SOUTHERN CALIFORNIA EDISON®

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Energy Storage Overview

SCE's Approach to Evaluating Energy Storage

January 12, 2011

EXECUTIVE SUMMARY

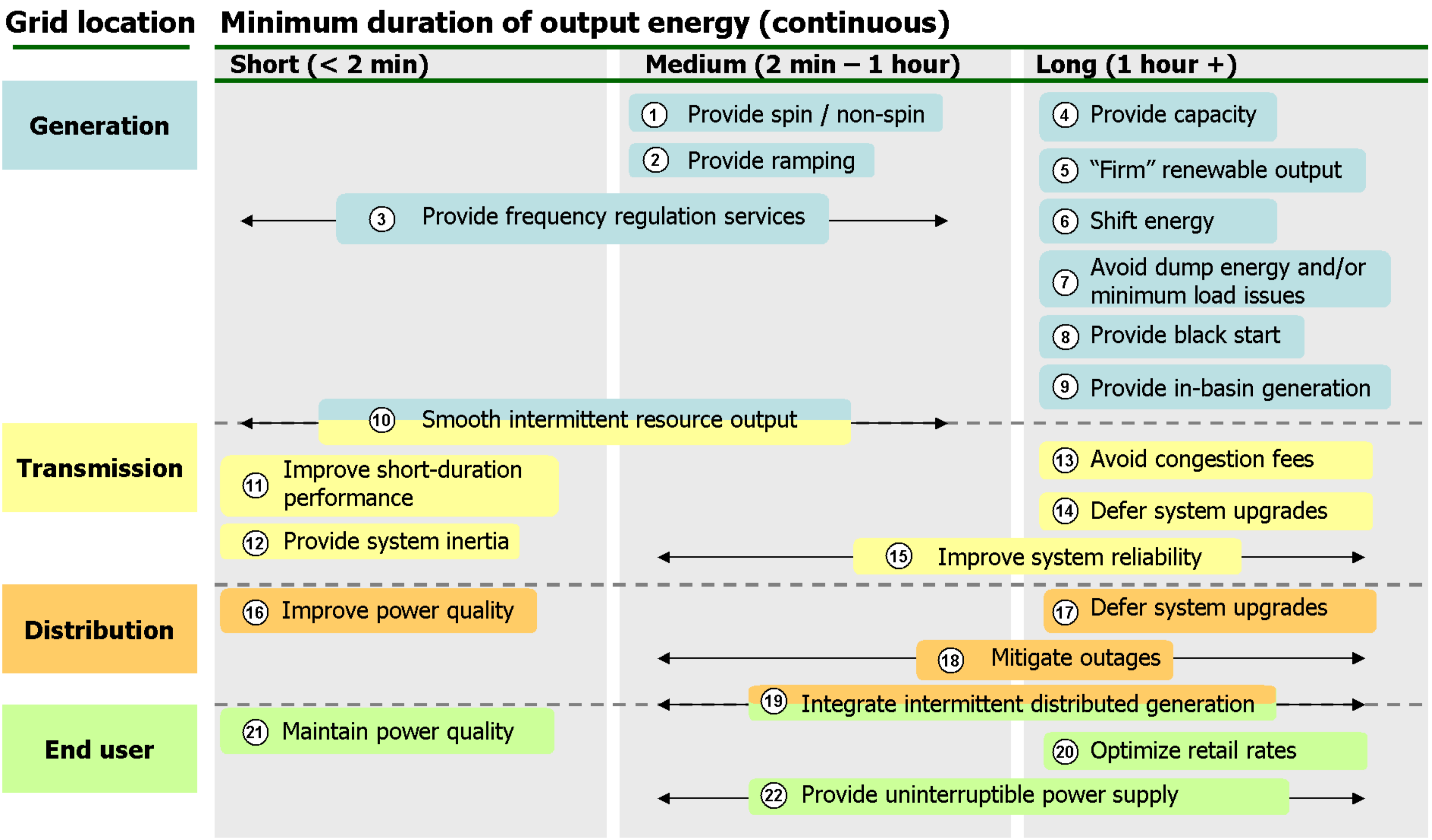
- SCE's long-standing interest in energy storage continues today through a comprehensive strategic planning effort.
- SCE approaches energy storage from the perspective of potential applications, and not technology capabilities.
- Energy storage is a broad and heterogeneous category, made up of numerous distinct operational uses and technologies.
- A primary challenge facing energy storage is to develop and evaluate specific and practical applications. Costs and benefits are situation-dependent, and will vary based on the nuances of each particular project.
- Much work remains to demonstrate applications in reality while resolving potential regulatory / policy issues and refining benefit / cost evaluations.

