Executive Summary

Energy Storage (ES) market in the United States is projected to grow six-folds to reach $2.5 Billion by 2020. California is the largest non-residential ES market today and is slated to grow in response to aggressive renewable energy goals. This report summarizes several present and future value streams available in California's energy market and looks at potential "value stacking" opportunities for energy storage. This work was performed by the students at UC Berkeley as part of BERC (Berkeley Energy and Resource Collaborative) Innovative Solutions program. In today's meeting we will present a summary of existing frameworks offered by (i) California wholesale electricity market, (ii) Load Serving Entities (LSEs) or utilities and (iii) Residential, Commercial & Industrial (C&I) customers in order to generate revenue from ES. This document presents a summary of value streams accessible to ES and their potential overlap. We will end the meeting with two sample use-cases that we find to be attractive in terms of maximizing the utility of ES followed by a brief discussion of energy arbitrage opportunities.

Value Streams accessible to ES in California

The business case for ES technology hinges upon the ability of ES to provide multiple services that are sought after by electricity grid operators, load serving entities (utilities) and end-users. The beneficiaries of these services can be divided into three main buckets – (i) Wholesale electricity market, (ii) Load Serving Entities (LSEs) or Utilities and (iii) Residential, Commercial & Industrial (C&I) consumers. Appendix I provides a summary of services that ES can provide to these stakeholders in California's energy market. Let us look at specific revenue stream frameworks that exist in California.

A. <u>Wholesale energy market (ISO/RTOs)</u>

Approximately 80% of California's wholesale electricity market is operated by California Independent System Operator (CAISO) and the rest controlled by municipal utilities which are similar to vertically integrated electric utilities. The wholesale electricity market in California offers ES owners three ways to generate revenue.

1. Non-Generator Resource (NGR)

NGR offers an opportunity for ES to fully participate in the wholesale electricity market like any conventional generator. It provides access to all revenue streams offered by the wholesale market – energy and four types of ancillary services (regulation, reserves, voltage support and black start). These services are explained in **Appendix I**. Providing these services as an NGR requires 24/7 participation in the wholesale market. This requirement can pose challenges to accessing other revenue streams outside wholesale electricity market. **Appendix II** elaborates our findings and thinking regarding energy arbitrage opportunities for ES in California.

2. Proxy Demand Resource (PDR) and Reliability Demand Response Resource (RDRR)

PDR (Proxy Demand Response) and RDRR (Reliability Demand Response Resource) frameworks were developed in response to FERC orders and CPUC rulings to integrate utility programs and provide open access to 3rd party participation. These programs allow the load to participate in the electricity market by offering to be curtailed (reduced output). ES when integrated with the load can create this "load curtailment" effect. ES can participate in PDR/RDRR through DRPs. (Demand Response Providers). Demand Response Use Guide (https://www.caiso.com/Documents/DemandResponseUserGuide.pdf) provides information on how to offer demand response service in California wholesale electricity market.
PDR bids into the CAISO market as supply and can provide services such as energy and ancillary services. RDRR, on the other hand, offers no ancillary services; it offers only energy. RDRR bids into the CAISO market as supply and can only be used for reliability purposes.

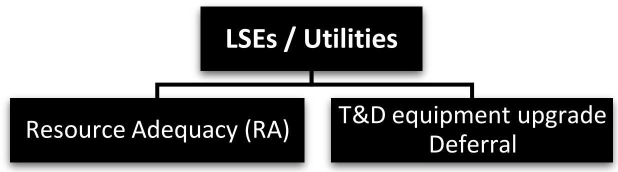
3. Distributed Energy Resource (DER)

DER can include any distribution connected resource regardless of size or interconnection point (behind or in front of the end-use customer meter). DERs can be very valuable if the resource aggregators have intelligent optimization systems at their disposal. ES is an important piece of the resource mix within DERs because it is the only predictable and fully controllable resource at distribution level. A final proposal is expected to be approved by California ISO board of governors in Q4 of 2016, which will facilitate greater participation by aggregated DER and provide energy and all four ancillary services.

Challenges: Regulatory framework and policy-making in California are playing catch-up with technology and control system innovation. For example, in order to access some of the aforementioned value streams, the telecommunication and control systems exist today, but different revenue metering arrangements will be necessary and will require a coordinated effort from the regulators, utilities and the distributed resource developers.

