co-minimize energy and demand charges as applicable under the tariff structure of the scenario.
- Cost areas – Capital cost of storage and interface, capital cost of Solar PV (if applicable), O&M costs, financing charges
- Operational benefit areas – Energy charge reduction, demand charge reduction
- Incentives – SGIP incentive for storage, CSI incentive for solar PV, FITC rebates for solar PV and storage (if applicable), tax benefit from accelerated depreciation

CPUC Rulemaking

- Develop a cost effectiveness (CE) evaluation methodology leveraging existing modeling tools
- Perform example use of the CE methodology for a subset of the Phase 1 prioritized energy storage (ES) use cases

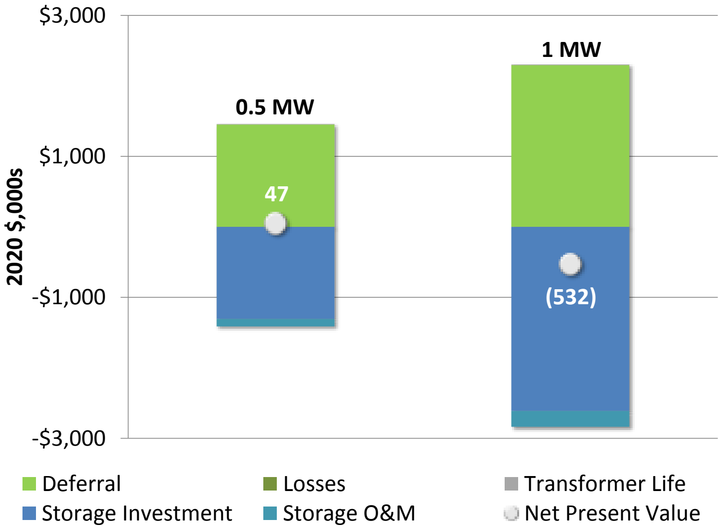
From R.10-12-007

> “(d) Ensure that the energy storage system procurement targets and policies that are established are technologically viable and ***cost effective***.” [emphasis added]

DNV KEMA is developing a methodology to inform the discussion rather than to propose a methodology for approval by the CPUC. Furthermore, examples of the CE methodology are not intended to determine energy storage CE.

Interim Use Case Results (Final coming soon…)

More available at: http://www.cpuc.ca.gov/PUC/energy/electric/storage.htm



Deferral is the primary benefit, and indirect benefits include loss savings. (Reliability benefits weren't translated to economic value). Sizing around this application produces the greatest cost-effectiveness.

Energy cost management proved to be cost-effective, particularly where tariff structures, storage size and load shapes coordinated well. (i.e., this case requires demand charges/TOU rates, and will not work for all customer profiles).

IRR 16.76%

Scenario set up							
Load		Resources		Tariffs		Financing	
Building	School	Solar PV	50 KW	2012	SDGE AL-TOU	% Debt	0.00%
Peak demand in 2012	900	Storage power capacity	50 KW	2013 - 2017	SDGE AL-TOU	Debt financing rate	7.49%
End use escalation rate	0.30%	Storage duration	2 hours			Equity hurdle rate	5.00%
Costs							
Solar PV ($/KW)	$5,440	Storage energy ($/KWhr)	$1,780	Storage power ($/KW)	$920		

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