SCE'S APPROACH TO ASSESSING ENERGY STORAGE

- **Step 1:** Identify operational uses
- **Step 2:** Develop practical applications
- **Step 3:** Match applications with technologies
- **Step 4:** Evaluate application-technology pairs

SCE approaches energy storage from the perspective of potential applications, and not technology capabilities.

POTENTIAL OPERATIONAL USES FOR STORAGE



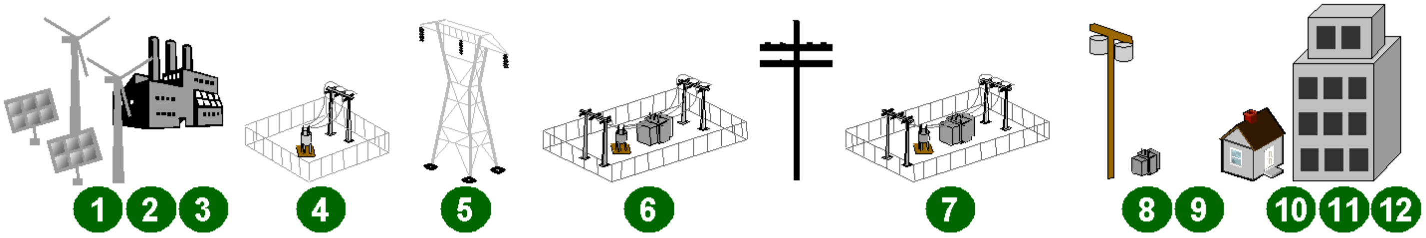
Grid location | **Minimum duration of output energy (continuous)**

Grid location	Short (< 2 min)	Medium (2 min – 1 hour)	Long (1 hour +)
Generation	③ Provide frequency regulation services	① Provide spin / non-spin ② Provide ramping	④ Provide capacity ⑤ "Firm" renewable output ⑥ Shift energy ⑦ Avoid dump energy and/or minimum load issues ⑧ Provide black start ⑨ Provide in-basin generation
Generation / Transmission	⑩ Smooth intermittent resource output		
Transmission	⑪ Improve short-duration performance ⑫ Provide system inertia	⑮ Improve system reliability	⑬ Avoid congestion fees ⑭ Defer system upgrades
Distribution	⑯ Improve power quality	⑱ Mitigate outages	⑰ Defer system upgrades
Distribution / End user		⑲ Integrate intermittent distributed generation	
End user	㉑ Maintain power quality	㉒ Provide uninterruptible power supply	⑳ Optimize retail rates

Energy storage is a broad and heterogeneous space made up of numerous potential operational uses across the electric value chain.

DEVELOPING STORAGE APPLICATIONS

Application	Description
① **Off-to-on peak intermittent energy shifting & firming**	Charge at the site of off-peak renewable and / or intermittent energy sources; discharge “firmed” energy onto grid during on-peak periods.
② **On-peak intermittent energy smoothing & shaping**	Charge / discharge seconds-to-minutes to smooth intermittent generation, and / or charge / discharge minutes-to-hours to shape energy profile.
③ **Ancillary service provision**	Provide ancillary service capacity in day-ahead markets and respond to ISO signaling in real time.
④ **Black start provision**	Unit sits fully charged, discharging when black start capability is required.
⑤ **Transmission infrastructure**	Use an energy storage device to defer upgrades or other technology on the transmission system.
⑥ **Distribution infrastructure**	Use an energy storage device to defer upgrades or other technology on the distribution system.
⑦ **Transportable distribution-level outage mitigation**	Use a transportable storage unit to provide supplemental power to end users during outages due to short-term distribution overload situations.
⑧ **Peak load shifting downstream of distribution system**	Charge device during off-peak downstream of the distribution system (below secondary transformer); discharge during 2-4 hour daily peak period.
⑨ **Intermittent distributed generation integration**	Charge / discharge device to balance local energy use with generation. Sited between the distributed generation & distribution grid to defer otherwise necessary distribution infrastructure upgrades.
⑩ **End-user time-of-use rate optimization**	Charge device when retail TOU prices are low, discharge when high (and / or to avoid demand response curtailment periods / charges).
⑪ **Uninterruptible power supply**	End-user deploys energy storage to improve power quality and / or provide back-up power during outages.
⑫ **Micro grid formation**	Energy storage is deployed in conjunction with local generation to separate from the grid, creating an islanded micro-grid.



SCE developed 12 representative storage applications.