B. Load Serving Entities / Electric utilities

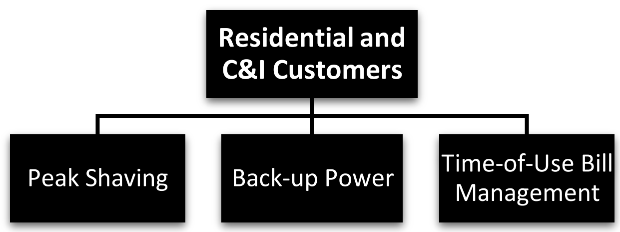
LSEs are required to demonstrate that adequate system, local and flexible capacity has been procured. ES can be valuable in meeting the new flexible RA requirement that is based on the largest 3-hour generation ramping needed for a given month. ES can also be utilized to eliminate or delay transmission and distribution (T&D) equipment upgrades. LSE may be willing to form an alliance or a revenue sharing agreement depending on the severity of constraint to be mitigated. These value streams are explained in **Appendix I**.



Challenges: A framework to share the ownership of an ES device as a T&D asset between LSE and end-user is still in formative stages. Rate-recovery of such T&D asset would pose a regulatory challenge.

C. Residential and C&I Consumers (Prosumers!)

Residential and C&I customers find ES valuable for reducing their electricity bills and for providing a source of back-up power. These customers are willing to directly pay for ES These value streams are explained in **Appendix I**.



Challenges: Use of energy storage brings economic value for residential and C&I consumers by optimizing their electricity usage. The main challenge is to create a framework that will allow energy storage to tap into wholesale electricity market while providing site-specific services to the end-user. Some initiatives such as PDR and DER mentioned in section A are trying to enable this overlap.

ES "Value stacking" in California

Because of the limited capability of energy storage to provide sustained MW output, it is very difficult to make a business case for ES using any single revenue stream from section 1. This brings us to the concept of "value stacking". Energy storage can generate much more value when multiple, stacked services are provided by the same device or fleet of devices [1].

Table 1 summarizes the opportunities for value stacking of services which are explained in **Appendix I**.

This value stacking grid is not a static representation; as regulations, policies and technology evolve we expect the overlap to increase. It is evident that services that can be offered in wholesale

Table 1 - Potential value stacking for ES

	R	A	Res	VS	B	RA	TD	CM	TOU	PS	BU*
Regulation (R)		✓	✓	✓	✓	×	×	×	×	×	✓
Arbitrage (A)			✓	✓	✓	×	×	×	✓	✓	✓
Reserves (Res)				✓	✓	×	×	×	×	×	✓
Voltage Support (VS)					✓	×	×	✓	✓	✓	✓
Black Start (B)						×	×	×	×	×	✓
Resource Adequacy (RA)							×	×	×	×	✓
T&D deferral (TD)								✓	×	×	✓
Congestion management (CM)									×	×	✓
TOU bill management (TOU)										✓	✓
Peak Shaving (PS)											✓
Back-up power* (BU)											

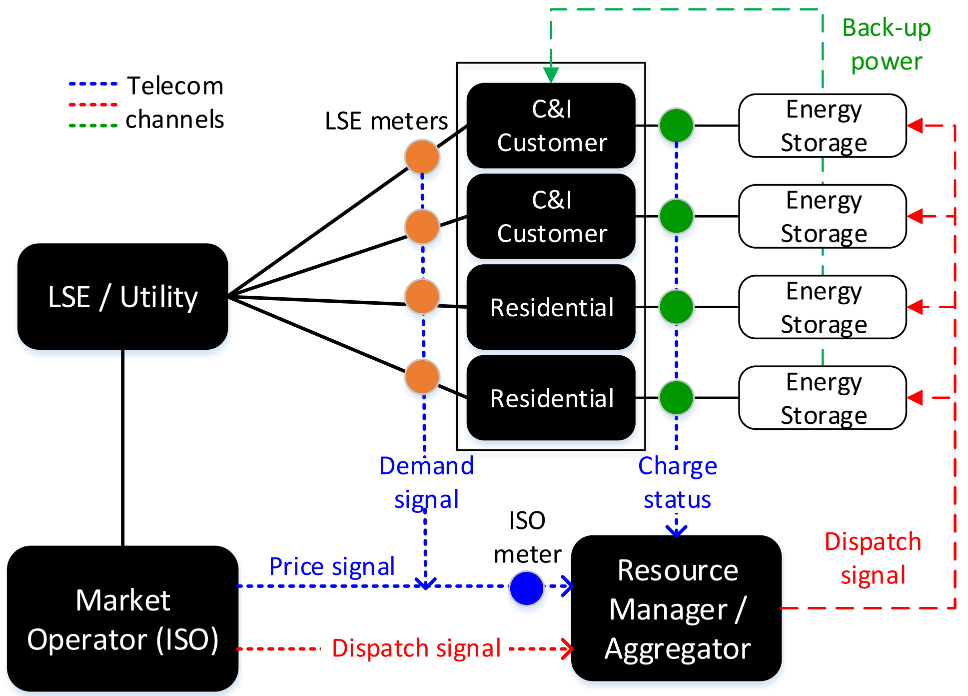
* Assuming that part of the storage is reserved for emergency back-up and the rest is available for accessing any other value stream.