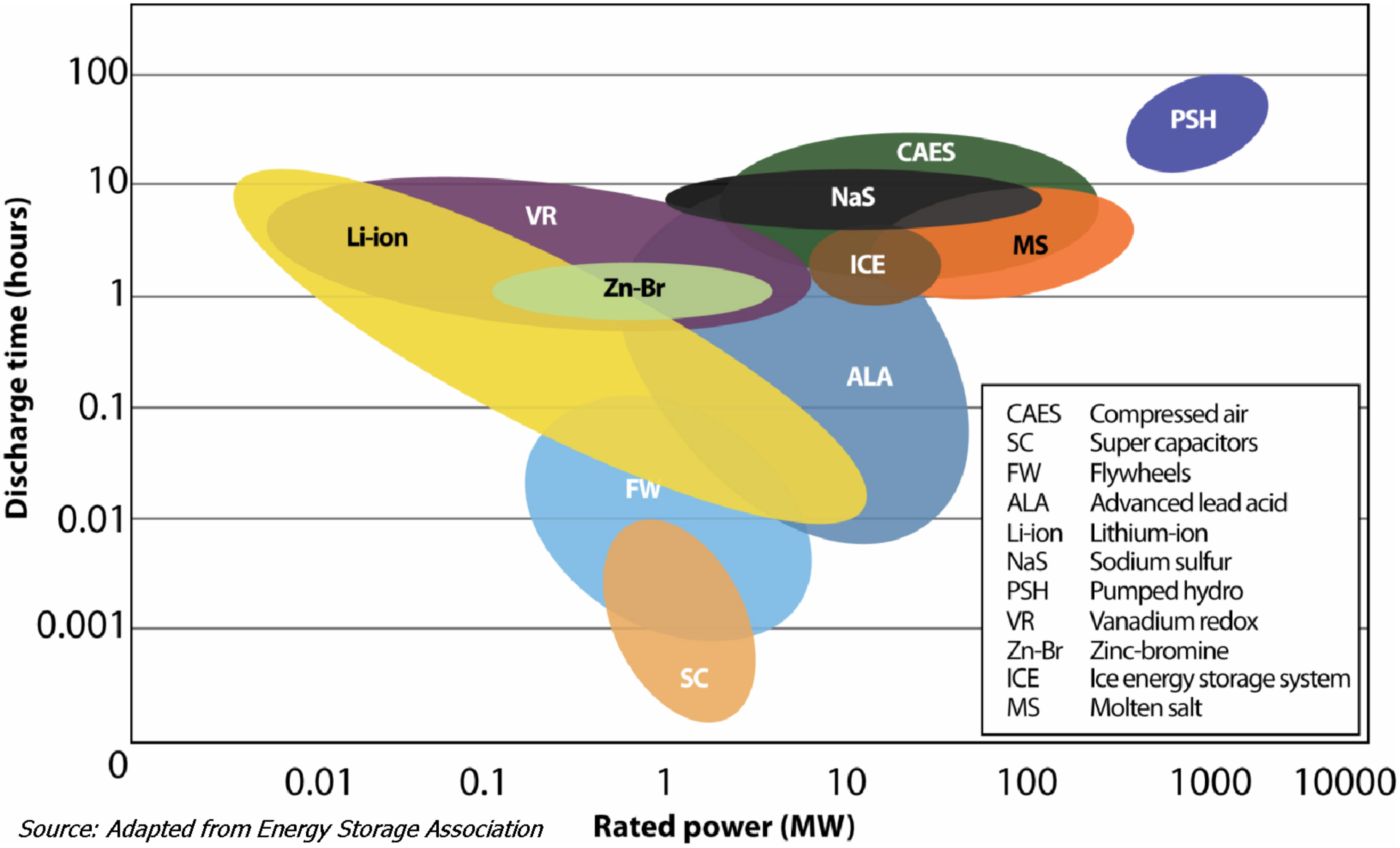
OPERATIONAL USES & APPLICATIONS

Application #: **Operational uses**	1 Off-to-on peak energy firming (G)	2 Intermittent energy smoothing (G)	3 Ancillary services (G)	4 Black start (G or T)	5 Infra-structure improvement (T)	6 Infra-structure improvement (D)	7 Outage mitigation (D)	8 Peak load shifting (D)	9 Intermittent DG integration (D or E)	10 End user rate optimization (E)	11 UPS (E)	12 Micro grid formation (E)
Spin / non spin			☑									
Ramping			☑									
Reg up / reg down			☑									
Resource adequacy / dependable operating capacity	☑							☑	●			●
Renewable output firming	☑											
Energy shifting - arbitrage	☑	●	●				☑	☑				
Avoid dump energy / minimum load issues	●						●	●				
Black start				☑								
In-basin generation								●	●			
Intermittent energy smoothing	☑	☑							●			
Short duration performance	●	●			●							
Inertia					●							
System reliability	●	●			●							
Congestion fee avoidance	●	●			●			●				
Upgrade deferral					☑							
Power quality						●	●	●	●			
Upgrade deferral						☑	●	●				●
Outage mitigation							☑	●	●	●		☑
Intermittent DG integration						●			☑			
Customer rate optimization / DR										☑		☑
Power quality										●	☑	●
Back-up power							●		●	●	☑	

- 🟦 Generation (G)
- 🟨 Transmission (T)
- 🟧 Distribution (D)
- 🟩 End user (E)
- ☑ Primary drivers
- ● Other potential uses

SCE's applications account for all operational uses.

TECHNOLOGY OVERVIEW



Source: Adapted from Energy Storage Association

Storage also encompasses many diverse technologies, which provide different operating capabilities that often don't overlap.

APPLICATION PREFERENCES & TECH MATCHING

Application preferences

Energy-to-power ratio:
Some applications require long duration of output energy, while others short bursts of high power. This determines whether to prioritize power or energy in technology choice.


Low energy-to-power ratio
High energy-to-power ratio

Frequency of charge-discharge:
Some applications, such as providing ancillary services, require frequent charging / discharging throughout a typical day. Others (e.g., black start) may require one (or fewer) charge / discharge cycle per year.


Once per year or fewer
Hundred + times per day

High energy density / power density:
Energy and power densities determine space / footprint requirements for the device. While large size may be acceptable for devices co-located with generation, other applications put a premium on small size.

Low operating & maintenance needs:
While lower operating and maintenance requirements are preferable, in some applications a moderate amount of O&M needs may be acceptable.

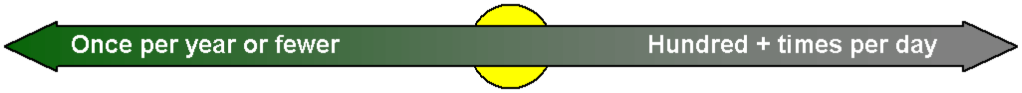
Limited obstacles to implementation (e.g., siting, licensing, environmental permitting):
Technologies that require more safety monitoring, environmental permitting, etc. are better suited to brownfield / remote / industrially zoned locations, rather than in residences or neighborhoods.

Application preferences determine "best fit" technologies.

TECHNOLOGY MATCH EXAMPLE: APP 1

Off-to-on peak intermittent energy shifting & firming at or near generation

● Critical
○ Not critical

Application preferences	Importance
Energy-to-power ratio: Requires energy output over a several hour duration. 	●
Frequency of charge-discharge: Requires ~1 charge-discharge cycle per day. 	●
High energy density / power density: Space is not usually a concern for generation-sited projects, so high density is not required. There may be some exceptions, depending on location.	○
Low operating & maintenance needs: Can have some hands-on maintenance requirements, as full-time staff may already be servicing nearby / co-located infrastructure.	◔
Limited obstacles to implementation (e.g., siting, licensing, environmental permitting): Typically constructed at brownfield generation sites, so complex implementation is less of a concern.	◔

Technology matches

- ***Lithium ion batteries***
- ***Sodium sulfur batteries***
- ***Sodium metal halide batteries***
- ***Flow batteries*** *(zinc-bromide, vanadium)*
- ***CAES***
- ***Pumped hydro***

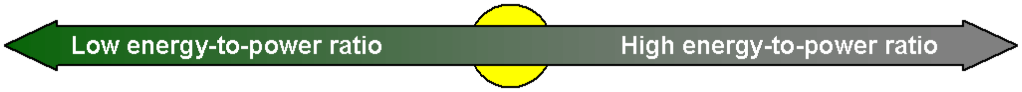
TECHNOLOGY MATCH EXAMPLE: APP 8

Peak load shifting downstream of distribution system

● Critical
○ Not critical

Application preferences — Importance

Energy-to-power ratio:
Balanced energy and power capabilities are required, for hour+ durations.



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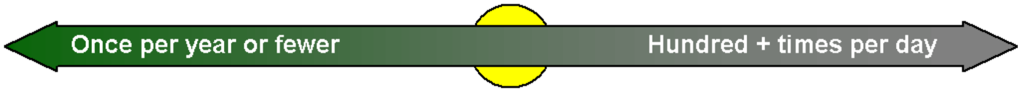
Frequency of charge-discharge:
Requires 1 charge-discharge cycle per day.