electricity market (blue), demonstrate an overlap with each other. Use Case I looks at how ES at a customer facility can achieve an overlap with the wholesale electricity market. The green labels indicate services that can benefit LSEs and utilities. These services do not demonstrate an extensive value overlap. Back-up power as typically used by data centers could work in conjunction with services that LSEs may be willing to pay for. Use Case II explores the possibility of such a partnership between ES owner and LSE.

ES Use cases

Use Case I: Back-up power + demand reduction + wholesale electricity market participation

Objective value streams: Back-up power, Time of Use Bill Management and value streams offered by wholesale electricity market (please refer to **Appendix I**).



Actors: ES owner, LSE or utility, wholesale market operator and an aggregator.

Rulings and policies relevant to this use case:
- Senate Bill No. 1090: Electricity: Rates – Default time-of-use pricing by 2019
- Senate Bill X1-2 (33% RPS goal by 2020) and Senate Bill 350 (50% RPS goal by 2030)
- ESDER and DERP initiatives to develop market rules and increase participation of DERs (https://www.caiso.com/informed/Pages/StakeholderProcesses/EnergyStorage_AggregatedDistributedEnergyResources.aspx)
- Net metering debate continues (California seems to be a relatively NM-friendly place)

Location of storage: At C&I facility and behind customer meter.

Operational requirements at a conceptual level: Telecommunication systems to provide market pricing signal to the ES (either directly or through an aggregator) are essential. An algorithm to forecast revenue generation will optimize ES operation. In case of aggregated ES devices, a control platform for operating multiple ES devices in a coordinated fashion is essential. Metering (aggregated or stand-alone) and real-time data acquisition are required for measuring the contribution of ES.

Pointers for future cost-benefit analysis

Benefits:

(1) The most attractive benefit of this use case depends on the type of load. From our discussions with some people at Stem, it was evident that loads that are "peaky" in nature derive a lot of value from demand charge reduction.

(2) TOU bill management will be attractive considering that all LSE's in California have to transition to TOU billing by 2019.

(3) This case will increase the utilization of existing and future renewables and help meet the 33% and 50% RPS goals in California.

(4) Energy arbitrage could be an attractive value stream as renewable penetration increases, but it will last for a limited period of time.

(5) Access to ES at customer end will help CAISO operate around sudden variability in renewable generation.

Costs:

Capital cost of ES[1] will see considerable downward pressure. This use-case will require an optimization platform for TOU bill management as well as telecommunication and data acquisition systems required to participate in the wholesale electricity market.

Use case II: Back-up power + T&D deferral + Resource Adequacy

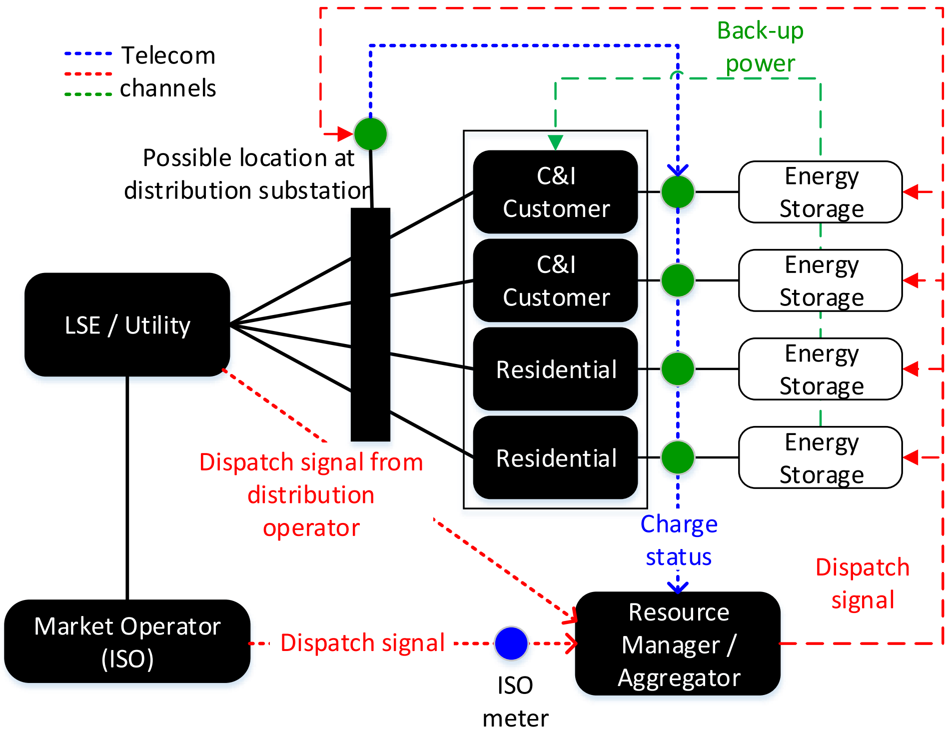
Objective value streams: Back-up power, T&D deferral and resource adequacy program (long-term contracts)