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High energy density / power density:
This application requires high power and energy in a small "transformer-sized" device, usually with location space constraints. ●

Low operating & maintenance needs:
Requires "hands-off" maintenance and monitoring, due to thousands of deployments across a service territory. ●

Limited obstacles to implementation (e.g., siting, licensing, environmental permitting):
Sited in neighborhoods, near end users. ●

Technology matches

- ***Lithium ion batteries***
- ***Sodium metal halide***
- ***Ice energy ****

* *Ice energy is not a perfect fit as it is on the customer side of the meter; but it simulates a "permanent load shift" as long as peak load is due to air conditioning*

EVALUATE APPLICATION-TECHNOLOGY PAIRS

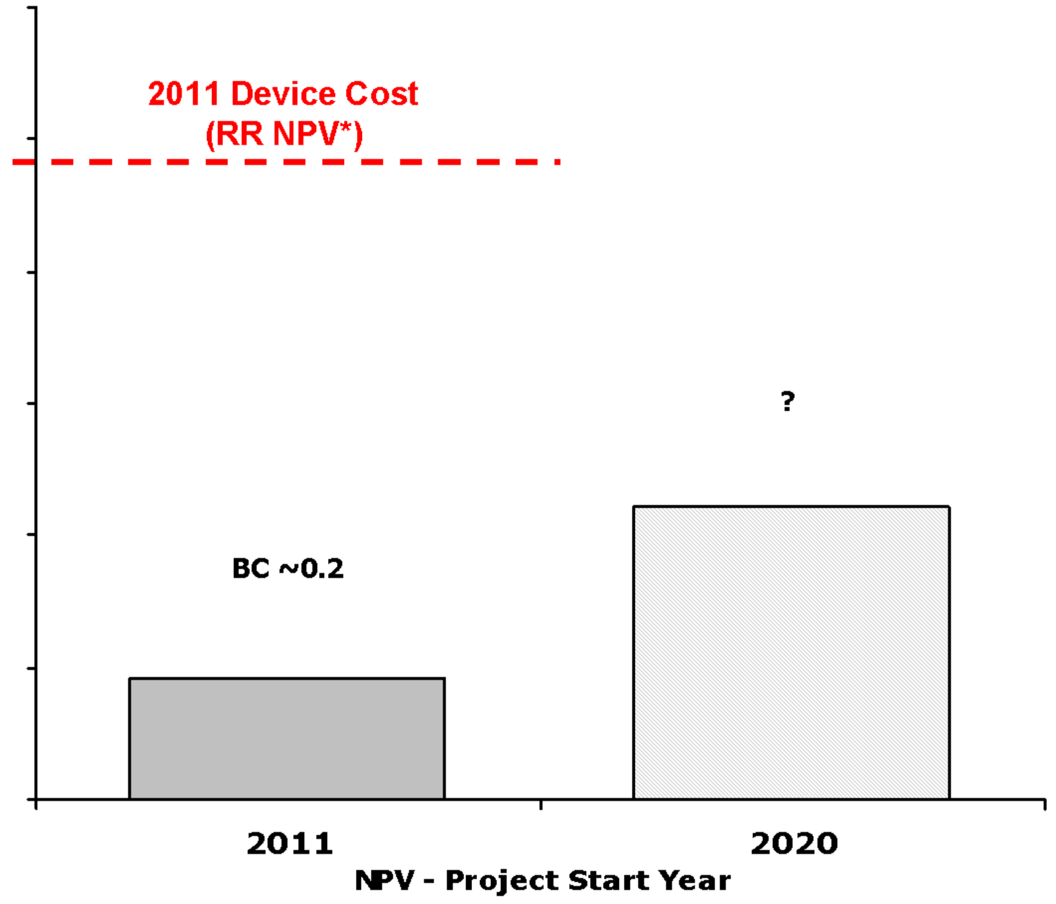
- SCE quantified the **net present value of total lifetime benefits** (application value streams) **and costs** (technology installed and operating)
- A few applications are discussed below (and will highlight apps 1 and 8 over the next few slides):

	Applications	Comments
1	**Off-to-on peak intermittent energy shifting & firming**	Valuation will vary based on the chosen technology match (there are several potential "best fit" options) and its associated costs.
2	**On-peak intermittent energy smoothing & shaping**	Little-to-no explicit value for this application currently. Valuation may improve if requirements for integrating variable energy resources increase.
3	**Ancillary service provision**	High variability for this valuation given the uncertainty of future California ancillary service market design and how storage might participate.
7	**Transportable distribution-level outage mitigation**	Valuation will vary widely based on individual circumstances. If / when cost effective, potential opportunities are low in number.
8	**Peak load shifting downstream of distribution system**	Valuation is highly dependent on technology cost (more than other applications).
10	**End-user retail rate optimization**	Future value will vary on the usage patterns of end users and their rate options.

Each application requires separate evaluation under often unique circumstances.

VALUATION EXAMPLE: APP 1 BENEFIT/COST SUMMARY

20 MW, 6 hour NaS battery



Pathways to cost-effectiveness

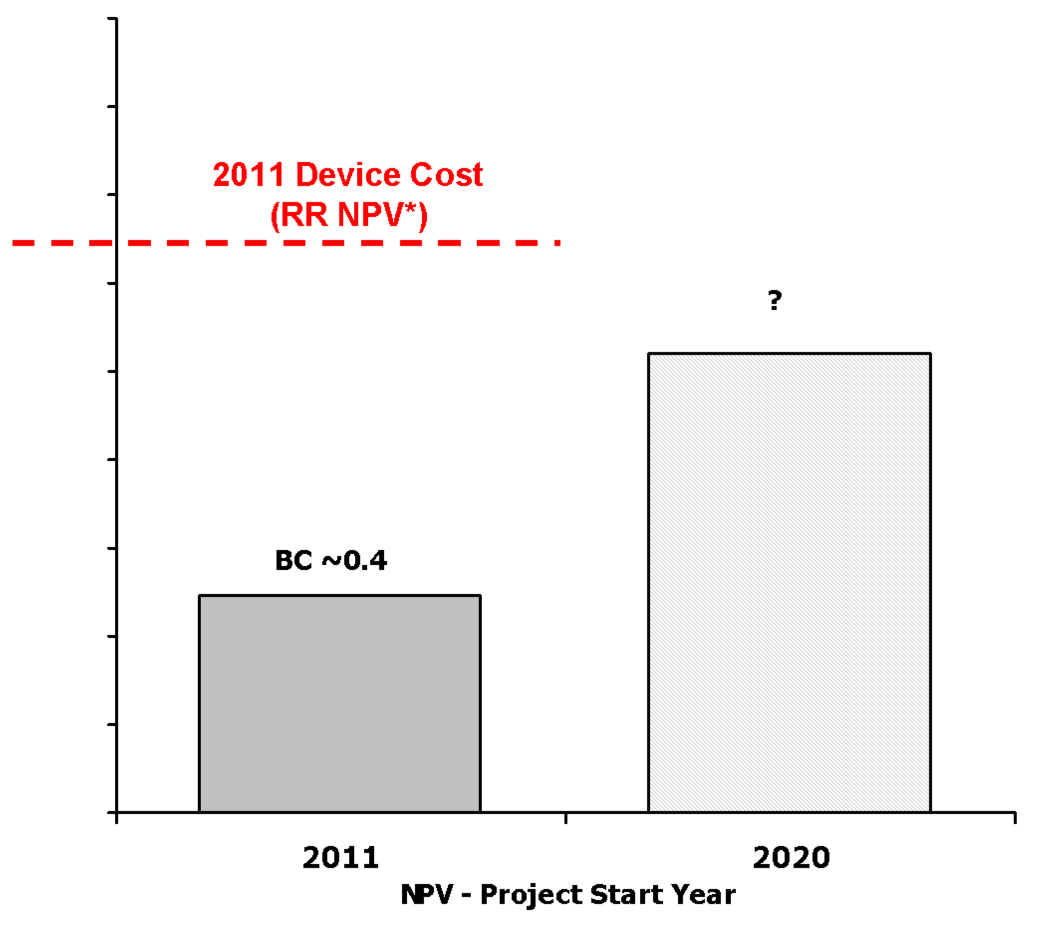
What you need to believe...	2020 B/C Ratio
Tech installed cost falls by 50% *(from $2,500 / kW for 6 hrs to $1,250)*	0.8
Market rents from energy arbitrage increase by 75% *(reflecting higher on-off peak spreads from renewables integration)*	0.5
The two above situations occur simultaneously	1.0

Application 1 may be promising by 2020.

** Revenue Requirement Net Present Value*

VALUATION EXAMPLE: APP 8 BENEFIT/COST SUMMARY

25 kW, 4 hour lithium ion battery



Pathways to cost-effectiveness

What you need to believe…	2020 B/C Ratio
Tech installed cost falls by 50% *(from $4,000 / kW for 4 hrs to $ 2,000)*	1.3
T&D deferred costs increase by 10%	0.7
Market rents from energy arbitrage increase by 50% *(reflecting higher on-off peak spreads from renewables integration)*	0.7
All three above situations occur simultaneously	1.5

Application 8 may be promising by 2020.