Actors: ES owner, intelligent platform provider or aggregator, LSE or utility, wholesale market operator. LSE may be willing to share the cost of ES if it helps eliminate or delay expensive equipment upgrade.

Rulings and policies relevant to this use case

- Assembly Bill No. 2514 ES Systems (1.3 GW ES procurement by 2020)
- Senate Bill X1-2 (33% RPS goal by 2020) and Senate Bill 350 (50% RPS goal by 2030)

Location of storage: At C&I facility, possibly inside the distribution substation feeding the data center (assuming the data center load is large enough)



Operational requirements at a conceptual level: Telecommunication systems to relay the need for T&D congestion management are required. These links will have to be from ISO as well as from LSE's distribution control centers. In case of aggregated ES devices, a control platform for operating multiple ES devices in a coordinated fashion is needed. Metering (aggregated or stand-alone) and real-time data acquisition are required for measuring the contribution of ES.

Pointers for future cost-benefit analysis

Benefits:

(1) Resource adequacy capacity payments – especially the new flexible capacity requirements could prove to be attractive for ES due to its fast response characteristics.

(2) Avoided cost of infrastructure rebuild or construction is an attractive proposition for California. Several load-centers in California are either densely populated or are environmentally sensitive. Avoided cost of infrastructure includes capital cost as well as environmental costs.

(3) Any arrangement that allows system operator (ISO) to dispatch ES will help achieve the goal of integrating renewable resources which are intermittent in nature.

Costs:

Capital cost of ES[1] will see considerable downward pressure. This use-case will add the costs of meeting utility installation standards and additional telecommunications as well as control systems required for achieving access to multiple value streams.

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[1] We talked to Tesla Energy and their energy storage experts indicated that almost 1/3rd capacity of the Gigafactory will be used for stationary ES.

Appendix 1: Summary of services provided by ES

Stake holder s	Service	Service description	Location of ES	Operational behavior of ES	Who will pay ES?	Direct benefit to?		Future Value of ES
						LSE / ISO	Consumer	
Wholesale electricity market (ISO/RTO)	Regulation	Generation-load balance	T&D**	ES can charge when reg-down service is needed and can discharge when reg-up service is needed	ISO	✓	×	↑↑
	Arbitrage	Buy low and sell high	T&D**	Charge ES when LMP (Locational Marginal Price) is low and discharge when it is high	ISO	✓	✓	↑ ↓
	Reserves	Spin and non-spin reserves to respond to loss of generation or any sudden changes in the system	T&D**	Discharge in case of sudden loss of generation	ISO	✓	×	↑
	Voltage Support	Maintain voltages within acceptable range	T&D**	Discharge when voltage drop below a certain level	ISO or LSEs	✓	×	-
	Black Start	Restore operation of bigger power plants after a blackout	Transmission	Discharge if the ES is charged	ISO	✓	×	↑
LSEs / Utilities	Resource Adequacy	Defer the need for new generation capacity by using excess renewables to charge ES during non-peak hours	T&D**	Charge ES during the time of renewable overgeneration and discharge during peak load hours	LSEs (utilities)	✓	×	↑
	T&D deferral	Defer the investments in T&D infrastructure to meet load growth	T&D	Discharge ES during hours when T&D equipment (typically lines and transformers) are expected to be overloaded	LSEs (utilities)	✓	×	↑↑
	Congestion management	Reduce transmission system congestion	Transmission	Discharge ES to mitigate overloading of transmission equipment	ISO and LSEs (utilities)	✓	×	↑↑
Residential and C&I Customers	TOU bill management	Optimize on-site electricity usage and electricity geneation	Residential or C&I	Charge and discharge ES to maximize the benefit to end-customer in terms of net cost of electricity	Residential or C&I customers	×	✓	↑↑
	Peak shaving	Reduce site-specific demand charge	Residential or C&I	Discharge ES during the hours of peak load	Residential or C&I customers	×	✓	↑↑
	Back-up power*	Provide emergency power for critical electrical load	Residential or C&I	Keep a part of ES charged for emergency back up and deploy it when the primary source fails	Residential or C&I customers	×	✓	-