** Revenue Requirement Net Present Value*

SCE'S ENERGY STORAGE NEXT STEPS

Regulatory Response

- Circulate and share SCE knowledge with stakeholder community
- Assist with identifying and resolving regulatory and policy issues which arise from specific applications
- Ensure storage deployments are in the best interests of ratepayers

Engineering Piloting

- Conduct engineering piloting / research to validate economic and technical viability of applications
- Focus on ARRA stimulus projects, communicating findings as they become available with internal and external storage stakeholders
- Help guide industry discussion on standards & protocols

Application Evaluation

- Continue to monitor technological developments, communicating with manufacturers about potential cost reductions and / or performance improvements
- Refine benefit calculations (e.g., variable renewable integration adders) with results of ongoing studies
- Update strategic planning figures with new information

Much work remains to demonstrate applications in reality while resolving potential regulatory / policy issues and refining benefit / cost evaluations.

CONCLUSIONS

- Valuing energy storage requires a consistent and thorough methodology:
  - Developing specific and practical applications which aggregate operational uses across the electric value chain
  - Identifying "best fit" technologies for each application
  - Evaluating specific application-technology pairs under both current and future circumstances
- Much work remains:
  - Testing / demonstrating the operational viability of storage on our grid
  - Refining benefit / cost valuations with new information
  - Addressing potential regulatory issues in this space

Appendix

SCE'S APPROACH TO ENERGY STORAGE

SCE has approached energy storage from two angles

Engineering Pilots and Demonstration Efforts

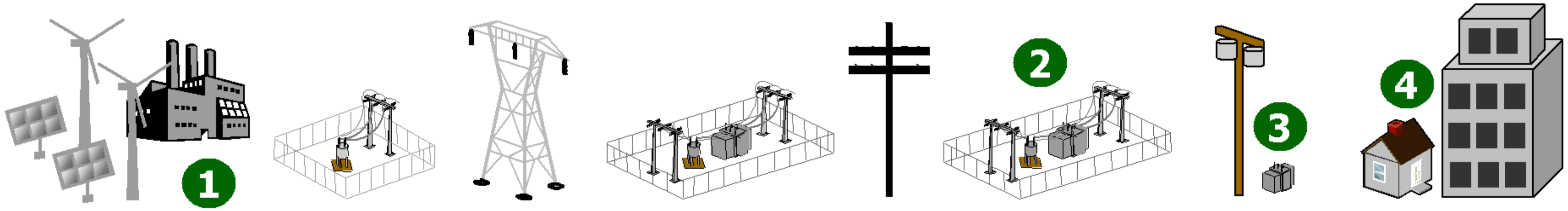
- ***Chino Battery Storage Project*** (1988-1996): demonstrated a 10 MW / 40 MWh lead acid battery
- ***Electric Vehicle Technical Center*** has tested a wide variety of battery chemistries, modules, and management systems since 1993 in a nationally recognized and certified research center
- ***Tehachapi Storage Project*** *
- ***Irvine Smart Grid Demonstration*** *

Strategic Planning

- Deepen SCE's understanding on energy storage technologies
- Define potential energy storage applications to communicate preferred specifications internally and externally
- Engage energy storage stakeholders and regulatory agencies in key policy issues
- Create a strategic "roadmap" for SCE's future engagement with energy storage

** See next slide and appendix for more detail*

SCE'S CURRENT PRIMARY STORAGE R&D EFFORTS



① Large-Scale Battery Storage

Name	Tehachapi Storage Project (TSP)
Objective	Evaluate a utility scale lithium-ion battery's ability to increase grid performance & integrate wind generation
Size	8 MW for 4 hours or 32 MWh
Cost	$53.5 million ~50% ARRA
Timeline	2010-2014

② Large Transportable Battery System

Name	Distributed Generation Storage Services Evaluation
Objective	Evaluate transportable, containerized Li-Ion battery systems in field & laboratory trials
Size	Two 2 MW / 500 kWh units
Cost	~ $3 million Part of ISGD* (sub-project 3)
Timeline	2010-2013

③ Community Energy Storage

Name	Community Energy Storage System Research
Objective	Enhance circuit efficiency, resilience and reliability
Size	Distributed units (25kW / 50kWh)
Cost	Part of ISGD* (sub-project 4)
Timeline	2011-2013

④ Residential Home Energy Storage

Name	Home Battery Pilot (HBP)
Objective	Evaluate home storage integration with customer HAN, EE, smart appliances, solar PV, PEV, etc.
Size	4kW / 10 kWh
Cost	~ $3 million Part of ISGD* (sub-project 1)
Timeline	2010-2013

** Irvine SmartGrid Demonstration: $80.2 million project ~ 50% ARRA funded*

APPLICATION 1 DETAILED EXAMPLE:

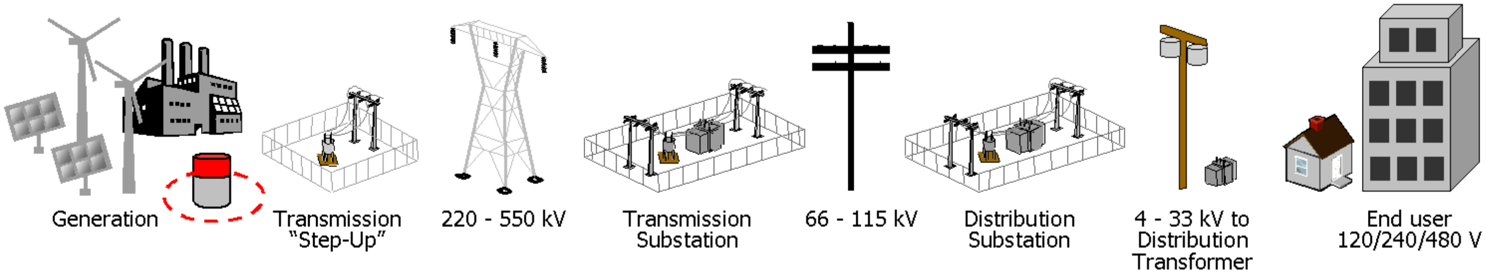
EXAMPLE

Off-to-on peak intermittent energy shifting & firming at or near generation

Application description

Charge at the site of off-peak renewable and/or intermittent energy sources (storage device should be sized to absorb several hours of energy); discharge "firmed" energy to grid during on-peak periods.

Physical Location on Grid



	Operational use ("benefits")	**Potential value metric**	**Comments**
Primary Drivers and Definite Operational Uses	Resource Adequacy / dependable operating capacity	Peak capacity avoided cost	Valuation is roughly modeled from the cost of a new peaking unit
	Intermittent energy firming	Specific renewable integration costs attributed to firming off-peak energy	Avoided integration cost of firmed on-peak gen instead of intermittent off-peak
	Wholesale price energy shifting (arbitrage)	Price differential between charge and discharge less efficiency losses	On-off peak spreads decrease with increasing penetrations of storage
	Intermittent energy smoothing	Specific renewable integration costs attributed to off-peak energy smoothing	This integration cost varies by technology and grid/portfolio circumstance, but may include avoided A/S procurement
Potential Other Operational Uses	Avoid dump energy / minimum load issues	Price differential between charge and discharge less efficiency losses	Value only if and when operational and/or economic over gen situations occur
	Transmission short duration performance improvement (voltage, frequency, fault duty)	Avoided cost of deferred/replaced infrastructure	But for storage, what costs would be incurred on the T system (if any) to counteract short-duration issues
	Transmission system reliability (longer-duration outages)	Avoided cost of deferred/replaced infrastructure	But for storage, what costs would be incurred on the T system (if any) to counteract long-duration issues
	Transmission fee avoidance	Transmission fees avoided	But for storage, what would have been paid for un-utilized reserved transmission

KEY EVALUATION ASSUMPTIONS

While each application required specific analyses and assumptions, the following cross-cutting assumptions were made for all evaluations:

Benefits (operational use valuation)

1. **Generation capacity:**
    - 2011 represented by current procurement price
    - 2020 uses cost of a new-build peaker
2. **Energy price forecast:**
    - Uses May 2010 gas & power price forecasts
    - Prices forecasted using current optimization model; potential intermittent renewables volatility is not fully captured
    - Forecast includes GHG pricing
3. **Ancillary service forecasting:**
    - 3-year average of historical pricing
    - Escalated at a higher rate than inflation (using preliminary shadow prices of CAISO 33% study)
4. **T&D capital deferred cost:**
    - Avoided peak D based on SmartConnect and DR valuation testimony (apps 7 & 8)
    - Avoided DG integration D and large-scale T based on SME estimates

Costs (tech installation and operating)

1. **Technology system cost:**
    - For full systems (e.g., not just battery module)
    - Uses vendor supplied indicative pricing based on existing technology specifications
2. **Site preparation and land cost:**
    - SME provided based on current storage installations, although this will vary substantially by specific site and technology parameters
3. **Operating cost:**
    - Estimated based on other existing installations, warranty costs, and SME input
4. **2020 technology cost forecast:**
    - Did not forecast future technology cost reductions / technology efficiency improvements
    - Escalated 2011 pricing for consistency
5. **Assumed 30% Investment Tax Credit (ITC)**
    - Consistent with pending federal legislation