** Assuming that adequate telemetry and aggregator framework is available to the distribution level ES

Appendix II: Energy Arbitrage

During our literature review and interviews with the industry experts, we noticed a theme around energy arbitrage – this value stream is not attractive in California. Since energy arbitrage is the most intuitive use of ES, it is possibly the most studied applications of storage in power systems, with value driven by on/off-peak price differences (i.e., the availability of low-cost generation during certain periods and the ability to displace higher-cost generation during other periods).

Figure 1 shows the actual average hourly CAISO market energy prices in a certain LAP (Load Aggregation Point) in the day-ahead market by hour of day for each season of the year in 2013 and 2014, and the simulated energy prices in the no-storage scenarios for 2024 from the production cost simulations performed by NREL [2].

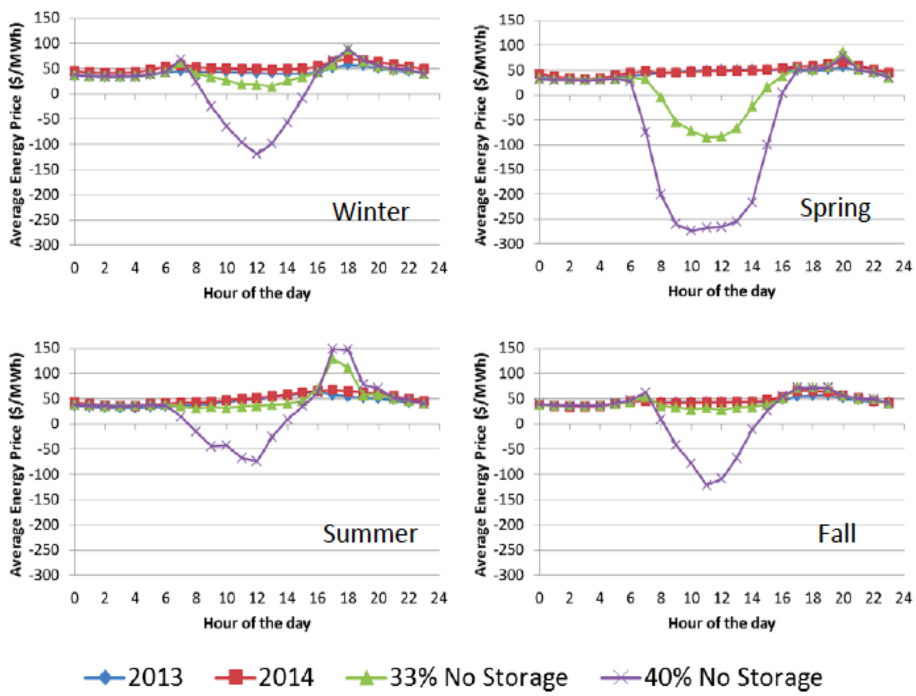

Figure 1 - Average hourly energy prices in different seasons

The simulated average hourly prices for many of the hours in the 2024 simulations are fairly similar to the current market prices. However, there is a significant difference in price patterns for the middle of the day without ES. In the middle of the day, renewable energy production in the 40% scenario displaces enough thermal generation and imports to be on the margin for up to one-third of the day. This means energy prices are set by renewable energy, which has a cost of -$300/MWh. Negative bid price can have a significant impact on energy arbitrage opportunities. Today the bid floor is -$150/MWh. In future CAISO plans to implement -$300/MWh. This one change in itself can increase the arbitrage opportunities.

Although it is safe to conclude that arbitrage opportunities will increase with increasing renewable penetration, it is important to note that as storage penetration increases the marginal value of storage will decline (saturation effect) [3, 4].

References

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2] Eichman J., Denholm P., Jorgenson J., Helman U., Operational Benefits of Meeting California's Energy Storage Targets, National Renewable Energy Laboratory, U.S. Department of Energy, NREL/TP-5400-65061

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